13th Edition



Understanding Nutrition

DIT 121

Whitney & Rolfes

Dietary Reference Intakes (DRI)

The Dietary Reference Intakes (DRI) include two sets of nutrient intake goals for individuals—the Recommended Dietary Allowance (RDA) and Adequate Intake (AI). The RDA reflects the average daily amount of a nutrient considered adequate to meet the needs of most healthy people. If there is insufficient evidence to determine an RDA, an AI is set. In addition, the Estimated Energy Requirement (EER) represents the average dietary energy intake considered adequate to maintain energy balance in healthy people.

The DRI also include the Tolerable Upper Intake Level (UL) that represents the estimated maximum daily amount of a nutrient that appears safe for most healthy people to consume on a regular basis. Turn the page for a listing of the UL for selected vitamins and minerals. Note that the absence of a UL for a nutrient does not indicate that it is safe to consume in high doses, but only that research is too limited to set a UL. Chapter 1 describes these DRI values in detail.

Estimated Energy Requirements (EER), Recommended Dietary Allowances (RDA), and Adequate Intakes (AI) for Water, Energy, and the Energy Nutrients

Age (yr)	Reference BMI (kg/m²)	Reference Height cm (in)	Reference Weight kg (lb)	Water[a] AI (L/day)	Energy EER[b] (kcal/day)	Carbohydrate RDA (g/day)	Total Fiber AI (g/day)	Total Fat AI (g/day)	Linoleic Acid AI (g/day)	Linolenic Acid[c] AI (g/day)	Protein RDA (g/day)[d]	Protein RDA (g/kg/day)
Males												
0–0.5	—	62 (24)	6 (13)	0.7[e]	570	60	—	31	4.4	0.5	9.1	1.52
0.5–1	—	71 (28)	9 (20)	0.8[f]	743	95	—	30	4.6	0.5	11	1.20
1–3[g]	—	86 (34)	12 (27)	1.3	1046	130	19	—	7	0.7	13	1.05
4–8[g]	15.3	115 (45)	20 (44)	1.7	1742	130	25	—	10	0.9	19	0.95
9–13	17.2	144 (57)	36 (79)	2.4	2279	130	31	—	12	1.2	34	0.95
14–18	20.5	174 (68)	61 (134)	3.3	3152	130	38	—	16	1.6	52	0.85
19–30	22.5	177 (70)	70 (154)	3.7	3067[h]	130	38	—	17	1.6	56	0.80
31–50	22.5[i]	177 (70)[i]	70 (154)[i]	3.7	3067[h]	130	38	—	17	1.6	56	0.80
>50	22.5[i]	177 (70)[i]	70 (154)[i]	3.7	3067[h]	130	30	—	14	1.6	56	0.80
Females												
0–0.5	—	62 (24)	6 (13)	0.7[e]	520	60	—	31	4.4	0.5	9.1	1.52
0.5–1	—	71 (28)	9 (20)	0.8[f]	676	95	—	30	4.6	0.5	11	1.20
1–3[g]	—	86 (34)	12 (27)	1.3	992	130	19	—	7	0.7	13	1.05
4–8[g]	15.3	115 (45)	20 (44)	1.7	1642	130	25	—	10	0.9	19	0.95
9–13	17.4	144 (57)	37 (81)	2.1	2071	130	26	—	10	1.0	34	0.95
14–18	20.4	163 (64)	54 (119)	2.3	2368	130	26	—	11	1.1	46	0.85
19–30	21.5	163 (64)	57 (126)	2.7	2403[j]	130	25	—	12	1.1	46	0.80
31–50	21.5[i]	163 (64)[i]	57 (126)[i]	2.7	2403[j]	130	25	—	12	1.1	46	0.80
>50	21.5[i]	163 (64)[i]	57 (126)[i]	2.7	2403[j]	130	21	—	11	1.1	46	0.80
Pregnancy												
1st trimester				3.0	+0	175	28	—	13	1.4	46	0.80
2nd trimester				3.0	+340	175	28	—	13	1.4	71	1.10
3rd trimester				3.0	+452	175	28	—	13	1.4	71	1.10
Lactation												
1st 6 months				3.8	+330	210	29	—	13	1.3	71	1.30
2nd 6 months				3.8	+400	210	29	—	13	1.3	71	1.30

NOTE: For all nutrients, values for infants are AI. Dashes indicate that values have not been determined.

[a]The water AI includes drinking water, water in beverages, and water in foods; in general, drinking water and other beverages contribute about 70 to 80 percent, and foods, the remainder. Conversion factors: 1 L = 33.8 fluid oz; 1 L = 1.06 qt; 1 cup = 8 fluid oz.

[b]The Estimated Energy Requirement (EER) represents the average dietary energy intake that will maintain energy balance in a healthy person of a given gender, age, weight, height, and physical activity level. The values listed are based on an "active" person at the reference height and weight and at the midpoint ages for each group until age 19. Chapter 8 and Appendix F provide equations and tables to determine estimated energy requirements.

[c]The linolenic acid referred to in this table and text is the omega-3 fatty acid known as alpha-linolenic acid.

[d]The values listed are based on reference body weights.

[e]Assumed to be from human milk.

[f]Assumed to be from human milk and complementary foods and beverages. This includes approximately 0.6 L (~2½ cups) as total fluid including formula, juices, and drinking water.

[g]For energy, the age groups for young children are 1–2 years and 3–8 years.

[h]For males, subtract 10 kcalories per day for each year of age above 19.

[i]Because weight need not change as adults age if activity is maintained, reference weights for adults 19 through 30 years are applied to all adult age groups.

[j]For females, subtract 7 kcalories per day for each year of age above 19.

SOURCE: Adapted from the *Dietary Reference Intakes series*, National Academies Press. Copyright 1997, 1998, 2000, 2001, 2002, 2004, 2005, 2011 by the National Academies of Sciences.

mmended Dietary Allowances (RDA) and Adequate Intakes (AI) for Vitamins

yr)	Thiamin RDA (mg/day)	Riboflavin RDA (mg/day)	Niacin RDA (mg/day)[a]	Biotin AI (µg/day)	Pantothenic acid AI (mg/day)	Vitamin B_6 RDA (mg/day)	Folate RDA (µg/day)[b]	Vitamin B_{12} RDA (µg/day)	Choline AI (mg/day)	Vitamin C RDA (mg/day)	Vitamin A RDA (µg/day)[c]	Vitamin D RDA (IU/day)[d]	Vitamin E RDA (mg/day)[e]	Vitamin K AI (µg/day)
	0.2	0.3	2	5	1.7	0.1	65	0.4	125	40	400	400 (10 µg)	4	2.0
	0.3	0.4	4	6	1.8	0.3	80	0.5	150	50	500	400 (10 µg)	5	2.5
n														
	0.5	0.5	6	8	2	0.5	150	0.9	200	15	300	600 (15 µg)	6	30
	0.6	0.6	8	12	3	0.6	200	1.2	250	25	400	600 (15 µg)	7	55
	0.9	0.9	12	20	4	1.0	300	1.8	375	45	600	600 (15 µg)	11	60
	1.2	1.3	16	25	5	1.3	400	2.4	550	75	900	600 (15 µg)	15	75
	1.2	1.3	16	30	5	1.3	400	2.4	550	90	900	600 (15 µg)	15	120
	1.2	1.3	16	30	5	1.3	400	2.4	550	90	900	600 (15 µg)	15	120
	1.2	1.3	16	30	5	1.7	400	2.4	550	90	900	600 (15 µg)	15	120
	1.2	1.3	16	30	5	1.7	400	2.4	550	90	900	800 (20 µg)	15	120
s														
	0.9	0.9	12	20	4	1.0	300	1.8	375	45	600	600 (15 µg)	11	60
	1.0	1.0	14	25	5	1.2	400	2.4	400	65	700	600 (15 µg)	15	75
	1.1	1.1	14	30	5	1.3	400	2.4	425	75	700	600 (15 µg)	15	90
	1.1	1.1	14	30	5	1.3	400	2.4	425	75	700	600 (15 µg)	15	90
	1.1	1.1	14	30	5	1.5	400	2.4	425	75	700	600 (15 µg)	15	90
	1.1	1.1	14	30	5	1.5	400	2.4	425	75	700	800 (20 µg)	15	90
ancy														
	1.4	1.4	18	30	6	1.9	600	2.6	450	80	750	600 (15 µg)	15	75
	1.4	1.4	18	30	6	1.9	600	2.6	450	85	770	600 (15 µg)	15	90
	1.4	1.4	18	30	6	1.9	600	2.6	450	85	770	600 (15 µg)	15	90
ion														
	1.4	1.6	17	35	7	2.0	500	2.8	550	115	1200	600 (15 µg)	19	75
	1.4	1.6	17	35	7	2.0	500	2.8	550	120	1300	600 (15 µg)	19	90
	1.4	1.6	17	35	7	2.0	500	2.8	550	120	1300	600 (15 µg)	19	90

For all nutrients, values for infants are AI. The glossary on the inside back cover defines
f nutrient measure.
recommendations are expressed as niacin equivalents (NE), except for recommendations
nts younger than 6 months, which are expressed as preformed niacin.
recommendations are expressed as dietary folate equivalents (DFE).

[c]Vitamin A recommendations are expressed as retinol activity equivalents (RAE).
[d]Vitamin D recommendations are expressed as cholecalciferol and assume an absence of adequate exposure to sunlight.
[e]Vitamin E recommendations are expressed as α-tocopherol.

ommended Dietary Allowances (RDA) and Adequate Intakes (AI) for Minerals

(yr)	Sodium AI (mg/day)	Chloride AI (mg/day)	Potassium AI (mg/day)	Calcium RDA (mg/day)	Phosphorus RDA (mg/day)	Magnesium RDA (mg/day)	Iron RDA (mg/day)	Zinc RDA (mg/day)	Iodine RDA (µg/day)	Selenium RDA (µg/day)	Copper RDA (µg/day)	Manganese AI (mg/day)	Fluoride AI (mg/day)	Chromium AI (µg/day)	Molybdenum RDA (µg/day)
s															
	120	180	400	200	100	30	0.27	2	110	15	200	0.003	0.01	0.2	2
	370	570	700	260	275	75	11	3	130	20	220	0.6	0.5	5.5	3
ar															
	1000	1500	3000	700	460	80	7	3	90	20	340	1.2	0.7	11	17
	1200	1900	3800	1000	500	130	10	5	90	30	440	1.5	1.0	15	22
	1500	2300	4500	1300	1250	240	8	8	120	40	700	1.9	2	25	34
3	1500	2300	4700	1300	1250	410	11	11	150	55	890	2.2	3	35	43
0	1500	2300	4700	1000	700	400	8	11	150	55	900	2.3	4	35	45
0	1500	2300	4700	1000	700	420	8	11	150	55	900	2.3	4	35	45
0	1300	2000	4700	1000	700	420	8	11	150	55	900	2.3	4	30	45
	1200	1800	4700	1200	700	420	8	11	150	55	900	2.3	4	30	45
es															
	1500	2300	4500	1300	1250	240	8	8	120	40	700	1.6	2	21	34
3	1500	2300	4700	1300	1250	360	15	9	150	55	890	1.6	3	24	43
0	1500	2300	4700	1000	700	310	18	8	150	55	900	1.8	3	25	45
0	1500	2300	4700	1000	700	320	18	8	150	55	900	1.8	3	25	45
0	1300	2000	4700	1200	700	320	8	8	150	55	900	1.8	3	20	45
	1200	1800	4700	1200	700	320	8	8	150	55	900	1.8	3	20	45
ancy															
	1500	2300	4700	1300	1250	400	27	12	220	60	1000	2.0	3	29	50
0	1500	2300	4700	1000	700	350	27	11	220	60	1000	2.0	3	30	50
0	1500	2300	4700	1000	700	360	27	11	220	60	1000	2.0	3	30	50
tion															
	1500	2300	5100	1300	1250	360	10	13	290	70	1300	2.6	3	44	50
0	1500	2300	5100	1000	700	310	9	12	290	70	1300	2.6	3	45	50
0	1500	2300	5100	1000	700	320	9	12	290	70	1300	2.6	3	45	50

For all nutrients, values for infants are AI. The glossary on the inside back cover defines units of nutrient measure.

Tolerable Upper Intake Levels (UL) for Vitamins

Age (yr)	Niacin (mg/day)[a]	Vitamin B_6 (mg/day)	Folate (µg/day)[a]	Choline (mg/day)	Vitamin C (mg/day)	Vitamin A (IU/day)[b]	Vitamin D (IU/day)	Vitamin E (mg/day)[c]
Infants								
0–0.5	—	—	—	—	—	600	1000 (25 µg)	—
0.5–1	—	—	—	—	—	600	1500 (38 µg)	—
Children								
1–3	10	30	300	1000	400	600	2500 (63 µg)	200
4–8	15	40	400	1000	650	900	3000 (75 µg)	300
9–13	20	60	600	2000	1200	1700	4000 (100 µg)	600
Adolescents								
14–18	30	80	800	3000	1800	2800	4000 (100 µg)	800
Adults								
19–70	35	100	1000	3500	2000	3000	4000 (100 µg)	1000
>70	35	100	1000	3500	2000	3000	4000 (100 µg)	1000
Pregnancy								
≤18	30	80	800	3000	1800	2800	4000 (100 µg)	800
19–50	35	100	1000	3500	2000	3000	4000 (100 µg)	1000
Lactation								
≤18	30	80	800	3000	1800	2800	4000 (100 µg)	800
19–50	35	100	1000	3500	2000	3000	4000 (100 µg)	1000

[a]The UL for niacin and folate apply to synthetic forms obtained from supplements, fortified foods, or a combination of the two.

[b]The UL for vitamin A applies to the preformed vitamin only.

[c]The UL for vitamin E applies to any form of supplemental α-tocopherol, fortified foods, or a combination of the two.

Tolerable Upper Intake Levels (UL) for Minerals

Age (yr)	Sodium (mg/day)	Chloride (mg/day)	Calcium (mg/day)	Phosphorus (mg/day)	Magnesium (mg/day)[d]	Iron (mg/day)	Zinc (mg/day)	Iodine (µg/day)	Selenium (µg/day)	Copper (µg/day)	Manganese (mg/day)	Fluoride (mg/day)	Molybdenum (µg/day)	Boron (mg/day)	Nickel (mg/day)	Vanadium (mg/day)
Infants																
0–0.5	—	—	1000	—	—	40	4	—	45	—	—	0.7	—	—	—	—
0.5–1	—	—	1500	—	—	40	5	—	60	—	—	0.9	—	—	—	—
Children																
1–3	1500	2300	2500	3000	65	40	7	200	90	1000	2	1.3	300	3	0.2	—
4–8	1900	2900	2500	3000	110	40	12	300	150	3000	3	2.2	600	6	0.3	—
9–13	2200	3400	3000	4000	350	40	23	600	280	5000	6	10	1100	11	0.6	—
Adolescents																
14–18	2300	3600	3000	4000	350	45	34	900	400	8000	9	10	1700	17	1.0	—
Adults																
19–50	2300	3600	2500	4000	350	45	40	1100	400	10,000	11	10	2000	20	1.0	1.8
51–70	2300	3600	2000	4000	350	45	40	1100	400	10,000	11	10	2000	20	1.0	1.8
>70	2300	3600	2000	3000	350	45	40	1100	400	10,000	11	10	2000	20	1.0	1.8
Pregnancy																
≤18	2300	3600	3000	3500	350	45	34	900	400	8000	9	10	1700	17	1.0	—
19–50	2300	3600	2500	3500	350	45	40	1100	400	10,000	11	10	2000	20	1.0	—
Lactation																
≤18	2300	3600	3000	4000	350	45	34	900	400	8000	9	10	1700	17	1.0	—
19–50	2300	3600	2500	4000	350	45	40	1100	400	10,000	11	10	2000	20	1.0	—

[d]The UL for magnesium applies to synthetic forms obtained from supplements or drugs only.

NOTE: An upper Limit was not established for vitamins and minerals not listed and for those age groups listed with a dash (—) because of a lack of data, not because these nutrients are safe to consume at any level of intake. All nutrients can have adverse effects when intakes are excessive.

SOURCE: Adapted with permission from the *Dietary Reference Intakes series*, National Academies Press. Copyright 1997, 1998, 2000, 2001, 2002, 2005, 2011 by the National Academies of Sciences.

Understanding Nutrition



© Blanche Branton/Shutterstock.com

CENGAGE LEARNING'S GLOBAL NUTRITION WATCH
GLOBAL NUTRITION RESOURCE CENTER

The science of nutrition depends on many other fields of research. Access Global Nutrition Watch and browse some of the recent articles listed on your dashboard. What fields of science are at the foundation of this nutrition research?

1 An Overview of Nutrition

Nutrition in Your Life

Believe it or not, you have probably eaten at least 20,000 meals in your life. Without any conscious effort on your part, your body uses the nutrients from those foods to make all its components, fuel all its activities, and defend itself against diseases. How successfully your body handles these tasks depends, in part, on your food choices. Nutritious food choices support healthy bodies. In the Nutrition Portfolio at the end of this chapter, you can see how your current food choices are influencing your health and risk of chronic diseases.

Although you may not always have been aware of it, **nutrition** has played a significant role in your life. Every day, several times a day, you select **foods** that influence your body's health for better or worse. Each day's food choices may benefit or harm your health only a little, but when these choices are repeated over years and decades, the rewards or consequences become major. That being the case, paying close attention to good eating habits now supports health benefits later. Conversely, carelessness about food choices can contribute to many **chronic diseases,** including heart disease, diabetes, and cancer. Of course, some people will become ill or die young no matter what choices they make, and others will live long lives despite making poor choices. For the majority of us, however, the food choices we make each and every day will benefit or impair our health in proportion to the wisdom of those choices.

Although most people realize that their food habits affect their health, they often choose foods for other reasons. After all, foods bring to the table a variety of pleasures, traditions, and associations as well as nourishment. The challenge, then, is to combine favorite foods and fun times with a nutritionally balanced **diet.**

LEARNING GPS

1.1 Food Choices 4
LEARN IT Describe how various factors influence personal food choices.

1.2 The Nutrients 6
LEARN IT Name the six major classes of nutrients and identify which are organic and which yield energy.
- Nutrients in Foods and in the Body 6
- The Energy-Yielding Nutrients: Carbohydrate, Fat, and Protein 8
- The Vitamins 11
- The Minerals 11
- Water 11

1.3 The Science of Nutrition 12
LEARN IT Explain the scientific method and how scientists use various types of research studies and methods to acquire nutrition information.
- Conducting Research 12
- Analyzing Research Findings 15
- Publishing Research 16

1.4 Dietary Reference Intakes 17
LEARN IT Define the four categories of the DRI and explain their purposes.
- Establishing Nutrient Recommendations 17
- Establishing Energy Recommendations 20
- Using Nutrient Recommendations 20
- Comparing Nutrient Recommendations 21

1.5 Nutrition Assessment 21
LEARN IT Explain how the four assessment methods are used to detect energy and nutrient deficiencies and excesses.
- Nutrition Assessment of Individuals 22
- Nutrition Assessment of Populations 24

1.6 Diet and Health 25
LEARN IT Identify several risk factors and explain their relationships to chronic diseases.
- Chronic Diseases 25
- Risk Factors for Chronic Diseases 26

Highlight 1 Nutrition Information and Misinformation 28
LEARN IT Recognize misinformation and describe how to identify reliable nutrition information.

nutrition: the science of the nutrients in foods and their actions within the body. A broader definition includes the study of human behaviors related to food and eating.

foods: products derived from plants or animals that can be taken into the body to yield energy and nutrients for the maintenance of life and the growth and repair of tissues.

chronic diseases: diseases characterized by slow progression and long duration. Examples include heart disease, diabetes, and some cancers.

- **chronos** = time

diet: the foods and beverages a person eats and drinks.

Before learning more about creating a healthful diet, take a moment to review the definition of *diet*. Note that *diet* does *not* mean a restrictive food plan designed for weight loss. It simply refers to the foods and beverages a person consumes. Whether it's a vegetarian diet, a weight-loss diet, or any other kind of diet depends on the types of foods and beverages a person chooses.

1.1 Food Choices

LEARN IT Describe how various factors influence personal food choices.

People decide what to eat, when to eat, how much to eat, and even whether to eat in highly personal ways based on a complex interaction of genetic, behavioral, or social factors rather than on an awareness of nutrition's importance to health.[1] A variety of food choices can support good health, and an understanding of human nutrition helps you make sensible selections more often.



© Corbis Premium RF/Alamy

An enjoyable way to learn about a culture is to taste the ethnic foods.

Preferences As you might expect, the number one reason most people choose certain foods is taste—they like the flavor. Two widely shared preferences are for the sweetness of sugar and the savoriness of salt. Liking high-fat foods also appears to be a universally common preference. Other preferences might be for the hot peppers common in Mexican cooking or the curry spices of Indian cuisine. Research suggests that genetics may influence taste perceptions and therefore food likes and dislikes.[2] Similarly, the hormones of pregnancy seem to influence food cravings and aversions (see Chapter 15).

Habit People sometimes select foods out of habit. They eat cereal every morning, for example, simply because they have always eaten cereal for breakfast. Eating a familiar food and not having to make any decisions can be comforting.

Ethnic Heritage and Regional Cuisines Among the strongest influences on food choices are ethnic heritage and regional cuisines. People tend to prefer the foods they grew up eating. Every country, and in fact every region of a country, has its own typical foods and ways of combining them into meals. These cuisines reflect a unique combination of local ingredients and cooking styles. Chowder in New England is made with clams, but in the Florida Keys conch is the featured ingredient. The Pacific Northwest is as famous for its marionberry pie as Georgia is for its peach cobbler. Philly has its cheesesteaks and New Orleans has its oyster po'boys. The "American diet" includes many ethnic foods and regional styles, all adding variety to the diet.

Enjoying traditional **ethnic foods** provides an opportunity to celebrate a person's heritage. People offering ethnic foods share a part of their culture with others, and those accepting the foods learn about another's way of life. Developing **cultural competence** honors individual preferences and is particularly important for professionals who help others plan healthy diets.[3]

Social Interactions Most people enjoy companionship while eating. It's fun to go out with friends for a meal or share a snack when watching a movie together. Meals are often social events, and sharing food is part of hospitality. Social customs invite people to accept food or drink offered by a host or shared by a group—regardless of hunger signals. Chapter 9 describes how people tend to eat more food when socializing with others.

Availability, Convenience, and Economy People often eat foods that are accessible, quick and easy to prepare, and within their financial means. Consumers who value convenience frequently eat out, bring home ready-to-eat meals, or have food delivered. Even when they venture into the kitchen, they want to prepare a meal in 15 to 20 minutes, using less than a half dozen ingredients—and those "ingredients" are often semiprepared foods, such as canned soups.

Consumer emphasis on convenience limits food choices to the selections offered on menus and products designed for quick preparation. Whether decisions

ethnic foods: foods associated with particular cultural groups.

cultural competence: having an awareness and acceptance of cultures and the ability to interact effectively with people of diverse cultures.

based on convenience meet a person's nutrition needs depends on the choices made. Eating a banana or a candy bar may be equally convenient, but the fruit provides more vitamins and minerals and less sugar and fat.

Rising food costs have shifted some consumers' priorities and changed their shopping habits. They are less likely to buy higher priced convenience foods and more likely to buy less-expensive store brand items and prepare home-cooked meals.[4] In fact, more than 80 percent of US consumers are eating home-cooked meals at least three times a week.[5] Those who frequently prepare their own meals eat fast food less often and are more likely to meet dietary guidelines for fat, calcium, fruits, vegetables, and whole grains. Not surprisingly, when eating out, consumers choose low-cost fast-food outlets over more expensive fine-dining restaurants.[6]

Positive and Negative Associations People tend to like particular foods associated with happy occasions—such as hot dogs at ball games or cake and ice cream at birthday parties. By the same token, people can develop aversions and dislike foods that they ate when they felt sick or that they were forced to eat in negative situations. Similarly, children learn to like and dislike certain foods when their parents use foods as rewards or punishments. Negative experiences can have long-lasting influences on food preferences. More than 50 years after World War II, veterans who had experienced intense combat in the Pacific dislike Chinese and Japanese food significantly more than their peers who were not engaged in battle or those who fought elsewhere.[7]

Emotions Some people cannot eat when they are emotionally upset. Others may eat in response to a variety of emotional stimuli—for example, to relieve boredom or depression or to calm anxiety. A depressed person may choose to eat rather than to call a friend. A person who has returned home from an exciting evening out may unwind with a late-night snack. These people may find emotional comfort, in part, because foods can influence the brain's chemistry and the mind's response. Carbohydrates and alcohol, for example, tend to calm, whereas proteins and caffeine are more likely to stimulate. Eating in response to emotions and stress can easily lead to overeating and obesity, but it may be helpful at times.[8] For example, sharing food at times of bereavement serves both the giver's need to provide comfort and the receiver's need to be cared for and to interact with others as well as to take nourishment.

Values Food choices may reflect people's religious beliefs, political views, or environmental concerns. For example, some Christians forgo meat on Fridays during Lent (the period prior to Easter), Jewish law includes an extensive set of dietary rules that govern the use of foods derived from animals, and Muslims fast between sunrise and sunset during Ramadan (the ninth month of the Islamic calendar). Some vegetarians select foods based on their concern for animal rights. A concerned consumer may boycott fruit picked by migrant workers who have been exploited. People may buy vegetables from local farmers to save the fuel and environmental costs of foods shipped from far away. They may also select foods packaged in containers that can be reused or recycled. Some consumers accept or reject foods that have been irradiated, grown organically, or genetically modified, depending on their approval of these processes (see Chapter and Highlight 19 for a complete discussion).

Body Weight and Image Sometimes people select certain foods and supplements that they believe will improve their physical appearance and avoid those they believe might be detrimental. Such decisions can be beneficial when based on sound nutrition and fitness knowledge, but decisions based on fads or carried to extremes undermine good health, as pointed out in later discussions of eating disorders (Highlight 8) and dietary supplements commonly used by athletes (Highlight 14).



© Wave Royalty Free/Alamy

To enhance your health, keep nutrition in mind when selecting foods. To protect the environment, shop at local markets and reuse cloth shopping bags.

Nutrition and Health Benefits Finally, of course, many consumers make food choices they believe will improve their health.[9] Food manufacturers and restaurant chefs have responded to scientific findings linking health with nutrition by offering an abundant selection of health-promoting foods and beverages. Foods that provide health benefits beyond their nutrient contributions are called **functional foods.**[10] Functional foods may include whole foods, modified foods, or fortified foods. Whole foods—as natural and familiar as oatmeal or tomatoes—are the simplest functional foods. In other cases, foods have been modified to provide health benefits, perhaps by lowering the fat contents. In still other cases, manufacturers have fortified foods by adding nutrients or **phytochemicals** that provide health benefits (see Highlight 13). Examples of these functional foods include orange juice fortified with calcium to help build strong bones and margarine made with a plant sterol that lowers blood cholesterol.

Consumers typically welcome new foods into their diets, provided that these foods are reasonably priced, clearly labeled, easy to find in the grocery store, and convenient to prepare. These foods must also taste good—as good as the traditional choices. Of course, a person need not eat any "special" foods to enjoy a healthy diet; many "regular" foods provide numerous health benefits as well. In fact, "regular" foods such as whole grains; vegetables and legumes; fruits; seafood, meats, poultry, eggs, nuts, and seeds; and milk products are among the healthiest choices a person can make.

REVIEW IT Describe how various factors influence personal food choices.

A person selects foods for a variety of reasons. Whatever those reasons may be, food choices influence health. Individual food selections neither make nor break a diet's healthfulness, but the balance of foods selected over time can make an important difference to health.[11] For this reason, people are wise to think "nutrition" when making their food choices.



© wavebreakmedia ltd/Shutterstock.com

Foods bring pleasure—and nutrients.

functional foods: foods that contain bioactive components that provide health benefits beyond their nutrient contributions.

phytochemicals (FIE-toe-KEM-ih-cals): nonnutrient compounds found in plants. Some phytochemicals have biological activity in the body.

- **phyto** = plant

energy: the capacity to do work. The energy in food is chemical energy. The body can convert this chemical energy to mechanical, electrical, or heat energy.

nutrients: chemical substances obtained from food and used in the body to provide energy, structural materials, and regulating agents to support growth, maintenance, and repair of the body's tissues. Nutrients may also reduce the risks of some diseases.

♦ Six classes of nutrients:
- Carbohydrates
- Lipids (fats)
- Proteins
- Vitamins
- Minerals
- Water

1.2 The Nutrients

LEARN IT Name the six major classes of nutrients and identify which are organic and which yield energy.

Biologically speaking, people eat to receive nourishment. Do you ever think of yourself as a biological being made of carefully arranged atoms, molecules, cells, tissues, and organs? Are you aware of the activity going on within your body even as you sit still? The atoms, molecules, and cells of your body continuously move and change, even though the structures of your tissues and organs and your external appearance remain relatively constant. The ongoing growth, maintenance, and repair of the body's tissues depend on the **energy** and the **nutrients** received from foods.

Nutrients in Foods and in the Body Amazingly, our bodies can derive all the energy, structural materials, and regulating agents we need from the foods we eat. This section introduces the nutrients that foods deliver and shows how they participate in the dynamic processes that keep people alive and well.

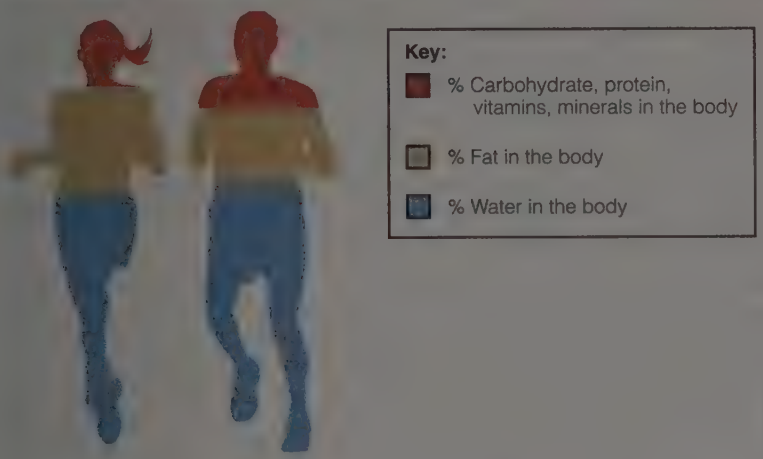
Nutrient Composition of Foods Chemical analysis of a food such as a tomato shows that it is composed primarily of water (95 percent). Most of the solid materials are carbohydrates, lipids (fats), and proteins. If you could remove these materials, you would find a tiny residue of vitamins, minerals, and other compounds. Water, carbohydrates, lipids, proteins, vitamins, and some of the minerals found in foods represent the six classes ♦ of nutrients—substances the body uses for the growth, maintenance, and repair of its tissues.

This book focuses mostly on the nutrients, but foods contain other compounds as well—fibers, phytochemicals, pigments, additives, alcohols, and others. Some are beneficial, some are neutral, and a few are harmful. Later sections of the book touch on these compounds and their significance.

Nutrient Composition of the Body A chemical analysis of your body would show that it is made of materials similar to those found in foods (see Figure 1-1). A healthy

> FIGURE 1-1 Body Composition of Healthy-Weight Men and Women

The human body is made of compounds similar to those found in foods—mostly water (60 percent) and some fat (18 to 21 percent for young men, 23 to 26 percent for young women), with carbohydrate, protein, vitamins, minerals, and other minor constituents making up the remainder. (Chapter 8 describes the health hazards of too little or too much body fat.)



© Cengage Learning 2013

150-pound body contains about 90 pounds of water and about 20 to 45 pounds of fat. The remaining pounds are mostly protein, carbohydrate, and the major minerals of the bones. Vitamins, other minerals, and incidental extras constitute a fraction of a pound.

Chemical Composition of Nutrients The simplest of the nutrients are the minerals. Each mineral is a chemical element; its atoms are all alike. As a result, its identity never changes. For example, iron may have different electrical charges, but the individual iron atoms remain the same when they are in a food, when a person eats the food, when the iron becomes part of a red blood cell, when the cell is broken down, and when the iron is lost from the body by excretion. The next simplest nutrient is water, a compound made of two elements—hydrogen and oxygen. Minerals and water are **inorganic** nutrients—which means they do not contain carbon.

The other four classes of nutrients (carbohydrates, lipids, proteins, and vitamins) are more complex. In addition to hydrogen and oxygen, they all contain carbon, an element found in all living things. They are therefore called **organic** compounds (meaning, literally, "alive"). This chemical definition of *organic* differs from the agricultural definition. As Chapter 19 explains, organic farming refers to growing crops and raising livestock according to standards set by the US Department of Agriculture (USDA). Protein and some vitamins also contain nitrogen and may contain other elements such as sulfur as well (see Table 1-1).

TABLE 1-1 Elements in the Six Classes of Nutrients

Notice that organic nutrients contain carbon.

	Carbon	Hydrogen	Oxygen	Nitrogen	Minerals
Inorganic Nutrients					
Minerals					✓
Water		✓	✓		
Organic Nutrients					
Carbohydrate	✓	✓	✓		
Lipid (fat)	✓	✓	✓		
Protein[a]	✓	✓	✓	✓	
Vitamins[b]	✓	✓	✓		

[a]Some proteins also contain the mineral sulfur.
[b]Some vitamins contain nitrogen; some contain minerals.

© Cengage Learning 2013

inorganic: not containing carbon or pertaining to living things.

- **in** = not

organic: in chemistry, a substance or molecule containing carbon-carbon bonds or carbon-hydrogen bonds. This definition excludes coal, diamonds, and a few carbon-containing compounds that contain only a single carbon and no hydrogen, such as carbon dioxide (CO_2), calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), and sodium cyanide ($NaCN$).

Essential Nutrients The body can make some nutrients, but it cannot make all of them. Also, it makes some in insufficient quantities to meet its needs and, therefore, must obtain these nutrients from foods. The nutrients that foods must supply are **essential nutrients.** When used to refer to nutrients, the word *essential* means more than just "necessary"; it means "needed from outside the body"—normally, from foods.

The Energy-Yielding Nutrients: Carbohydrate, Fat, and Protein

In the body, three of the organic nutrients can be used to provide energy: carbohydrate, fat, and protein. In contrast to these **energy-yielding nutrients,** vitamins, minerals, and water do not yield energy in the human body.

Carbohydrate, fat, and protein are sometimes called *macronutrients* because the body requires them in relatively large amounts (many grams daily). In contrast, vitamins and minerals are *micronutrients,* required only in small amounts (milligrams or micrograms daily).

TABLE 1-2 kCalorie Values of Energy Nutrients

Nutrients	Energy (kcal/g)
Carbohydrate	4
Fat	9
Protein	4

NOTE: Alcohol contributes 7 kcalories per gram that can be used for energy, but it is not considered a nutrient because it interferes with the body's growth, maintenance, and repair.

© Cengage Learning (TNY)

Energy Measured in kCalories The energy released from carbohydrates, fats, and proteins can be measured in **calories**—tiny units of energy so small that a single apple provides tens of thousands of them. To ease calculations, energy is expressed in 1000-calorie metric units known as kilocalories (shortened to kcalories, but commonly called "calories"). When you read in popular books or magazines that an apple provides "100 calories," it actually means 100 kcalories. This book uses the term *kcalorie* and its abbreviation *kcal* throughout, as do other scientific books and journals. The "How To" on p. 9 provides a few tips on "thinking metric."

Energy from Foods The amount of energy a food provides depends on how much carbohydrate, fat, and protein it contains. ♦ When completely broken down in the body, a gram of carbohydrate yields about 4 kcalories of energy; a gram of protein also yields 4 kcalories; and a gram of fat yields 9 kcalories (see Table 1-2).* The "How To" on p. 10 explains how to calculate the energy available from foods.

♦ Energy-yielding nutrients:
- Carbohydrate
- Fat
- Protein

Because fat provides more energy per gram, it has a greater **energy density** than either carbohydrate or protein. Figure 1-2 compares the energy density of two breakfast options, and later chapters describe how foods with a high energy

FIGURE 1-2 Energy Density of Two Breakfast Options Compared

Gram for gram, ounce for ounce, and bite for bite, foods with a high energy density deliver more kcalories than foods with a low energy density. Both of these breakfast options provide 500 kcalories, but the cereal with milk, fruit salad, scrambled egg, turkey sausage, and toast with jam offers three times as much food as the doughnuts (based on weight); it has a lower energy density than the doughnuts. Selecting a variety of foods also helps to ensure nutrient adequacy.



LOWER ENERGY DENSITY
This 450-gram breakfast delivers 500 kcalories, for an energy density of 1.1 (500 kcal ÷ 450 g = 1.1 kcal/g).



HIGHER ENERGY DENSITY
This 144-gram breakfast delivers 500 kcalories, for an energy density of 3.5 (500 kcal ÷ 144 g = 3.5 kcal/g).

© Matthew Farruggio (both)

essential nutrients: nutrients a person must obtain from food because the body cannot make them for itself in sufficient quantity to meet physiological needs; also called *indispensable nutrients.* About 40 nutrients are currently known to be essential for human beings.

energy-yielding nutrients: the nutrients that break down to yield energy the body can use:
- Carbohydrate
- Fat
- Protein

calories: units by which energy is measured. Energy provided by foods and beverages is measured in *kilocalories* (1000 calories equal 1 kilocalorie), abbreviated *kcalories* or *kcal.* One kcalorie is the amount of heat necessary to raise the temperature of 1 kilogram (kg) of water 1°C. The scientific use of the term *kcalorie* is the same as the popular use of the term *calorie.*

energy density: a measure of the energy a food provides relative to the weight of the food (kcalories per gram).

*For those using kilojoules: 1 g carbohydrate = 17 kJ; 1 g protein = 17 kJ; 1 g fat = 37 kJ; and 1 g alcohol = 29 kJ.

density help with weight *gain*, whereas those with a low energy density help with weight *loss*.

One other substance contributes energy—alcohol. Alcohol, however, is not considered a nutrient. Unlike the essential nutrients, alcohol does not sustain life. In fact, it interferes with the growth, maintenance, and repair of the body. Its only common characteristic with nutrients is that it yields energy (7 kcalories per gram) when metabolized in the body.

>How To

Think Metric

Like other scientists, nutrition scientists use metric units of measure. They measure food energy in kilocalories, people's height in centimeters, people's weight in kilograms, and the weights of foods and nutrients in grams, milligrams, or micrograms. For ease in using these measures, it helps to remember that the prefixes on the grams imply 1000. For example, a *kilo*gram is 1000 grams, a *milli*gram is 1/1000 of a gram, and a *micro*gram is 1/1000 of a milligram.

Most food labels and many recipes provide "dual measures," listing both household measures, such as cups, quarts, and teaspoons, and metric measures, such as milliliters, liters, and grams. This practice gives people an opportunity to gradually learn to "think metric."

A person might begin to "think metric" by simply observing the measure—by noticing the amount of soda in a 2-liter bottle, for example. Through such experiences, a person can become familiar with a measure without having to do any conversions.

The international unit for measuring food energy is the *joule*—the amount of energy expended when 1 kilogram is moved 1 meter by a force of 1 newton. The joule is thus a measure of *work* energy, whereas the kcalorie is a measure of *heat* energy. While many scientists and journals report their findings in kilojoules (kJ), many others, particularly those in the United States, use kcalories (kcal). To convert energy measures from kcalories to kilojoules, multiply by 4.2; to convert kilojoules to kcalories, multiply by 0.24. For example, a 50-kcalorie cookie provides 210 kilojoules:

$$50 \text{ kcal} \times 4.2 = 210 \text{ kJ}$$

Appendix K provides assistance and conversion factors for these and other units of measure.

Volume: Liters (L)

1 L = 1000 milliliters (mL)
0.95 L = 1 quart
1 mL = 0.03 fluid ounces
240 mL = 1 cup



© Felicia Martinez/PhotoEdit

A liter of liquid is approximately one US quart. (Four liters are only about 5 percent more than a gallon.)

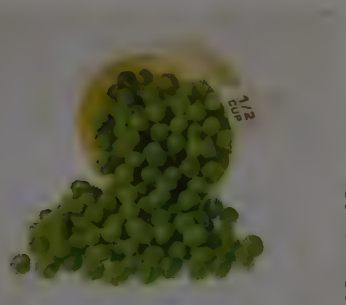


© Felicia Martinez/PhotoEdit

One cup is about 240 milliliters; a half-cup of liquid is about 120 milliliters.

Weight: Grams (g)

1 g = 1000 milligrams (mg)
1 g = 0.04 ounce (oz)
1 oz = 28.35 g (or 30 g)
100 g = 3½ oz
1 kilogram (kg) = 1000 g
1 kg = 2.2 pounds (lb)
454 g = 1 lb



© Thomas Harm & Tom Peterson/Quest Photographic Inc

A half-cup of vegetables weighs about 100 grams; one pea weighs about ½ gram.



© Tony Freeman/PhotoEdit

A 5-pound bag of potatoes weighs about 2 kilograms, and a 176-pound person weighs 80 kilograms.

A kilogram is slightly more than 2 lb; conversely, a pound is about ½ kg.

TRY IT Convert your body weight from pounds to kilograms and your height from inches to centimeters.

How To

Calculate the Energy Available from Foods

To calculate the energy available from a food, multiply the number of grams of carbohydrate, protein, and fat by 4, 4, and 9, respectively. Then add the results together. For example, 1 slice of bread with 1 tablespoon of peanut butter on it contains 16 grams carbohydrate, 7 grams protein, and 9 grams fat:

16 g carbohydrate × 4 kcal/g = 64 kcal
7 g protein × 4 kcal/g = 28 kcal
9 g fat × 9 kcal/g = 81 kcal
Total = 173 kcal

From this information, you can calculate the percentage of kcalories each of the energy nutrients contributes to the total. To determine the percentage of kcalories from fat, for example, divide the 81 fat kcalories by the total 173 kcalories:

81 fat kcal ÷ 173 total kcal = 0.468 (rounded to 0.47)

Then multiply by 100 to get the percentage:

0.47 × 100 = 47%

Dietary recommendations that urge people to limit fat intake to 20 to 35 percent of kcalories refer to the day's total energy intake, not to individual foods. Still, if the proportion of fat in each food choice throughout a day exceeds 35 percent of kcalories, then the day's total surely will, too. Knowing that this snack provides 47 percent of its kcalories from fat alerts a person to the need to make lower-fat selections at other times that day.

TRY IT Calculate the energy available from a bean burrito with cheese (55 grams carbohydrate, 15 grams protein, and 12 grams fat). Determine the percentage of kcalories from each of the energy nutrients.

Most foods contain all three energy-yielding nutrients, as well as vitamins, minerals, water, and other substances. For example, meat contains water, fat, vitamins, and minerals as well as protein. Bread contains water, a trace of fat, a little protein, and some vitamins and minerals in addition to its carbohydrate. Only a few foods are exceptions to this rule, the common ones being sugar (pure carbohydrate) and oil (essentially pure fat).

Energy in the Body When the body uses carbohydrate, fat, or protein to fuel its activities, the bonds between the nutrient's atoms break. As the bonds break, they release energy. Some of this energy is released as heat, but some is used to send electrical impulses through the brain and nerves, to synthesize body compounds, and to move muscles. Thus the energy from food supports every activity from quiet thought to vigorous sports.

If the body does not use these nutrients to fuel its current activities, it converts them into storage compounds (such as body fat), to be used between meals and overnight when fresh energy supplies run low. If more energy is consumed than expended, the result is an increase in energy stores and weight gain. Similarly, if less energy is consumed than expended, the result is a decrease in energy stores and weight loss.

When consumed in excess of energy needs, alcohol, too, can be converted to body fat and stored. When alcohol contributes a substantial portion of the energy in a person's diet, the harm it does far exceeds the problems of excess body fat. (Highlight 7 describes the effects of alcohol on health and nutrition.)

Other Roles of Energy-Yielding Nutrients In addition to providing energy, carbohydrates, fats, and proteins provide the raw materials for building the body's tissues and regulating its many activities. In fact, protein's role as a fuel source is relatively minor compared with both the other two energy-yielding nutrients and its other roles. Proteins are found in structures such as the muscles and skin and

help to regulate activities such as digestion and energy metabolism. (Chapter 6 presents a full discussion on proteins.)

The Vitamins The **vitamins** are also organic, but they do not provide energy. Instead, they facilitate the release of energy from carbohydrate, fat, and protein and participate in numerous other activities throughout the body.

Each of the 13 vitamins has its own special roles to play.* One vitamin enables the eyes to see in dim light, another helps protect the lungs from air pollution, and still another helps make the sex hormones—among other things. When you cut yourself, one vitamin helps stop the bleeding and another helps repair the skin. Vitamins busily help replace old red blood cells and the lining of the digestive tract. Almost every action in the body requires the assistance of vitamins.

Vitamins can function only if they are intact, but because they are complex organic molecules, they are vulnerable to destruction by heat, light, and chemical agents. This is why the body handles them carefully, and why nutrition-wise cooks do, too. The strategies of cooking vegetables at moderate temperatures for short times and using small amounts of water help to preserve the vitamins.

The Minerals In the body, some **minerals** are put together in orderly arrays in such structures as bones and teeth. Minerals are also found in the fluids of the body, which influences fluid balance and distribution. Whatever their roles, minerals do not yield energy.

Only 16 minerals are known to be essential in human nutrition.** Others are being studied to determine whether they play significant roles in the human body. Still other minerals, such as lead, are environmental contaminants that displace the nutrient minerals from their workplaces in the body, disrupting body functions. The problems caused by contaminant minerals are described in Chapter 13.

Because minerals are inorganic, they are indestructible and need not be handled with the special care that vitamins require. Minerals can, however, be bound by substances that interfere with the body's ability to absorb them. They can also be lost during food-refining processes or during cooking when they leach into water that is discarded.

Water Water provides the environment in which nearly all the body's activities are conducted. It participates in many metabolic reactions and supplies the medium for transporting vital materials to cells and carrying waste products away from them. Water is discussed fully in Chapter 12, but it is mentioned in every chapter. If you watch for it, you cannot help but be impressed by water's participation in all life processes.

REVIEW IT Name the six major classes of nutrients and identify which are organic and which yield energy.

Foods provide nutrients—substances that support the growth, maintenance, and repair of the body's tissues. The six classes of nutrients include:

- Carbohydrates
- Lipids (fats)
- Proteins
- Vitamins
- Minerals
- Water

Foods rich in the energy-yielding nutrients (carbohydrate, fat, and protein) provide the major materials for building the body's tissues and yield energy for the body's use or storage. Energy is measured in kcalories—a measure of heat energy. Vitamins, minerals, and water do not yield energy; instead they facilitate a variety of activities in the body.



© Blend Images/Jupiterimages.com

Water is an essential nutrient and naturally carries varying amounts of several minerals.

*The water-soluble vitamins are vitamin C and the eight B vitamins: thiamin, riboflavin, niacin, vitamins B_6 and B_{12}, folate, biotin, and pantothenic acid. The fat-soluble vitamins are vitamins A, D, E, and K. The water-soluble vitamins are the subject of Chapter 10 and the fat-soluble vitamins, of Chapter 11.

**The major minerals are calcium, phosphorus, potassium, sodium, chloride, magnesium, and sulfate. The trace minerals are iron, iodine, zinc, chromium, selenium, fluoride, molybdenum, copper, and manganese. Chapters 12 and 13 are devoted to the major and trace minerals, respectively.

vitamins: organic, essential nutrients required in small amounts by the body for health.

minerals: inorganic elements. Some minerals are essential nutrients required in small amounts by the body for health.

Without exaggeration, nutrients provide the physical and metabolic basis for nearly all that we are and all that we do. The next section introduces the science of nutrition with emphasis on the research methods scientists have used in uncovering the wonders of nutrition.

1.3 The Science of Nutrition

LEARN IT Explain the scientific method and how scientists use various types of research studies and methods to acquire nutrition information.

The science of nutrition is the study of the nutrients and other substances in foods and the body's handling of them. Its foundation depends on several other sciences, including biology, biochemistry, and physiology. As sciences go, nutrition is young, but as you can see from the size of this book, much has happened in nutrition's short life. And it is currently experiencing a tremendous growth spurt as scientists apply knowledge gained from sequencing the human **genome.** The integration of nutrition, genomics, and molecular biology has opened a whole new world of study called **nutritional genomics**—the science of how nutrients affect the activities of genes and how genes affect the interactions between diet and disease. Highlight 6 describes how nutritional genomics is shaping the science of nutrition, and examples of nutrient–gene interactions appear throughout later sections of the book.

Conducting Research

Consumers sometimes depend on personal experience or reports from friends to gather information on nutrition. Such a personal account of an experience or event is known as an **anecdote** and is not accepted as reliable scientific information. In contrast, researchers use the scientific method to guide their work (see Figure 1-3). As the figure shows, research always begins with a problem or a question. For example, "What foods or nutrients might protect against the common cold?" In search of an answer, scientists make an educated guess **(hypothesis),** such as "foods rich in vitamin C reduce the number of common colds." Then they systematically conduct research studies to collect data that will test the hypothesis (see the glossary on p. 13 for definitions of research terms). Some examples of various types of research designs are presented in Figure 1-4 on p. 14. Because each type of study has strengths and weaknesses, some provide stronger evidence than others, as Figure 1-4 explains.

In attempting to discover whether a nutrient relieves symptoms or cures a disease, researchers deliberately manipulate one variable (for example, the amount of vitamin C in the diet) and measure any observed changes (perhaps the number of colds). As much as possible, all other conditions are held constant. The following paragraphs illustrate how this is accomplished.

Controls

In studies examining the effectiveness of vitamin C, researchers typically divide the **subjects** into two groups. One group (the **experimental group**) receives a vitamin C supplement, and the other (the **control group**) does not. Researchers observe both groups to determine whether one group has fewer, milder, or shorter colds than the other. The following discussion describes some of the pitfalls inherent in an experiment of this kind and ways to avoid them.

In sorting subjects into two groups, researchers must ensure that each person has an equal chance of being assigned to either the experimental group or the control group. This is accomplished by **randomization;** that is, the subjects are chosen randomly from the same population by flipping a coin or some other method involving chance. Randomization helps to ensure that the two groups are "equal" and that observed differences reflect the treatment and not other factors.

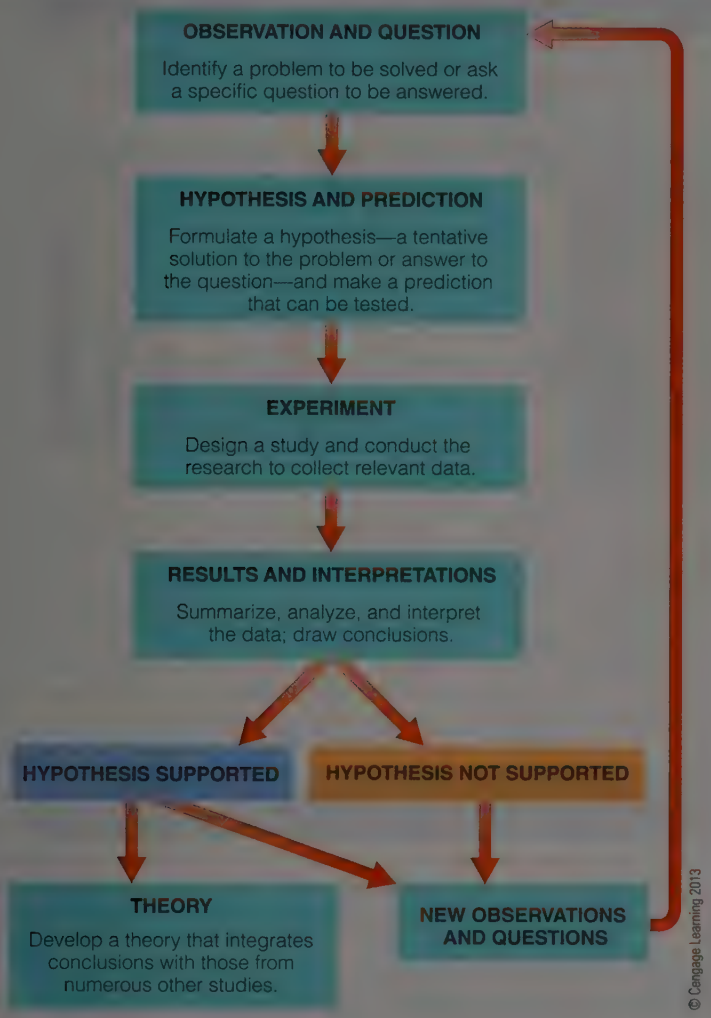
Importantly, the two groups of people must be similar and must have the same track record with respect to colds to rule out the possibility that observed differences in the rate, severity, or duration of colds might have occurred anyway. If, for example, the control group would normally catch twice as many colds as the experimental group, then the findings prove nothing.

genome (GEE-nome): the complete set of genetic material (DNA) in an organism or a cell. The study of genomes is called *genomics.*

nutritional genomics: the science of how nutrients affect the activities of genes (*nutrigenomics*) and how genes affect the interactions between diet and disease (*nutrigenetics*).

> FIGURE 1-3 The Scientific Method

Research scientists follow the scientific method. Note that most research generates new questions, not final answers. Thus the sequence begins anew, and research continues in a somewhat cyclical way.



GLOSSARY OF RESEARCH TERMS

anecdote: a personal account of an experience or event; not reliable scientific information.

blind experiment: an experiment in which the subjects do not know whether they are members of the experimental group or the control group.

control group: a group of individuals similar in all possible respects to the experimental group except for the treatment. Ideally, the control group receives a placebo while the experimental group receives a real treatment.

correlation (CORE-ee-LAY-shun): the simultaneous increase, decrease, or change in two variables. If A increases as B increases, or if A decreases as B decreases, the correlation is *positive*. (This does not mean that A causes B or vice versa.) If A increases as B decreases, or if A decreases as B increases, the correlation is *negative*. (This does not mean that A prevents B or vice versa.) Some third factor may account for both A and B.

double-blind experiment: an experiment in which neither the subjects nor the researchers know which subjects are members of the experimental group and which are serving as control subjects, until after the experiment is over.

experimental group: a group of individuals similar in all possible respects to the control group except for the treatment. The experimental group receives the real treatment.

hypothesis (hi-POTH-eh-sis): an unproven statement that tentatively explains the relationships between two or more variables.

peer review: a process in which a panel of scientists rigorously evaluates a research study to assure that the scientific method was followed.

placebo (pla-SEE-bo): an inert, harmless medication given to provide comfort and hope; a sham treatment used in controlled research studies.

placebo effect: a change that occurs in response to expectations about the effectiveness of a treatment that actually has no pharmaceutical effects.

randomization (RAN-dom-ih-ZAY-shun): a process of choosing the members of the experimental and control groups without bias.

replication (REP-lih-KAY-shun): repeating an experiment and getting the same results.

subjects: the people or animals participating in a research project.

theory: a tentative explanation that integrates many and diverse findings to further the understanding of a defined topic.

validity (va-LID-ih-tee): having the quality of being founded on fact or evidence.

variables: factors that change. A variable may depend on another variable (for example, a child's height depends on his age), or it may be independent (for example, a child's height does not depend on the color of her eyes). Sometimes both variables correlate with a third variable (a child's height and eye color both depend on genetics).

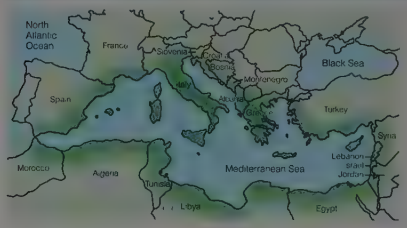
> FIGURE 1-4 Examples of Research Designs

EPIDEMIOLOGICAL STUDIES research the incidence, distribution, and control of disease in a population. Epidemiological studies include cross-sectional, case-control, and cohort studies.

Strengths:
- Can narrow down the list of possible causes
- Can raise questions to pursue through other research

Weaknesses:
- Cannot control variables that may influence the development or the prevention of a disease
- Cannot prove cause and effect

CROSS-SECTIONAL STUDIES



Researchers observe how much and what kinds of foods a group of people eat and how healthy those people are. Their findings identify factors that might influence the incidence of a disease in various populations.

Example. Many people in the Mediterranean region drink more wine, eat more fat from olive oil, and yet have a lower incidence of heart disease than northern Europeans and North Americans.

CASE-CONTROL STUDIES

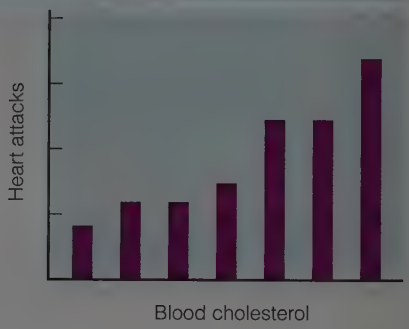


Lester V. Bergman/CORBIS

Researchers compare people who do and do not have a given condition such as a disease, closely matching them in age, gender, and other key variables so that differences in other factors will stand out. These differences may account for the condition in the group that has it.

Example. People with goiter lack iodine in their diets.

COHORT STUDIES



Researchers analyze data collected from a selected group of people (a cohort) at intervals over a certain period of time.

Example. Data collected periodically over the past several decades from more than 5000 people randomly selected from the town of Framingham, Massachusetts, in 1948 have revealed that the risk of heart attack increases as blood cholesterol increases.

EXPERIMENTAL STUDIES test cause and effect relationships between variables. Experimental studies include laboratory-based studies—on animals or in test tubes (in vitro)—and human intervention (or clinical) trials.

Strengths:
- Can control conditions (for the most part)
- Can determine effects of a variable
- Can apply some findings on human beings to some groups of human beings

Weaknesses:
- Cannot apply results from test tubes or animals to human beings
- Cannot generalize findings on human beings to all human beings
- Cannot use certain treatments for clinical or ethical reasons

LABORATORY-BASED ANIMAL STUDIES

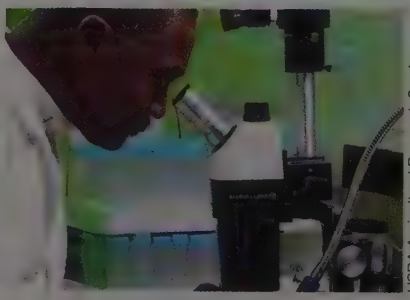


© R. Benali/Getty Images

Researchers feed animals special diets that provide or omit specific nutrients and then observe any changes in health. Such studies test possible disease causes and treatments in a laboratory where all conditions can be controlled.

Example. Mice fed a high-fat diet eat less food than mice given a lower-fat diet, so they receive the same number of kcalories—but the mice eating the fat-rich diet become severely obese.

LABORATORY-BASED IN VITRO STUDIES



USDA Agricultural Research Service

Researchers examine the effects of a specific variable on a tissue, cell, or molecule isolated from a living organism.

Example. Laboratory studies find that fish oils inhibit the growth and activity of the bacteria implicated in ulcer formation.

HUMAN INTERVENTION (OR CLINICAL) TRIALS



© Photodisc/Getty Images

Researchers ask people to adopt a new behavior (for example, eat a citrus fruit, take a vitamin C supplement, or exercise daily). These trials help determine the effectiveness of such interventions on the development or prevention of disease.

Example. Heart disease risk factors improve when men receive fresh-squeezed orange juice daily for 2 months compared with those on a diet low in vitamin C—even when both groups follow a diet high in saturated fat.

© Cengage Learning 2013

In experiments involving a nutrient, the diets of both groups must also be similar, especially with respect to the nutrient being studied. If those in the experimental group were receiving less vitamin C from their usual diet, then any effects of the supplement may not be apparent.

Sample Size To ensure that chance variation between the two groups does not influence the results, the groups must be large. For example, if one member of a group of five people catches a bad cold by chance, he will pull the whole group's average toward bad colds; but if one member of a group of 500 catches a bad cold, she will not unduly affect the group average. Statistical methods are used to determine whether differences between groups of various sizes support a hypothesis.

Placebos If people who take vitamin C for colds *believe* it will cure them, their chances of recovery may improve. Taking anything believed to be beneficial may hasten recovery. This phenomenon, the result of expectations, is known as the **placebo effect.** In experiments designed to determine vitamin C's effect on colds, this mind-body effect must be rigorously controlled. Severity of symptoms is often a subjective measure, and people who believe they are receiving treatment may report less severe symptoms.

One way experimenters control for the placebo effect is to give pills to all participants. Those in the experimental group, for example, receive pills containing vitamin C, and those in the control group receive a **placebo**—pills of similar appearance and taste containing an inactive ingredient. This way, the expectations of both groups will be equal. It is not necessary to convince all subjects that they are receiving vitamin C, but the extent of belief or unbelief must be the same in both groups. A study conducted under these conditions is called a **blind experiment**—that is, the subjects do not know (are blind to) whether they are members of the experimental group (receiving treatment) or the control group (receiving the placebo).

Double Blind When both the subjects and the researchers do not know which subjects are in which group, the study is called a **double-blind experiment.** Being fallible human beings and having an emotional and sometimes financial investment in a successful outcome, researchers might record and interpret results with a bias in the expected direction. To prevent such bias, the pills are coded by a third party, who does not reveal to the experimenters which subjects are in which group until all results have been recorded.

Analyzing Research Findings

Research findings must be analyzed and interpreted with an awareness of each study's limitations. Scientists must be cautious about drawing any conclusions until they have accumulated a body of evidence from multiple studies that have used various types of research designs. As evidence accumulates, scientists begin to develop a **theory** that integrates the various findings and explains the complex relationships.

Correlations and Causes Researchers often examine the relationships between two or more **variables**—for example, daily vitamin C intake and the number of colds or the duration and severity of cold symptoms. Importantly, researchers must be able to observe, measure, or verify the variables selected. Findings sometimes suggest no **correlation** between variables (regardless of the amount of vitamin C consumed, the number of colds remains the same). Other times, studies find either a **positive correlation** (the more vitamin C, the more colds) or a **negative correlation** (the more vitamin C, the fewer colds). Notice that in a positive correlation, both variables change in the same direction, regardless of whether the direction is "more" or "less"—"the more vitamin C, the more colds" is a positive correlation, just as is "the less vitamin C, the fewer colds." In a negative correlation, the two variables change in opposite directions: "the less vitamin C, the more colds" or "the more vitamin C, the fewer colds." Also notice that a positive correlation does not necessarily reflect a desired outcome, nor does a negative correlation always reflect an unwanted outcome.

Correlational evidence proves only that variables are associated, not that one is the cause of the other. To actually prove that A causes B, scientists have to find evidence of the *mechanism*—that is, an explanation of how A might cause B.

Cautious Conclusions When researchers record and analyze the results of their experiments, they must exercise caution in their interpretation of the findings. For example, in an epidemiological study, scientists may use a specific segment of the population—say, men 18 to 30 years old. When the scientists draw conclusions, they are careful not to generalize the findings to men and women of all ages. Similarly, scientists performing research studies using animals are cautious in applying their findings to human beings. Conclusions from any one research study are always tentative and take into account findings from studies conducted by other scientists as well. As evidence accumulates, scientists gain confidence about making recommendations that affect people's health and lives. Still, their statements are worded cautiously, such as "A diet high in fruits and vegetables *may* protect against *some* cancers."

Quite often, as scientists approach an answer to one research question, they raise several more questions, so future research projects are never lacking. Further scientific investigation then seeks to answer questions, such as "What substance or substances within fruits and vegetables provide protection?" If those substances turn out to be the vitamins found so abundantly in fresh produce, then "How much is needed to offer protection?" "How do these vitamins protect against cancer?" "Is it their action as antioxidant nutrients?" "If not, might it be another action or even another substance that accounts for the protection fruits and vegetables provide against cancer?" (Highlight 11 explores the answers to these questions and reviews recent research on antioxidant nutrients and disease.)

Publishing Research

The findings from a research study are submitted to a board of reviewers composed of other scientists who rigorously evaluate the study to assure that the scientific method was followed—a process known as **peer review.** The reviewers critique the study's hypothesis, methodology, statistical significance, and conclusions. They also note the funding source, recognizing that financial support may bias scientific conclusions.[12] If the reviewers consider the conclusions to be well supported by the evidence—that is, if the research has **validity**—they endorse the work for publication in a scientific journal where others can read it. This raises an important point regarding information found on the Internet: much gets published without the rigorous scrutiny of peer review. Consequently, readers must assume greater responsibility for examining the data and conclusions presented—often without the benefit of journal citations. Highlight 1 offers guidance in determining whether website information is reliable. Table 1-3 describes the parts of a typical research article.

Even when a new finding is published or released to the media, it is still only preliminary and not very meaningful by itself. Other scientists will need to confirm or disprove the findings through **replication.** To be accepted into the body of nutrition knowledge, a finding must stand up to rigorous, repeated testing in

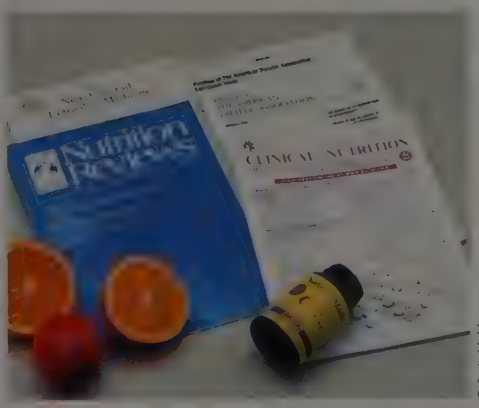
TABLE 1-3 Parts of a Research Article

- *Abstract.* The abstract provides a brief overview of the article.
- *Introduction.* The introduction clearly states the purpose of the current study.
- *Review of literature.* A comprehensive review of the literature reveals all that science has uncovered on the subject to date.
- *Methodology.* The methodology section defines key terms and describes the instruments and procedures used in conducting the study.
- *Results.* The results report the findings and may include tables and figures that summarize the information.
- *Conclusions.* The conclusions drawn are those supported by the data and reflect the original purpose as stated in the introduction. Usually, they answer a few questions and raise several more.
- *References.* The references reflect the investigator's knowledge of the subject and should include an extensive list of relevant studies (including key studies several years old as well as current ones).

© Cengage Learning 2013

experiments performed by several different researchers. What we "know" in nutrition results from years of replicating study findings. Communicating the latest finding in its proper context without distorting or oversimplifying the message is a challenge for scientists and journalists alike. For a helpful scientific overview of current topics in nutrition, look for review articles in scholarly journals such as *Nutrition Reviews*. Similar to a review article, a meta-analysis study uses the power of a computer to combine and reanalyze the results of many previously published studies on a single topic.

With each report from scientists, the field of nutrition changes a little—each finding contributes another piece to the whole body of knowledge. People who know how science works understand that single findings, like single frames in a movie, are just small parts of a larger story. Over years, the picture of what is "true" in nutrition gradually changes, and dietary recommendations change to reflect the current understanding of scientific research. Highlight 5 provides a detailed look at how dietary fat recommendations have evolved over the past several decades as researchers have uncovered the relationships between the various kinds of fat and their roles in supporting or harming health.



© Craig M. Moore

Knowledge about the nutrients and their effects on health comes from scientific studies.

REVIEW IT Explain the scientific method and how scientists use various types of research studies and methods to acquire nutrition information.

Scientists learn about nutrition by conducting experiments that follow the protocol of scientific research. In designing their studies, researchers randomly assign control and experimental groups, seek large sample sizes, provide placebos, and remain blind to treatments. Their findings must be reviewed and replicated by other scientists before being accepted as valid.

The characteristics of well-designed research have enabled scientists to study the actions of nutrients in the body. Such research has laid the foundation for quantifying how much of each nutrient the body needs.

1.4 Dietary Reference Intakes

LEARN IT Define the four categories of the DRI and explain their purposes.

Using the results of thousands of research studies, nutrition experts have produced a set of standards that define the amounts of energy, nutrients, other dietary components, and physical activity that best support health. These recommendations are called **Dietary Reference Intakes (DRI)**, and they reflect the collaborative efforts of researchers in both the United States and Canada.*[13] The inside front cover of this book provides a handy reference for DRI values.

Establishing Nutrient Recommendations The DRI Committee consists of highly qualified scientists who base their estimates of nutrient needs on careful examination and interpretation of scientific evidence. These recommendations apply to healthy people and may not be appropriate for people with diseases that increase or decrease nutrient needs. The next several paragraphs discuss specific aspects of how the committee goes about establishing the values that make up the DRI:

- Estimated Average Requirements (EAR)
- Recommended Dietary Allowances (RDA)
- Adequate Intakes (AI)
- Tolerable Upper Intake Levels (UL)

Estimated Average Requirements (EAR) The committee reviews hundreds of research studies to determine the **requirement** for a nutrient—how much is needed in the diet. The committee selects a different criterion for each nutrient

Dietary Reference Intakes (DRI): a set of nutrient intake values for healthy people in the United States and Canada. These values are used for planning and assessing diets and include:

- Estimated Average Requirements (EAR)
- Recommended Dietary Allowances (RDA)
- Adequate Intakes (AI)
- Tolerable Upper Intake Levels (UL)

requirement: the lowest continuing intake of a nutrient that will maintain a specified criterion of adequacy.

*The DRI reports are produced by the Food and Nutrition Board, Institute of Medicine of the National Academies, with active involvement of scientists from Canada.

based on its roles in supporting various activities in the body and in reducing disease risks.[14]

An examination of all the available data reveals that each person's body is unique and has its own set of requirements. Men differ from women, and needs change as people grow from infancy through old age. For this reason, the committee clusters its recommendations for people into groups based on gender and age. Even so, the exact requirements for people of the same gender and age are likely to be different. Person A might need 40 units of a particular nutrient each day; person B might need 35; and person C might need 57. Looking at enough people might reveal that their individual requirements fall into a symmetrical distribution, with most near the midpoint and only a few at the extremes (see the left side of Figure 1-5). Using this information, the committee determines an **Estimated Average Requirement (EAR)** for each nutrient—the average amount that appears sufficient for half of the population. In Figure 1-5, the EAR is shown as 45 units.

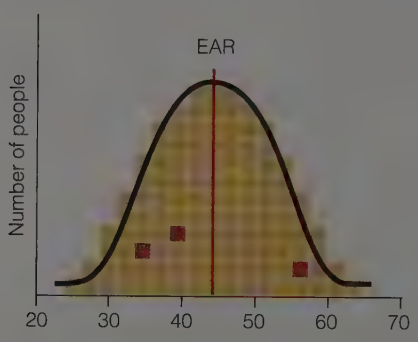
Recommended Dietary Allowances (RDA) Once a nutrient *requirement* is established, the committee must decide what intake to *recommend* for everybody—the **Recommended Dietary Allowance (RDA).** As you can see by the distribution in Figure 1-5, the EAR (shown in the figure as 45 units) is probably closest to everyone's need. If people consumed exactly the average requirement of a given nutrient each day, however, approximately half of the population would develop deficiencies of that nutrient—in Figure 1-5, for example, person C would be among them. Recommendations are therefore set greater than the EAR to meet the needs of most healthy people.

Small amounts greater than the daily requirement do no harm, whereas amounts less than the requirement may lead to health problems. When people's nutrient intakes are consistently **deficient** (less than the requirement), their nutrient stores decline, and over time this decline leads to poor health and deficiency symptoms. Therefore, to ensure that the nutrient RDA meet the needs of as many people as possible, the RDA are set near the top end of the range of the population's estimated requirements.

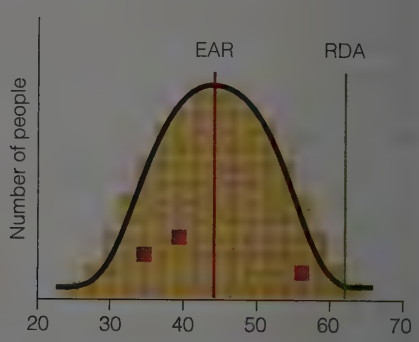
In this example, a reasonable RDA might be 63 units a day (see the right side of Figure 1-5). Such a point can be calculated mathematically so that the needs of about 98 percent of a population are included. Almost everybody—including person C whose needs were more substantial than the average—would

> FIGURE 1-5 Estimated Average Requirements (EAR) and Recommended Dietary Allowances (RDA) Compared

Each square in the graphs below represents a person with unique nutritional requirements. (The text discusses three of these people—A, B, and C.) Some people require only a small amount of nutrient X and some require a lot. Most people, however, fall somewhere in the middle.



The Estimated Average Requirement (EAR) for a nutrient is the amount that meets the needs of about half of the population (shown here by the red line).



The Recommended Dietary Allowance (RDA) for a nutrient (shown here in green) is set well above the EAR, meeting the needs of about 98% of the population.

Estimated Average Requirement (EAR): the average daily amount of a nutrient that will maintain a specific biochemical or physiological function in half the healthy people of a given age and gender group.

Recommended Dietary Allowance (RDA): the average daily amount of a nutrient considered adequate to meet the known nutrient needs of practically all healthy people; a goal for dietary intake by individuals.

deficient: inadequate; a nutrient amount that fails to meet the body's needs and eventually results in deficiency symptoms.

© Cengage Learning 2013

consume enough of the nutrient if they met this dietary goal. Relatively few people's requirements would exceed this recommendation, and even then, they wouldn't exceed by much.

Adequate Intakes (AI) For some nutrients, such as vitamin K, there is insufficient scientific evidence to determine an EAR (which is needed to set an RDA). In these cases, the committee establishes an **Adequate Intake (AI)** instead of an RDA. An AI reflects the average amount of a nutrient that a group of healthy people consumes. Like the RDA, the AI may be used as nutrient goals for individuals.

Although both the RDA and the AI serve as nutrient intake goals for individuals, their differences are noteworthy. An RDA for a given nutrient is based on enough scientific evidence to expect that the needs of almost all healthy people will be met. An AI, on the other hand, must rely more heavily on scientific judgments because sufficient evidence is lacking. For this reason, AI values are more tentative than RDA values. The table on the inside front cover identifies which nutrients have an RDA and which have an AI. Later chapters present the RDA and AI values for vitamins and minerals.

Tolerable Upper Intake Levels (UL) As mentioned earlier, the recommended intakes for nutrients are generous, yet they may not be sufficient for every individual for every nutrient. Nevertheless, it is probably best not to exceed these recommendations by very much or very often. Individual tolerances for high doses of nutrients vary, and somewhere beyond the recommended intake is a point beyond which a nutrient is likely to become toxic. This point is known as the **Tolerable Upper Intake Level (UL)**. It is naïve—and inaccurate—to think of recommendations as minimum amounts. A more accurate view is to see a person's nutrient needs as falling within a range, with marginal and danger zones at each end for intakes that are either inadequate or excessive (see Figure 1-6).

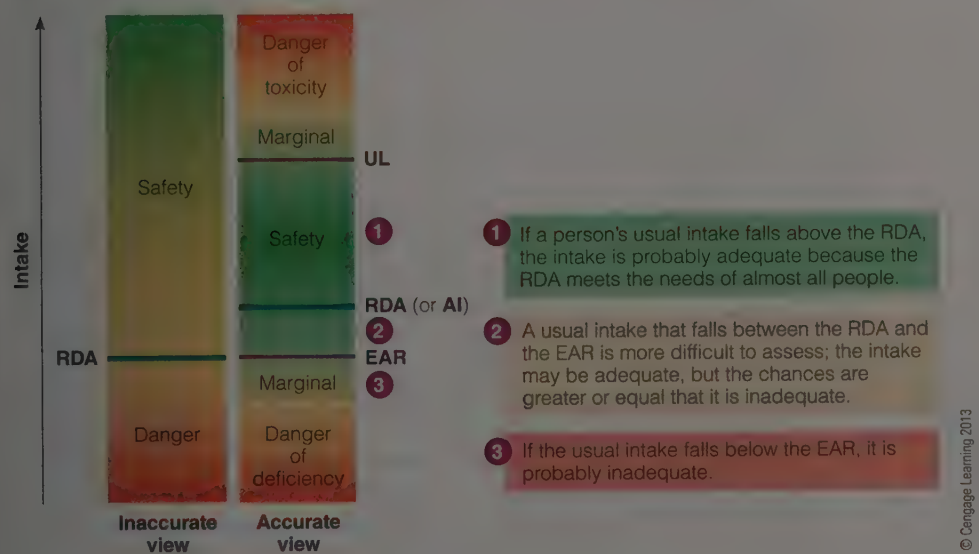
Paying attention to upper levels is particularly useful in guarding against the overconsumption of nutrients, which may occur when people use large-dose dietary supplements and fortified foods regularly. Later chapters discuss the dangers associated with excessively high intakes of vitamins and minerals, and the inside front cover (p. C) presents tables of upper levels for selected nutrients.

Adequate Intake (AI): the average daily amount of a nutrient that appears sufficient to maintain a specified criterion; a value used as a guide for nutrient intake when an RDA cannot be determined.

Tolerable Upper Intake Level (UL): the maximum daily amount of a nutrient that appears safe for most healthy people and beyond which there is an increased risk of adverse health effects.

> FIGURE 1-6 Inaccurate versus Accurate View of Nutrient Intakes

The RDA (or AI) for a given nutrient represents a point that lies within a range of appropriate and reasonable intakes between toxicity and deficiency. Both of these recommendations are high enough to provide reserves in times of short-term dietary inadequacies, but not so high as to approach toxicity. Nutrient intakes above or below this range may be equally harmful.



© Cengage Learning 2013

Establishing Energy Recommendations

In contrast to the RDA and AI values for nutrients, the recommendation for energy is not generous. Excess energy cannot be readily excreted and is eventually stored as body fat. These reserves may be beneficial when food is scarce, but they can also lead to obesity and its associated health consequences.

Estimated Energy Requirement (EER)

The energy recommendation—called the **Estimated Energy Requirement (EER)**—represents the average dietary energy intake (kcalories per day) that will maintain energy balance in a person who has a healthy body weight and level of physical activity. Balance is key to the energy recommendation. Enough food energy is needed to sustain a healthy and active life, but too much can lead to weight gain and obesity. Because *any* amount in excess of energy needs will result in weight gain, no upper level for energy has been determined.

Acceptable Macronutrient Distribution Ranges (AMDR)

People don't eat energy directly; they derive energy from foods containing carbohydrates, fats, and proteins. Each of these three energy-yielding nutrients contributes to the total energy intake, and those contributions vary in relation to one another. The DRI committee has determined that the composition of a diet that provides adequate energy and nutrients and reduces the risk of chronic diseases is:

- 45 to 65 percent kcalories from carbohydrate
- 20 to 35 percent kcalories from fat
- 10 to 35 percent kcalories from protein

These values are known as **Acceptable Macronutrient Distribution Ranges (AMDR)**.

Using Nutrient Recommendations

Although the intent of nutrient recommendations seems simple, they are the subject of much misunderstanding and controversy. Perhaps the following facts will help put them in perspective:

1. Estimates of adequate energy and nutrient intakes apply to *healthy* people. They need to be adjusted for malnourished people or those with medical problems who may require supplemented or restricted dietary intakes.

2. *Recommendations* are not minimum requirements, nor are they necessarily optimal intakes for all individuals. Recommendations can target only "most" of the people and cannot account for individual variations in nutrient needs—yet. Given the recent explosion of knowledge about genetics, the day may be fast approaching when nutrition scientists will be able to determine an individual's optimal nutrient needs. Until then, registered dietitians and other qualified health professionals can help determine if recommendations should be adjusted to meet individual needs. (Highlight 1 introduces *registered dietitians [RD]* and *dietetic technicians registered [DTR]* as the college-educated food and nutrition specialists who are qualified to evaluate people's nutritional health and needs.)

3. Most nutrient goals are intended to be met through diets composed of a variety of *foods* whenever possible. Because foods contain mixtures of nutrients and nonnutrients, they deliver more than just those nutrients covered by the recommendations. Excess intakes of vitamins and minerals are unlikely when they come from foods. Using dietary supplements to meet nutrient goals raises the risks of toxicity.

4. Recommendations apply to *average* daily intakes. Trying to meet the recommendations for every nutrient every day is difficult and unnecessary. The length of time over which a person's intake can deviate from the average without risk of deficiency or overdose varies for each nutrient, depending on how the body uses and stores the nutrient. For most nutrients (such as thiamin and vitamin C), deprivation would lead to rapid development of deficiency

Estimated Energy Requirement (EER): the average dietary energy intake that maintains energy balance and good health in a person of a given age, gender, weight, height, and level of physical activity.

Acceptable Macronutrient Distribution Ranges (AMDR): ranges of intakes for the energy nutrients that provide adequate energy and nutrients and reduce the risk of chronic diseases.

symptoms (within days or weeks); for others (such as vitamin A and vitamin B_{12}), deficiencies would develop more slowly (over months or years).

5. Each of the DRI categories serves a unique purpose. For example, the EAR are most appropriately used to develop and evaluate nutrition programs for *groups* such as schoolchildren or military personnel. The RDA (or AI if an RDA is not available) can be used to set goals for *individuals*. The UL serve as a reminder to keep nutrient intakes less than amounts that increase the risk of toxicity—not a common problem when nutrients derive from foods, but a real possibility for some nutrients if supplements are used regularly. With these understandings, professionals can use the DRI for a variety of purposes.[15]



© Photodisc/Getty Images

Don't let the DRI "alphabet soup" of nutrient intake standards confuse you. Their names make sense when you learn their purposes.

Comparing Nutrient Recommendations At least 40 different nations and international organizations have published nutrient standards similar to those used in the United States and Canada. Slight differences may be apparent, reflecting differences both in the interpretation of the data from which the standards were derived and in the food habits and physical activities of the populations they serve.

Many countries use the recommendations developed by two international groups: FAO (Food and Agriculture Organization) and WHO (World Health Organization). The FAO/WHO nutrient recommendations are considered sufficient to maintain health in nearly all healthy people worldwide and are provided in Appendix I.

REVIEW IT Define the four categories of the DRI and explain their purposes.

The Dietary Reference Intakes (DRI) are a set of nutrient intake values that can be used to plan and evaluate diets for healthy people. The Estimated Average Requirement (EAR) defines the amount of a nutrient that supports a specific function in the body for half of the population. The Recommended Dietary Allowance (RDA) is based on the Estimated Average Requirement and establishes a goal for dietary intake that will meet the needs of almost all healthy people. An Adequate Intake (AI) serves a similar purpose when an RDA cannot be determined. The Estimated Energy Requirement (EER) defines the average amount of energy intake needed to maintain energy balance, and the Acceptable Macronutrient Distribution Ranges (AMDR) define the proportions contributed by carbohydrate, fat, and protein to a healthy diet. The Tolerable Upper Intake Level (UL) establishes the highest amount that appears safe for regular consumption.

1.5 Nutrition Assessment

LEARN IT Explain how the four assessment methods are used to detect energy and nutrient deficiencies and excesses.

What happens when a person doesn't consume enough or consumes too much of a specific nutrient or energy? If the deficiency or excess is significant over time, the person experiences symptoms of **malnutrition.** With a deficiency of energy, the person may display the symptoms of **undernutrition** by becoming extremely thin, losing muscle tissue, and becoming prone to infection and disease. With a deficiency of a nutrient, the person may experience skin rashes, depression, hair loss, bleeding gums, muscle spasms, night blindness, or other symptoms. Similarly, over time, regular intakes in excess of needs may also have adverse effects. With an excess of energy, the person may become obese and vulnerable to diseases associated with **overnutrition,** such as heart disease and diabetes. With a sudden nutrient overdose, the person may experience hot flashes, yellowing skin, a rapid heart rate, low blood pressure, or other symptoms.

Malnutrition symptoms—such as diarrhea, skin rashes, and fatigue—are easy to miss because they resemble the symptoms of other diseases. But a person who has learned how to use assessment techniques to detect malnutrition can identify when these conditions are caused by poor nutrition and can recommend steps to

malnutrition: any condition caused by excess or deficient food energy or nutrient intake or by an imbalance of nutrients.

- **mal** = bad

undernutrition: deficient energy or nutrients.

overnutrition: excess energy or nutrients.

correct it. This discussion presents the basics of nutrition assessment; many more details are offered in later chapters and in Appendix E.

Nutrition Assessment of Individuals To prepare a **nutrition assessment,** a registered dietitian, dietetic technician registered, or other trained health-care professional uses:

- Historical information
- Anthropometric measurements
- Physical examinations
- Laboratory tests

Each of these methods involves collecting data in various ways and interpreting each finding in relation to the others to create a total picture.

Historical Information One step in evaluating nutrition status is to obtain information about a person's history with respect to health status, socioeconomic status, drug use, and diet. The health history reflects a person's medical record and may reveal a disease that interferes with the person's ability to eat or the body's use of nutrients. The person's family history of major diseases is also noteworthy, especially for conditions such as heart disease that have a genetic tendency to run in families. Economic circumstances may show a financial inability to buy foods or inadequate kitchen facilities in which to prepare them. Social factors such as marital status, ethnic background, and educational level also influence food choices and nutrition status. A drug history, including all prescribed and over-the-counter medications, may highlight possible interactions that lead to nutrient deficiencies (as described in Highlight 17). A diet history that examines a person's intake of foods, beverages, and dietary supplements may reveal either a surplus or inadequacy of nutrients or energy.

To take a diet history, the assessor collects data about the foods a person eats. The data may be collected by recording the foods the person has eaten over a period of 24 hours, 3 days, or a week or more or by asking what foods the person typically eats and how much of each. The days in the record must be fairly typical of the person's diet, and portion sizes must be recorded accurately. To determine the amounts of nutrients consumed, the assessor usually enters the foods and their portion sizes into a computer using a diet analysis program. This step can also be done manually by looking up each food in a table of food composition such as Appendix H in this book. The assessor then compares the calculated nutrient intakes with the DRI to determine the probability of adequacy. Alternatively, the diet history might be compared against standards such as the USDA Food Patterns or *Dietary Guidelines* (described in Chapter 2).

An estimate of energy and nutrient intakes from a diet history, when combined with other sources of information, can help confirm or rule out the *possibility* of suspected nutrition problems. A sufficient intake of a nutrient does not guarantee adequacy, and an insufficient intake does not always indicate a deficiency. Such findings, however, warn of possible problems.

Anthropometric Measurements A second technique that may help to reveal nutrition problems is taking **anthropometric** measures such as height and weight. The assessor compares a person's measurements with standards specific for gender and age or with previous measures on the same individual. (Chapter 8 presents information on body weight and its standards, and Appendix E includes growth charts for children.)

Measurements taken periodically and compared with previous measurements reveal patterns and indicate trends in a person's overall nutrition status, but they provide little information about specific nutrients. Instead, measurements out of line with expectations may reveal such problems as growth failure in children, wasting or swelling of body tissues in adults, and obesity—conditions that may reflect energy or nutrient deficiencies or excesses.

Physical Examinations A third nutrition assessment technique is a physical examination looking for clues to poor nutrition status. Visual inspection of the

nutrition assessment: a comprehensive analysis of a person's nutrition status that uses health, socioeconomic, drug, and diet histories; anthropometric measurements; physical examinations; and laboratory tests.

anthropometric (AN-throw-poe-MET-rick): relating to measurement of the physical characteristics of the body, such as height and weight.

- **anthropos** = human
- **metric** = measuring

hair, eyes, skin, posture, tongue, and fingernails can provide such clues. In addition, information gathered from an interview can help identify symptoms. The examination requires skill because many physical signs and symptoms reflect more than one nutrient deficiency or toxicity—or even nonnutrition conditions. Like the other assessment techniques, a physical examination alone does not yield firm conclusions. Instead, physical examinations reveal possible imbalances that must be confirmed by other assessment techniques, or they confirm results from other assessment measures.

Laboratory Tests A fourth way to detect a developing deficiency, imbalance, or toxicity is to take samples of blood or urine, analyze them in the laboratory, and compare the results with normal values for a similar population. Laboratory tests are most useful in uncovering early signs of malnutrition before symptoms appear. In addition, they can confirm suspicions raised by other assessment methods.

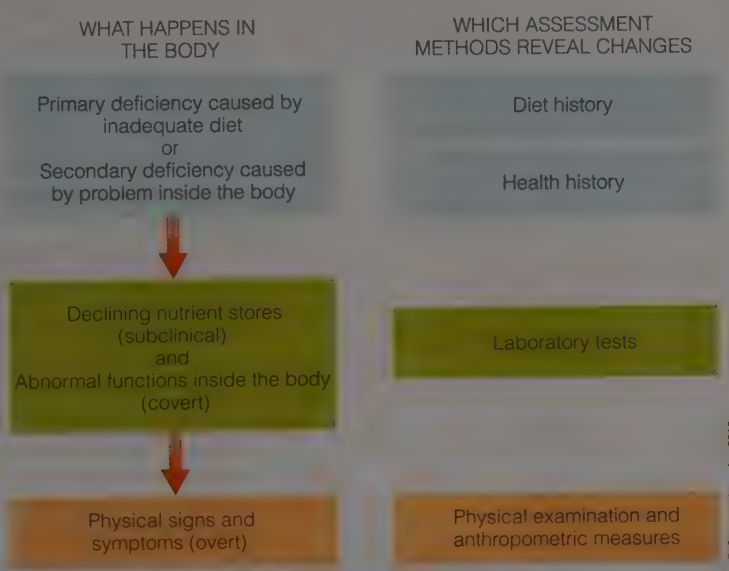
Iron, for Example The mineral iron can be used to illustrate the stages in the development of a nutrient deficiency and the assessment techniques useful in detecting them. The **overt**, or outward, signs of an iron deficiency appear at the end of a long sequence of events. Figure 1-7 describes what happens in the body as a nutrient deficiency progresses and shows which assessment methods can reveal those changes.

First, the body has too little iron—either because iron is lacking in the person's diet (a **primary deficiency**) or because the person's body doesn't absorb enough, excretes too much, or uses iron inefficiently (a **secondary deficiency**). A diet history provides clues to primary deficiencies; a health history provides clues to secondary deficiencies.

Next, the body begins to use up its stores of iron. At this stage, the deficiency might be described as a **subclinical deficiency.** It exists as a **covert** condition, and although it might be detected by laboratory tests, outward signs are not yet apparent.

> FIGURE 1-7 Stages in the Development of a Nutrient Deficiency

Internal changes precede outward signs of deficiencies. Outward signs of sickness, however, need not appear before a person takes corrective measures. Laboratory tests can help determine nutrient status in the early stages.



© Cengage Learning 2013



© Blend Images/Alamy

A peek inside the mouth provides clues to a person's nutrition status. An inflamed tongue may indicate a deficiency of one of the B vitamins, and mottled teeth may reveal fluoride toxicity, for example.

overt (oh-VERT): out in the open and easy to observe.

- **ouvrir** = to open

primary deficiency: a nutrient deficiency caused by inadequate dietary intake of a nutrient.

secondary deficiency: a nutrient deficiency caused by something other than an inadequate intake such as a disease condition or drug interaction that reduces absorption, accelerates use, hastens excretion, or destroys the nutrient.

subclinical deficiency: a deficiency in the early stages, before the outward signs have appeared.

covert (KOH-vert): hidden, as if under covers.

- **couvrir** = to cover

Finally, the body's iron stores are exhausted. Now, it cannot make enough iron-containing red blood cells to replace those that are aging and dying. Iron is needed in red blood cells to carry oxygen to all the body's tissues. When iron is lacking, fewer red blood cells are made, the new ones are pale and small, and every part of the body feels the effects of oxygen shortage. At this point in time, the overt symptoms of deficiency appear—weakness, fatigue, pallor, and headaches, reflecting the iron-deficient state of the blood. A physical examination and interview will reveal these symptoms.

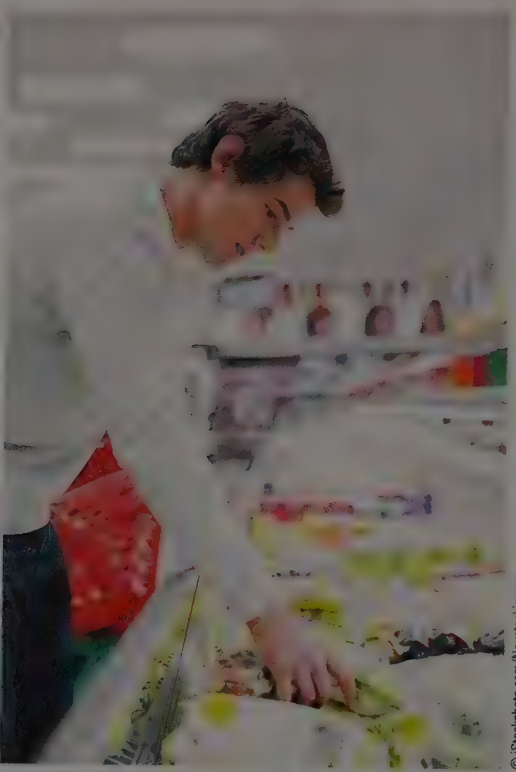
Nutrition Assessment of Populations

To assess a population's nutrition status, researchers conduct surveys using techniques similar to those used on individuals. The data collected are then used by various agencies for numerous purposes, including the development of national health goals.

National Nutrition Surveys

The National Nutrition Monitoring program coordinates the many nutrition-related surveys and research activities of various federal agencies. The integration of two major national surveys provides comprehensive data efficiently. One survey collects data on the kinds and amounts of foods people eat.* The other survey examines the people themselves, using anthropometric measurements, physical examinations, and laboratory tests.** The data provide valuable information on several nutrition-related conditions, such as growth retardation, heart disease, and nutrient deficiencies. National nutrition surveys often oversample high-risk groups (low-income families, pregnant women, adolescents, the elderly, African Americans, and Mexican Americans) to glean an accurate estimate of their health and nutrition status.

The resulting wealth of information from the national nutrition surveys is used for a variety of purposes. For example, Congress uses this information to establish public policy on nutrition education, food assistance programs, and the regulation of the food supply. Scientists use the information to establish research priorities. The food industry uses these data to guide decisions in public relations and product development. The Dietary Reference Intakes and other major reports that examine the relationships between diet and health depend on information collected from these nutrition surveys. These data also provide the basis for developing and monitoring national health goals.



© iStockphoto.com/Neustockimages

National surveys provide valuable information about the kinds of foods people eat.

National Health Goals

The **Healthy People** program sets priorities and guides policies that "increase the quality and years of healthy life" and "eliminate health disparities." At the start of each decade, the program sets goals for improving the nation's health during the next ten years. Nutrition is one of many topic areas, each with numerous objectives. Table 1-4 lists the nutrition and weight status objectives for 2020, and Appendix J lists nutrition-related objectives from other topic areas.

Progress in meeting the 2010 goals was mixed. A few objectives were met, about half made some progress, and several showed no progress—or even moved in the wrong direction.[16] The objective to reduce average blood cholesterol levels was achieved, but objectives to eat more fruits, vegetables, and whole grains and to increase physical activity showed little or no improvement. Trends in overweight and obesity actually worsened. Clearly, "what we eat in America" must change if we hope to meet the Healthy People goals.

National Trends

What do we eat in America and how has it changed over the past 40 years? The short answer to both questions is "a lot." We eat more meals away from home, particularly at fast-food restaurants. We eat larger portions. We drink more sweetened beverages and eat more energy-dense, nutrient-poor foods such as candy and chips. We snack frequently. As a result of these dietary habits, our energy intake has risen and, consequently, so has the incidence of overweight and obesity. Overweight and obesity, in turn, profoundly influence our health—as the next section explains.

Healthy People: a national public health initiative under the jurisdiction of the US Department of Health and Human Services (DHHS) that identifies the most significant preventable threats to health and focuses efforts toward eliminating them.

*This survey is called *What We Eat in America*.

**This survey is known as the National Health and Nutrition Examination Survey (NHANES).

TABLE 1-4 Healthy People 2020 Nutrition and Weight Status Objectives

- Increase the proportion of adults who are at a healthy weight
- Reduce the proportion of adults who are obese
- Reduce iron deficiency among young children and females of childbearing age
- Reduce iron deficiency among pregnant females
- Reduce the proportion of children and adolescents who are overweight or obese
- Increase the contribution of fruits to the diets of the population aged 2 years and older
- Increase the variety and contribution of vegetables to the diets of the population aged 2 years and older
- Increase the contribution of whole grains to the diets of the population aged 2 years and older
- Reduce consumption of saturated fat in the population aged 2 years and older
- Reduce consumption of sodium in the population aged 2 years and older
- Increase consumption of calcium in the population aged 2 years and older
- Increase the proportion of worksites that offer nutrition or weight management classes or counseling
- Increase the proportion of physician office visits that include counseling or education related to nutrition or weight
- Eliminate very low food security among children in US households
- Prevent inappropriate weight gain in youth and adults
- Increase the proportion of primary care physicians who regularly measure the body mass index of their patients
- Reduce consumption of kcalories from solid fats and added sugars in the population aged 2 years and older
- Increase the number of states that have state-level policies that incentivize food retail outlets to provide foods that are encouraged by the *Dietary Guidelines*
- Increase the number of states with nutrition standards for foods and beverages provided to preschool-aged children in childcare
- Increase the percentage of schools that offer nutritious foods and beverages outside of school meals

© Cengage Learning 2013

NOTE: Nutrition and Weight Status is one of 38 topic areas, each with numerous objectives. Several of the other topic areas have nutrition-related objectives, and these are presented in Appendix J.
SOURCE: www.healthypeople.gov

REVIEW IT Explain how the four assessment methods are used to detect energy and nutrient deficiencies and excesses.

People become malnourished when they get too little or too much energy or nutrients. Deficiencies, excesses, and imbalances of nutrients lead to malnutrition diseases. To detect malnutrition in individuals, health-care professionals use a combination of four nutrition assessment methods. Reviewing historical information on diet and health may suggest a possible nutrition problem. Laboratory tests may detect a possible nutrition problem in its earliest stages, whereas anthropometric measurements and physical examinations pick up on the problem only after it causes symptoms. National surveys use similar assessment methods to measure people's food consumption and to evaluate the nutrition status of populations.

1.6 Diet and Health

LEARN IT Identify several risk factors and explain their relationships to chronic diseases.

Foods play a vital role in supporting health. Early nutrition research focused on identifying the nutrients in foods that would prevent such common diseases as rickets and scurvy, the vitamin D– and vitamin C–deficiency diseases. With this knowledge, developed countries have successfully defended against nutrient deficiency diseases. World hunger and nutrient deficiency diseases still pose a major health threat in developing countries, however, but not because of a lack of nutrition knowledge (as Chapter 20 explains). More recently, nutrition research has focused on chronic diseases associated with energy and nutrient excesses. Chronic diseases are responsible for 7 out of 10 deaths among US adults. Once thought to be "rich countries' problems," chronic diseases have now become epidemic in developing countries as well—contributing to three out of five deaths worldwide.[17]

TABLE 1-5 Leading Causes of Death in the United States

	Percentage of Total Deaths
1. **Heart disease**	24.1
2. **Cancers**	23.3
3. Chronic lung diseases	5.6
4. **Strokes**	5.2
5. Accidents	4.8
6. Alzheimer's disease	3.4
7. **Diabetes mellitus**	2.8
8. Pneumonia and influenza	2.0
9. Kidney disease	2.0
10. Suicide	1.5

© Cengage Learning 2013

NOTE: The diseases highlighted in bold have relationships with diet.
SOURCE: Deaths: Preliminary data for 2010, *National Vital Statistics Reports*, January 11, 2012, Centers for Disease Control and Prevention, www.cdc.gov/nchs.

Chronic Diseases Table 1-5 lists the ten leading causes of death in the United States. These "causes" are stated as if a single condition such as heart disease caused death, but most chronic diseases arise from multiple factors over many

years. A person who died of heart disease may have been overweight, had high blood pressure, been a cigarette smoker, and spent years eating a diet high in saturated fat and getting too little exercise.

Of course, not all people who die of heart disease fit this description, nor do all people with these characteristics die of heart disease. People who are overweight might die from the complications of diabetes instead, or those who smoke might die of cancer. They might even die from something totally unrelated to any of these factors, such as an automobile accident. Still, statistical studies have shown that certain conditions and behaviors are linked to certain diseases.

Table 1-5 highlights four of the top seven causes of death as having a link with diet. Notice that these four diseases—heart disease, cancers, strokes, and diabetes—account for more than half of the deaths each year.

Risk Factors for Chronic Diseases

Factors that increase or reduce the *risk* of developing chronic diseases can be identified by analyzing statistical data. A strong association between a **risk factor** and a disease means that when the factor is present, the *likelihood* of developing the disease increases. It does not mean that all people with the risk factor will develop the disease. Similarly, a lack of risk factors does not guarantee freedom from a given disease. On the average, though, the more risk factors in a person's life, the greater that person's chances of developing the disease. Conversely, the fewer risk factors in a person's life, the better the chances for good health.

Risk Factors Persist

Risk factors tend to persist over time. Without intervention, a young adult with high blood pressure will most likely continue to have high blood pressure as an older adult, for example. Thus, to minimize the damage, early intervention is most effective.

Risk Factors Cluster

Risk factors tend to cluster. For example, a person who is obese may be physically inactive, have high blood pressure, and have high blood cholesterol—all risk factors associated with heart disease. Multiple risk factors act synergistically to increase the risk of disease dramatically. Intervention that focuses on one risk factor often benefits the others as well. For example, physical activity can help reduce weight. Physical activity and weight loss will, in turn, help to lower blood pressure and blood cholesterol.

TABLE 1-6 Factors Contributing to Deaths in the United States

Factors	Percentage of Deaths
Tobacco	18
Poor diet/inactivity	15
Alcohol	4
Microbial agents	3
Toxic agents	2
Motor vehicles	2
Firearms	1
Sexual behavior	1
Illicit drugs	1

SOURCE: A. H. Mokdad and coauthors, Actual causes of death in the United States, 2000, *Journal of the American Medical Association* 291 (2004): 1238–1245, with corrections from *Journal of the American Medical Association* 293 (2005): 298.

© Cengage Learning 2013

Risk Factors in Perspective

The most prominent factor—contributing to one of every five deaths each year in the United States—is tobacco use, followed closely by diet and activity patterns, and then alcohol use (see Table 1-6).[18] Risk factors such as smoking, poor dietary habits, physical inactivity, and alcohol consumption are personal behaviors that can be changed. Decisions to not smoke, to eat a well-balanced diet, to engage in regular physical activity, and to drink alcohol in moderation (if at all) improve the likelihood that a person will enjoy good health. Other risk factors, such as genetics, gender, and age, also play important roles in the development of chronic diseases, but they cannot be changed. Health recommendations acknowledge the influence of such factors on the development of disease, but they must focus on the factors that are changeable.

Health Behaviors in the United States

Despite evidence linking certain behaviors with chronic diseases, many Americans continue to engage in unhealthy behaviors. An estimated 20 percent of US adults consume five or more drinks in a single day at least once a year; 20 percent are cigarette smokers; 40 percent are physically inactive; 60 percent are either overweight or obese; and 30 percent average 6 hours or less of sleep per day.[19] For the two out of three Americans who do not smoke or drink alcohol excessively, the one choice that can influence long-term health prospects more than any other is diet.

REVIEW IT Identify several risk factors and explain their relationships to chronic diseases.

Within the range set by genetics, a person's choice of diet influences long-term health. Diet has no influence on some diseases but is linked closely to others. Personal life choices, such as engaging in physical activity and using tobacco or alcohol, also affect health for the better or worse.

risk factor: a condition or behavior associated with an elevated frequency of a disease but not proved to be causal. Leading risk factors for chronic diseases include obesity, cigarette smoking, high blood pressure, high blood cholesterol, physical inactivity, and a diet high in saturated fats and low in vegetables, fruits, and whole grains.

The next several chapters provide many more details about nutrients and how they support health. Whenever appropriate, the discussion shows how diet influences each of today's major diseases. Dietary recommendations appear again and again, as each nutrient's relationships with health are explored. Most people who follow the recommendations will benefit and can enjoy good health into their later years.


© UpperCut Images/SuperStock

Physical activity can be both fun and beneficial.

Nutrition Portfolio

Each chapter in this book ends with simple Nutrition Portfolio activities that invite you to review key messages and consider whether your personal choices are meeting the dietary goals introduced in the text. By using the information you are recording in Diet Analysis Plus, the dietary tracking software that accompanies this text, and keeping a journal of these Nutrition Portfolio assignments, you can examine how your knowledge and behaviors change as you progress in your study of nutrition.

Your food choices play a key role in keeping you healthy and reducing your risk of chronic diseases. After you have recorded at least one day's foods in Diet Analysis Plus, look at that day's choices and record your answers to the following in your journal:

- Identify the factors that most influence your food choices for meals and snacks.
- List the chronic disease risk factors and conditions (listed in the definition of *risk factor,* p. 26) that you have.
- Describe lifestyle changes you can make to improve your chances of enjoying good health.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at www.cengagebrain.com.

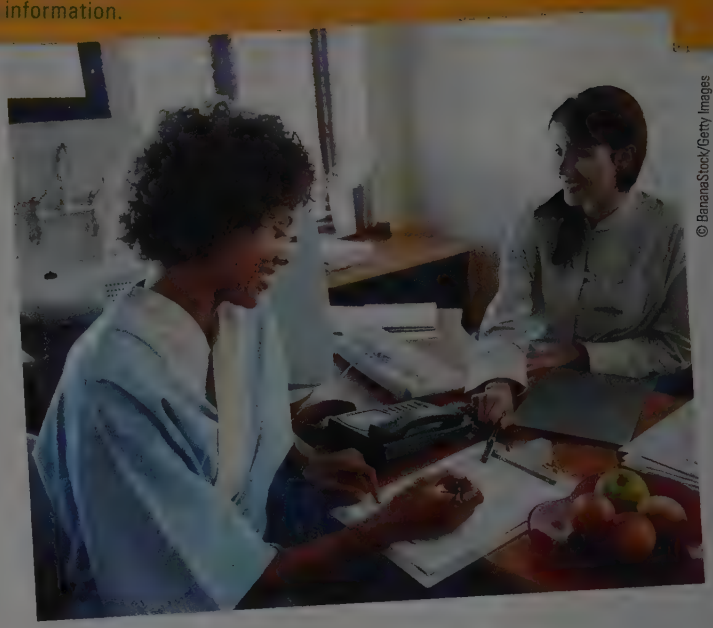
STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. E. R. Grimm and N. I. Steinle, Genetics of eating behavior: Established and emerging concepts, *Nutrition Reviews* 69 (2011): 52–60.
2. B. J. Tepper, Nutritional implications of genetic taste variation: The role of PROP sensitivity and other taste phenotypes, *Annual Review of Nutrition* 28 (2008): 367–388.
3. K. Stein, Navigating cultural competency: In preparation for an expected standard in 2010, *Journal of the American Dietetic Association* 109 (2009): 1676–1688.
4. J. Tillotson, Americans' food shopping in today's lousy economy (part 3), *Nutrition Today* 44 (2009): 265–268.
5. Food Marketing Institute, www.fmi.org/research, accessed 19 January 2011.
6. J. Tillotson, Americans' food shopping in today's lousy economy (part 2), *Nutrition Today* 44 (2009): 218–221.
7. B. Wansink, K. van Ittersum, and C. Werle, How negative experiences shape long-term food preferences. Fifty years from the World War II combat front, *Appetite* 52 (2009): 750–752.
8. A. D. Ozier and coauthor, Overweight and obesity are associated with emotion- and stress-related eating as measured by the Eating and Appraisal Due to Emotions and Stress Questionnaire, *Journal of the American Dietetic Association* 108 (2008): 49–56.
9. International Food Information Council Foundation, *2010 Food & Health Survey,* www.foodinsight.org.
10. Position of the American Dietetic Association: Functional foods, *Journal of the American Dietetic Association* 104 (2004): 814–826.
11. Position of the American Dietetic Association: Total diet approach to communicating food and nutrition information, *Journal of the American Dietetic Association* 107 (2007): 1224–1232.
12. S. Rowe and coauthors, Funding food science and nutrition research: Financial conflicts and scientific integrity, *American Journal of Clinical Nutrition* 89 (2009): 1285–1291.
13. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Calcium and Vitamin D* (Washington, D.C.: National Academies Press, 2011); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate* (Washington, D.C.: National Academies Press, 2005); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc* (Washington, D.C.: National Academies Press, 2001); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids* (Washington, D.C.: National Academies Press, 2000); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline* (Washington, D.C.: National Academies Press, 1998); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride* (Washington, D.C.: National Academies Press, 1997).
14. R. M. Russell, Current framework for DRI development: What are the pros and cons? *Nutrition Reviews* 66 (2008): 455–458.
15. Practice paper of the American Dietetic Association: Using the Dietary Reference Intakes, *Journal of the American Dietetic Association* 111 (2011): 762–770.
16. E. J. Sondik and coauthors, Progress toward the Healthy People 2010 goals and objectives, *Annual Review of Public Health* 31 (2010): 271–281.
17. K. M. V. Narayan, M. K. Ali, and J. P. Koplan, Global noncommunicable diseases: Where worlds meet, *New England Journal of Medicine* 363 (2010): 1196–1198.
18. A. H. Mokdad and coauthors, Actual causes of death in the United States, 2000, *Journal of the American Medical Association* 291 (2004): 1238–1245.
19. C. A. Schoenborn and P. F. Adams, Health behaviors of adults: United States, 2005–2007, National Center for Health Statistics, *Vital and Health Statistics,* 2010, www.cdc.gov/nchs/data/series/sr_10/sr10_245.pdf.

LEARN IT Recognize misinformation and describe how to identify reliable nutrition information.

Nutrition Information and Misinformation



© BananaStock/Getty Images

How can people distinguish valid nutrition information from misinformation? One excellent approach is to notice *who* is providing the information. The "who" behind the information is not always evident, though, especially in the world of electronic media. Keep in mind that *people* create websites on the Internet, just as people write books and report the news. In all cases, consumers need to determine whether the person is qualified to provide nutrition information.

This highlight begins by examining the unique potential as well as the problems of relying on the Internet and the media for nutrition information. It continues with a discussion of how to identify reliable nutrition information that applies to all resources, including the Internet and the news. (The accompanying glossary defines related terms.)

Nutrition on the Internet

Got a question? The **Internet** has an answer. An estimated two out of three US adults use the Internet to look up health information or learn about health topics in online chat groups.[1] The Internet offers endless opportunities to obtain high-quality information, but it also delivers an abundance of incomplete, misleading, and inaccurate information.[2] Simply put: anyone can publish anything.

With hundreds of millions of **websites,** searching for nutrition information can be an overwhelming experience, with no guarantees of finding accurate information. When using the Internet, keep in mind that the quality of health-related information available covers a broad range. You must evaluate websites for their accuracy, just as you would any other source. The accompanying "How To" provides tips for determining whether a website is reliable.

One of the most trustworthy sites used by scientists and others is the US National Library of Medicine's PubMed, which provides free access to more than 20 million abstracts (short descriptions) of research papers published in scientific journals around the world. Many abstracts provide links to the full articles. Figure H1-1 (p. 30) introduces this valuable resource.

Did you receive an e-mail warning of the health dangers associated with aspartame? If so, you've been a victim of urban scarelore. When

GLOSSARY

Academy of Nutrition and Dietetics: the professional organization of dietitians in the United States; formerly the American Dietetic Association. The Canadian equivalent is Dietitians of Canada, which operates similarly.

accredited: approved; in the case of medical centers or universities, certified by an agency recognized by the US Department of Education.

certified nutritionist or **certified nutritional consultant** or **certified nutrition therapist:** a person who has been granted a document declaring his or her authority as a nutrition professional.

dietetic technician: a person who has completed a minimum of an associate's degree from an accredited university or college and an approved dietetic technician program that includes a supervised practice experience. See also *dietetic technician, registered.*

dietetic technician, registered (DTR): a dietetic technician who has passed a national examination and maintains registration through continuing professional education.

dietitian: a person trained in nutrition, food science, and diet planning. See also *registered dietitian.*

diploma mills: entities without valid accreditation that provide worthless degrees.

DTR: see *dietetic technician, registered.*

fraudulent: the promotion, for financial gain, of devices, treatments, services, plans, or products (including diets and supplements) that alter or claim to alter a human condition without proof of safety or effectiveness.

Internet (the Net): a worldwide network of millions of computers linked together to share information.

license to practice: permission under state or federal law, granted on meeting specified criteria, to use a certain title (such as dietitian) and offer certain services. *Licensed dietitians* may use the initials *LD* after their names.

misinformation: false or misleading information.

public health dietitians: dietitians who specialize in providing nutrition services through organized community efforts.

RD: see *registered dietitian.*

registered dietitian (RD): a person who has completed a minimum of a bachelor's degree from an accredited university or college, has completed approved course work and a supervised practice program, has passed a national examination, and maintains registration through continuing professional education.

registration: listing; with respect to health professionals, listing with a professional organization that requires specific course work, experience, and passing of an examination.

websites: Internet resources composed of text and graphic files, each with a unique URL (Uniform Resource Locator) that names the site (for example, www.usda.gov).

nutrition information arrives in unsolicited e-mails, be suspicious if:

- The person sending it to you didn't write it and you cannot determine who did or if that person is a nutrition expert
- The phrase "Forward this to everyone you know" appears
- The phrase "This is not a hoax" appears because chances are good that it is
- The news is sensational and you've never heard about it from legitimate sources
- The language is emphatic and the text is sprinkled with capitalized words and exclamation marks
- No references are given or, if present, are of questionable validity when examined
- The message has been debunked on websites such as **www.quackwatch.org, www.snopes.com,** or **www.urbanlegends.com.**

>How To

Determine whether a Website Is Reliable

To determine whether a website offers reliable nutrition information, ask the following questions:

- **Who?** Who is responsible for the site? Is it staffed by qualified professionals? Look for the authors' names and credentials. Have experts reviewed the content for accuracy?
- **When?** When was the site last updated? Because nutrition is an ever-changing science, sites need to be dated and updated frequently.
- **Where?** Where is the information coming from? The three letters following the dot in a Web address identify the site's affiliation. Addresses ending in "gov" (government), "edu" (educational institute), and "org" (organization) generally provide reliable information; "com" (commercial) sites represent businesses and, depending on their qualifications and integrity, may or may not offer dependable information.
- **Why?** Why is the site giving you this information? Is the site providing a public service or selling a product? Many commercial sites provide accurate information, but some do not. When money is the prime motivation, be aware that the information may be biased.

If you are satisfied with the answers to all of the previous questions, then ask this final question:

- **What?** What is the message, and is it in line with other reliable sources? Information that contradicts common knowledge should be questioned. Many reliable sites provide links to other sites to facilitate your quest for knowledge, but this provision alone does not guarantee a reputable intention. Be aware that any site can link to any other site without permission.

TRY IT Visit a nutrition website and answer the five "W" questions to determine whether it is a reliable resource.

Nutrition in the News

Consumers get much of their nutrition information from Internet websites, television news, and magazine articles, which have heightened awareness of how diet influences the development of diseases. Consumers benefit from news coverage of nutrition when they learn to make lifestyle changes that will improve their health. Sometimes, however, popular reports mislead consumers and create confusion. They often tell a lopsided story quickly instead of presenting the integrated results of research studies or a balance of expert opinions.

Tight deadlines and limited understanding sometimes make it difficult to provide a thorough report. Hungry for the latest news, the media often report scientific findings quickly and prematurely—without benefit of careful interpretation, replication, or peer review. Usually, the reports present findings from a single, recently released study, making the news current and controversial. Consequently, the public receives diet and health news fast, but not always in perspective. Reporters may twist inconclusive findings into "meaningful discoveries" when pressured to write catchy headlines and sensational stories.

As a result "surprising new findings" sometimes seem to contradict one another, and consumers may feel frustrated and betrayed. Occasionally, the reports are downright false, but more often the apparent contradictions are simply the normal result of science at work. A single study contributes to the big picture, but when viewed alone, it can easily distort the image. To be meaningful the conclusions of any study must be presented cautiously within the context of other research findings.

Identifying Nutrition Experts

Regardless of whether the medium is electronic, print, or video, consumers need to ask whether the person behind the information is qualified to speak on nutrition. If the creator of an Internet website recommends eating three pineapples a day to lose weight, a trainer at the gym praises a high-protein diet, or a health-food store clerk suggests an herbal supplement, should you believe these people? Can you distinguish between accurate news reports and infomercials on television? Have you noticed that many televised nutrition messages are presented by celebrities, athletes, psychologists, food editors, and chefs—that is, almost anyone except a **dietitian**? When you are confused or need sound dietary advice, whom should you ask?

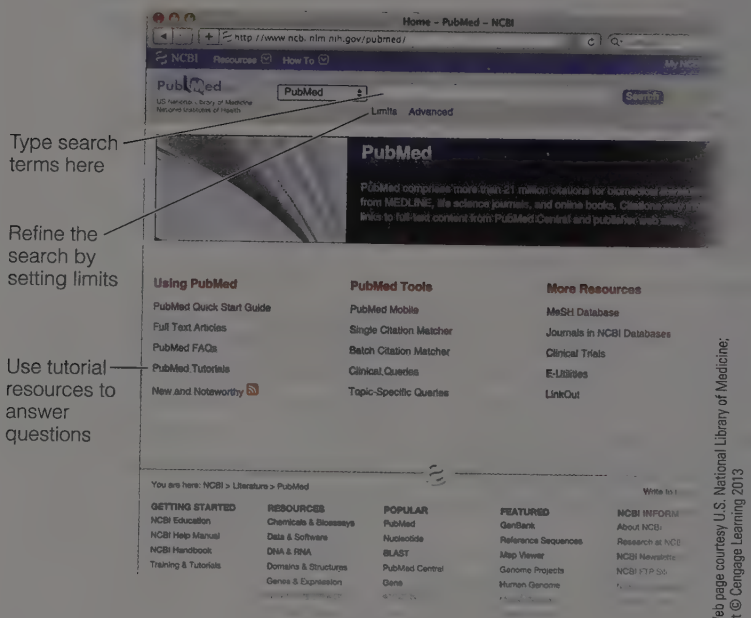
Physicians and Other Health-Care Professionals

Many people turn to physicians or other health-care professionals for dietary advice, expecting them to know about all health-related matters. But are they the best sources of accurate and current information on nutrition? Only about 30 percent of all medical schools in the United

> FIGURE H1-1 PubMed (www.pubmed.gov): Internet Resource for Scientific Nutrition References

The US National Library of Medicine's PubMed website offers tutorials to help teach beginners to use the search system effectively. Often, simply visiting the site, typing a query in the "Search for" box, and clicking "Go" will yield satisfactory results.

For example, to find research concerning calcium and bone health, typing "calcium bone" nets more than 30,000 results. Try setting limits on dates, types of articles, languages, and other criteria to obtain a more manageable number of abstracts to peruse.



Web page courtesy U.S. National Library of Medicine; art © Cengage Learning 2013

States require students to take a separate nutrition course; less than half require the minimum 25 hours of nutrition instruction recommended by the National Academy of Sciences. By comparison, most students reading this text are taking a nutrition class that provides an average of 45 hours of instruction.

The **Academy of Nutrition and Dietetics** (formerly the American Dietetic Association) asserts that standardized nutrition education should be included in the curricula for all health-care professionals: physicians, nurses, physician's assistants, dental hygienists, physical and occupational therapists, social workers, psychologists, and all others who provide services directly to clients. When these professionals understand the relevance of nutrition in the treatment and prevention of diseases and have command of reliable nutrition information, then all the people they serve will also be better informed.

Most health-care professionals appreciate the connections between health and nutrition. Those who have specialized in clinical nutrition are especially well qualified to speak on the subject. Few, however, have the time or experience to develop diet plans and provide detailed diet instructions for clients. Often they wisely refer clients to a qualified nutrition expert—a **registered dietitian (RD).**

Registered Dietitian (RD)

A registered dietitian (RD) has the educational background necessary to deliver reliable nutrition advice and care.[3] To become an RD, a person must earn an undergraduate degree requiring about 60 credit hours in nutrition, food science, and other related subjects; complete a year's clinical internship or the equivalent; pass a national examination administered by the Academy of Nutrition and Dietetics; and maintain up-to-date knowledge and **registration** by participating in required continuing education activities, such as attending seminars, taking courses, or conducting research.

Some states allow anyone to use the title dietitian or nutritionist, but others allow only an RD or people with specified qualifications to call themselves dietitians. Many states provide a further guarantee: a state registration, certification, or **license to practice.** In this way, states identify people who have met minimal standards of education and experience. Still, these state standards may fall short of those defining an RD. Similarly, some alternative educational programs qualify a graduate as a **certified nutritionist, certified nutritional consultant,** or **certified nutrition therapist**—terms that sound authoritative but lack the credentials of an RD. In fact, even Eddie, an English cocker spaniel, was able to obtain a certificate of membership from the American Association of Nutritional Consultants.[4]

Dietitians perform a multitude of duties in many settings in most communities. They work in the food industry, pharmaceutical companies, home health agencies, long-term care institutions, private practice, public health departments, research centers, education settings, fitness centers, and hospitals. Depending on their work settings, dietitians can assume a number of different job responsibilities and positions. In hospitals, administrative dietitians manage the foodservice system; clinical dietitians provide client care; and nutrition support team dietitians coordinate nutrition care with other health-care professionals. In the food industry, dietitians conduct research, develop products, and market services.

Public health dietitians who work in government-funded agencies such as health departments or clinics play a key role in delivering nutrition services to people in the community. Among their many



© Courtesy of the Academy of Nutrition and Dietetics

Eddie displays his membership certificate from an association of nutritional consultants. His human companion, Connie Diekman, is a registered dietitian and past president of the Academy of Nutrition and Dietetics (formerly the American Dietetic Association).

roles, public health dietitians help plan, coordinate, and evaluate food assistance programs; act as consultants to other agencies; manage finances; and much more.

Dietetic Technician, Registered (DTR)

In some facilities, a **dietetic technician** assists registered dietitians in both administrative and clinical responsibilities. A dietetic technician has been educated and trained to work under the guidance of a registered dietitian; upon passing a national examination, the title changes to **dietetic technician, registered (DTR).**

Other Dietary Employees

In addition to the dietetic technician, other dietary employees may include clerks, aides, cooks, porters, and assistants. These dietary employees do not have extensive formal training in nutrition, and their ability to provide accurate information may be limited.

Identifying Fake Credentials

In contrast to registered dietitians, thousands of people obtain fake nutrition degrees and claim to be nutrition consultants or doctors of "nutrimedicine." These and other such titles may sound meaningful, but most of these people lack the established credentials and training of an RD. If you look closely, you can see signs of their fake expertise.

Consider educational background, for example. The minimum standards of education for a dietitian specify a bachelor of science (BS) degree in food science and human nutrition or related fields from an **accredited** college or university.* Such a degree generally requires 4 to 5 years of study. Similarly, minimum standards of education for a dietetic technician specify an associate degree that typically requires 2 years of study. In contrast, a fake nutritionist may display a degree from a 6-month course. Such a degree simply falls short. In some cases, businesses posing as schools offer even less—they sell certificates to anyone who pays the fees. To obtain these "degrees," a candidate need not attend any classes, read any books, or pass any examinations.

To safeguard educational quality, an accrediting agency recognized by the US Department of Education (DOE) certifies that certain schools meet criteria established to ensure that an institution provides complete and accurate schooling. Unfortunately, fake nutrition degrees are available from schools "accredited" by phony accrediting agencies. Acquiring false degrees and credentials is especially easy today, with **diploma mills** and **fraudulent** businesses operating via the Internet.

Knowing the qualifications of someone who provides nutrition information can help you determine whether that person's advice might be harmful or helpful. Don't be afraid to ask for credentials. Table H1-1 on p. 32 lists credible sources of nutrition information.

Red Flags of Nutrition Quackery

Figure H1-2 on p. 32 features eight red flags consumers can use to identify nutrition **misinformation.** Sales of unproven and dangerous products have always been a concern, but the Internet now provides merchants with an easy and inexpensive way to reach millions of customers around the world. Because of the difficulty in regulating the Internet, fraudulent and illegal sales of medical products have hit a bonanza. As is the case with the air, no one owns the Internet, and similarly, no one has control over the pollution. Countries have different laws regarding sales of drugs, dietary supplements, and other health products, but applying these laws to the Internet marketplace is almost impossible. Even if illegal activities could be defined and identified, finding the person responsible for a particular website is not always possible. Websites can appear and disappear in a blink of a cursor. Now, more than ever, consumers must heed the caution "Buyer beware."

In summary, when you hear nutrition news, consider its source. Ask yourself these two questions: Is the person providing the information qualified to speak on nutrition? Is the information based on valid scientific research? If not, find a better source. After all, your health depends on it.

*To ensure the quality and continued improvement of nutrition and dietetics education programs, an agency known as the Commission on Accreditation for Dietetics Education (CADE) establishes and enforces eligibility requirements and accreditation standards for programs preparing students for careers as registered dietitians or dietetics technicians. Programs meeting those standards are accredited by CADE.

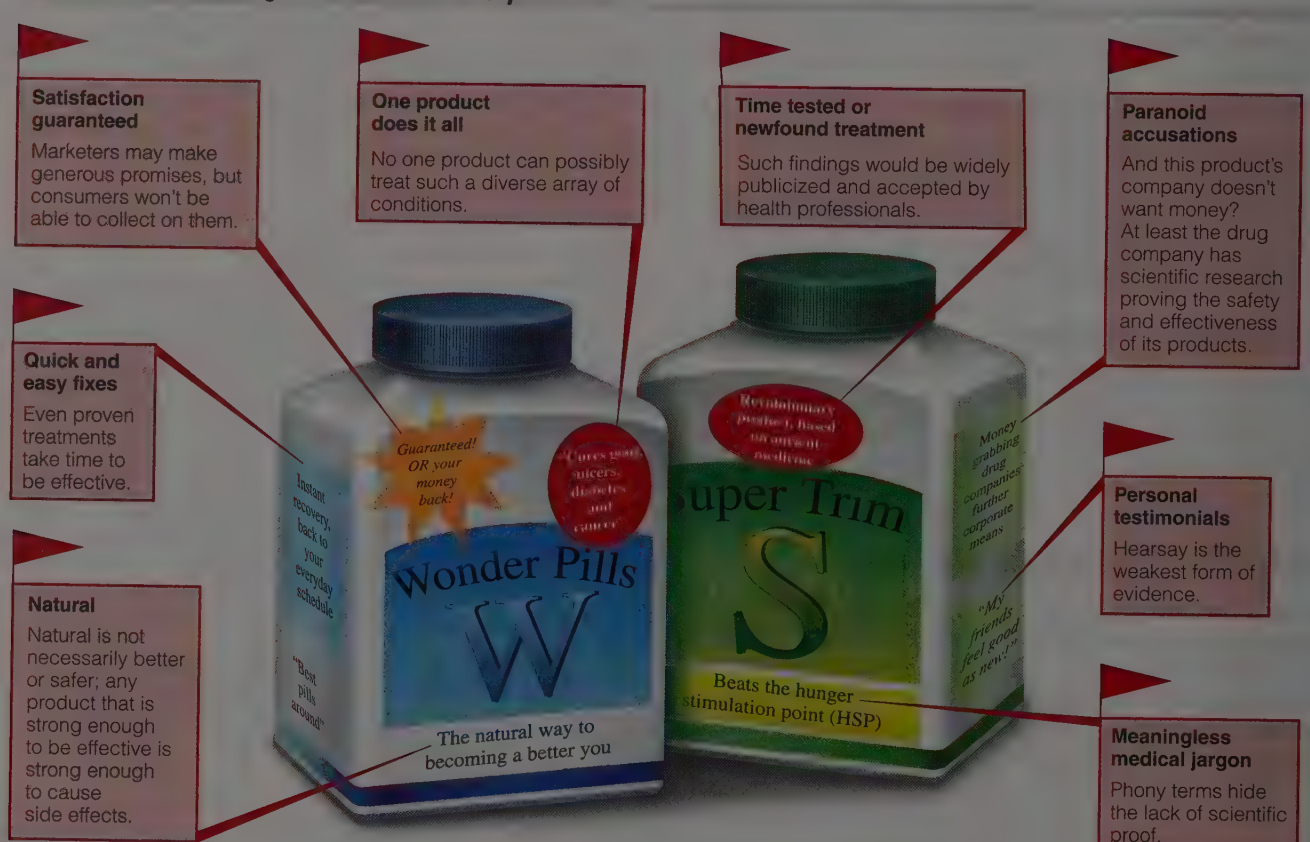
TABLE H1-1 Credible Sources of Nutrition Information

Government agencies, volunteer associations, consumer groups, and professional organizations provide consumers with reliable health and nutrition information. Credible sources of nutrition information include:

- Nutrition and food science departments at a university or community college
- Local agencies such as the health department or County Cooperative Extension Service
- Government resources such as:
  - Centers for Disease Control and prevention (CDC) — **www.cdc.gov**
  - Department of Agriculture (USDA) — **www.usda.gov**
  - Department of Health and Human Services (DHHS) — **www.hhs.gov**
  - Dietary Guidelines for Americans — **www.cnpp.usda.gov/dietaryguidelines.htm**
  - Food and Drug Administration (FDA) — **www.fda.gov**
  - Health Canada — **www.hc-sc.gc.ca/index-eng.php**
  - Healthy People — **www.healthypeople.gov**
  - Let's Move! — **www.letsmove.gov**
  - MyPlate — **www.choosemyplate.gov**
  - National Institutes of Health — **www.nih.gov**
  - Physical Activity Guidelines for Americans — **www.health.gov/paguidelines**
- Volunteer health agencies such as:
  - American Cancer Society — **www.cancer.org**
  - American Diabetes Association — **www.diabetes.org**
  - American Heart Association — **www.americanheart.org**
- Reputable consumer groups such as:
  - American Council on Science and Health — **www.acsh.org**
  - Federal Citizen Information Center — **www.usa.gov**
  - International Food Information Council — **www.foodinsight.org**
- Professional health organizations such as:
  - Academy of Nutrition and Dietetics — **www.eatright.org**
  - American Medical Association — **www.ama-assn.org**
  - Dietitians of Canada — **www.dietitians.ca**
- Journals such as:
  - *American Journal of Clinical Nutrition* — **www.ajcn.org**
  - *Journal of the Academy of Nutrition and Dietetics* — **www.adajournal.org**
  - *New England Journal of Medicine* — **www.nejm.org**
  - *Nutrition Reviews* — **www.ilsi.org**

© Cengage Learning 2013

> FIGURE H1-2 Red Flags of Nutrition Quackery



© Cengage Learning 2013

REFERENCES

1. R. A. Cohen and P. F. Adams, Use of the Internet for health information: United States, 2009, *NCHS Data Brief,* July 2011.
2. Position of the American Dietetic Association: Food and nutrition misinformation, *Journal of the American Dietetic Association* 106 (2006): 601–607.
3. Position of the American Dietetic Association: The roles of registered dietitians and dietetic technicians, registered in health promotion and disease prevention, *Journal of the American Dietetic Association* 106 (2006): 1875–1884.
4. Who's dishing out your nutrition advice? Consumers beware: Make sure your source is a registered dietitian, www.eatright.org, accessed March 3, 2008.



© iStockphoto/Jupiterimages

CENGAGE LEARNING'S GLOBAL NUTRITION
GLOBAL NUTRITION RESOURCE CENTER

The USDA recently updated many of its guidelines, including the introduction of MyPlate. Go to Nutrition Basics and Tools → Nutrition Standards & Guidelines to learn more about these updates. How do these updates help consumers create a well-balanced diet?

2 Planning a Healthy Diet

LEARNING GPS

2.1 Principles and Guidelines 35

LEARN IT Explain how each of the diet-planning principles can be used to plan a healthy diet.

- Diet-Planning Principles 36
- Dietary Guidelines for Americans 38

2.2 Diet-Planning Guides 40

LEARN IT Use the USDA Food Patterns to develop a meal plan within a specified energy allowance.

- USDA Food Patterns 40
- Exchange Lists 46
- Putting the Plan into Action 47
- From Guidelines to Groceries 49

2.3 Food Labels 53

LEARN IT Compare and contrast the information on food labels to make selections that meet specific dietary and health goals.

- The Ingredient List 53
- Nutrition Facts Panel 54
- Claims on Labels 56
- Consumer Education 58

Vegetarian Diets 62

LEARN IT Develop a well-balanced vegetarian meal plan.

Nutrition in Your Life

You make food choices—deciding what to eat and how much to eat—more than 1000 times every year. We eat so frequently that it's easy to choose a meal without giving any thought to its nutrient contributions or health consequences. Even when we want to make healthy choices, we may not know which foods to select or how much to consume. With a few tools and tips, you can learn to plan a healthy diet. In the Nutrition Portfolio exercise at the end of this chapter, you can compare your current diet against a healthy eating plan.

Chapter 1 explained that the body's many activities are supported by the nutrients delivered by the foods people eat. Food choices made over years influence the body's health, and consistently poor choices increase the risks of developing chronic diseases. This chapter shows how a person can select from the tens of thousands of available foods to create a diet that supports good health. Fortunately, most foods provide several nutrients, so one trick for wise diet planning is to select a combination of foods that deliver a full array of nutrients. This chapter begins by introducing the diet-planning principles and dietary guidelines that assist people in selecting foods that will deliver sufficient nutrients without excess energy (kcalories).

2.1 Principles and Guidelines

LEARN IT Explain how each of the diet-planning principles can be used to plan a healthy diet.

How well you nourish yourself does not depend on the selection of any one food. Instead, it depends on the overall **eating pattern**—the combination of many different foods and beverages at numerous meals over days, months, and years.[1] Diet-planning principles and dietary guidelines are key concepts to keep in mind

eating pattern: customary intake of foods and beverages over time.



© Polara Studios Inc.

To ensure an adequate and balanced diet, eat a variety of foods daily, choosing different foods from each group.

whenever you are selecting foods—whether shopping at the grocery store, choosing from a restaurant menu, or preparing a home-cooked meal.

Diet-Planning Principles

Diet planners have developed several ways to select foods. Whatever plan or combination of plans they use, though, they keep in mind the six basic diet-planning principles ♦ listed in the margin.

♦ Diet-planning principles:
- Adequacy
- Balance
- kCalorie (energy) control
- Nutrient density
- Moderation
- Variety

Adequacy

Adequacy reflects a diet that provides sufficient energy and enough of all the nutrients to meet the needs of healthy people. Take the essential nutrient iron, for example. Because the body loses some iron each day, people have to replace it by eating foods that contain iron. A person whose diet fails to provide enough iron-rich foods may develop the symptoms of iron-deficiency anemia: the person may feel weak, tired, and listless; have frequent headaches; and find that even the smallest amount of muscular work brings disabling fatigue. To prevent these deficiency symptoms, a person must include foods that supply adequate iron. The same is true for all the other essential nutrients introduced in Chapter 1.

Balance

Balance in the diet helps to ensure adequacy. The art of balancing the diet involves consuming enough—but not too much—of different types of foods in proportion to one another. In a balanced diet, foods rich in some nutrients do not crowd out foods that are rich in other nutrients. The essential minerals calcium and iron, taken together, illustrate the importance of dietary balance. Meat is rich in iron but poor in calcium. Conversely, milk is rich in calcium but poor in iron. Use some meat for iron; use some milk for calcium; and save some space for other foods, too, because a diet consisting of milk and meat alone would not be adequate. For the other nutrients, people need to eat other protein foods, whole grains, vegetables, and fruits.

kCalorie (Energy) Control

Designing an adequate diet within a reasonable kcalorie allowance requires careful planning. Once again, balance plays a key role. The amount of energy coming into the body from foods should balance with the amount of energy being used by the body to sustain its metabolic and physical activities. Upsetting this balance leads to gains or losses in body weight. The discussion of energy balance and weight control in Chapters 8 and 9 examines this issue in more detail, but one key to **kcalorie control** is to select foods of high **nutrient density**.

Nutrient Density

Nutrient density promotes adequacy and kcalorie control. To eat well without overeating, select nutrient-dense foods—that is, foods that deliver the most nutrients for the least food energy.[2] Consider foods containing calcium, for example. You can get about 300 milligrams of calcium from either 1½ ounces of cheddar cheese or 1 cup of fat-free milk, but the cheese delivers about twice as much food energy (kcalories) as the milk. The fat-free milk, then, is twice as calcium dense as the cheddar cheese; it offers the same amount of calcium for half the kcalories. Both foods are excellent choices for adequacy's sake alone, but to achieve adequacy while controlling kcalories, the fat-free milk is the better choice. (Alternatively, a person could select a low-fat cheddar cheese with its kcalories comparable to fat-free milk.) The accompanying "How To" describes how to compare foods based on nutrient density.

Just as a financially responsible person pays for rent, food, clothes, and tuition on a limited budget, healthy people obtain iron, calcium, and all the other essential nutrients on a limited energy (kcalorie) allowance. Success depends on getting many nutrients for each kcalorie "dollar." As Figure 2-1 illustrates, a breakfast of cereal, fruit, egg, and sausage delivers many more nutrients than a couple of doughnuts—even though they both provide about the same number of kcalories. A person who makes nutrient-dense choices can meet daily nutrient needs on a lower energy budget. Such choices support good health.

adequacy (dietary): providing all the essential nutrients, fiber, and energy in amounts sufficient to maintain health.

balance (dietary): providing foods in proportion to one another and in proportion to the body's needs.

kcalorie (energy) control: management of food energy intake.

nutrient density: a measure of the nutrients a food provides relative to the energy it provides. The more nutrients and the fewer kcalories, the higher the nutrient density.

>How To

Compare Foods Based on Nutrient Density

One way to evaluate foods is simply to notice their nutrient contribution *per serving*: 1 cup of milk provides about 300 milligrams of calcium, and ½ cup of fresh, cooked turnip greens provides about 100 milligrams. Thus a serving of milk offers three times as much calcium as a serving of turnip greens. To get 300 milligrams of calcium, a person could choose either 1 cup of milk or 1½ cups of turnip greens.

Another valuable way to evaluate foods is to consider their nutrient density—their nutrient contribution *per kcalorie*. Fat-free milk delivers about 85 kcalories with its 300 milligrams of calcium. To calculate the nutrient density, divide milligrams by kcalories:

$$\frac{300 \text{ mg calcium}}{85 \text{ kcal}} = 3.5 \text{ mg per kcal}$$

Do the same for the fresh turnip greens, which provide 15 kcalories with the 100 milligrams of calcium:

$$\frac{100 \text{ mg calcium}}{15 \text{ kcal}} = 6.7 \text{ mg per kcal}$$

The more milligrams per kcalorie, the greater the nutrient density. Turnip greens are more calcium dense than milk. They provide more calcium *per kcalorie* than milk, but milk offers more calcium *per serving*. Both approaches offer valuable information, especially when combined with a realistic appraisal. What matters most is which are you more likely to consume—1½ cups of turnip greens or 1 cup of milk? You can get 300 milligrams of calcium from either, but the greens will save you about 40 kcalories (the savings would be even greater if you usually use whole milk).

Keep in mind, too, that calcium is only one of the many nutrients that foods provide. Similar calculations for protein, for example, would show that fat-free milk provides more protein both *per kcalorie* and *per serving* than turnip greens—that is, milk is more protein dense. Combining variety with nutrient density helps to ensure the adequacy of all nutrients.

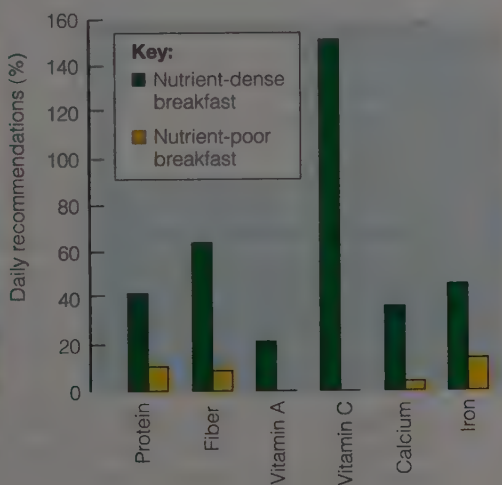
TRY IT Compare the thiamin density of 3 ounces of lean t-bone steak (174 kcalories, 0.09 milligrams thiamin) with ½ cup of fresh cooked broccoli (27 kcalories, 0.05 milligrams thiamin).

> FIGURE 2-1 Nutrient Density of Two Breakfast Options Compared

Chapter 1 presented this figure, illustrating energy density—that for the same number of kcalories, the breakfast on the left delivered less energy per gram of food, which benefits weight management. These two breakfasts also illustrate nutrient density—that for the same number of kcalories, the breakfast on the left delivers more nutrients per kcalorie.



Nutrient-dense breakfast





Nutrient-poor breakfast

Photos: © Matthew Farruggio; Art © Cengage Learning 2013

Foods that are notably low in nutrient density—such as potato chips, candy, and colas—are called **empty-kcalorie foods.** The kcalories these foods provide are called "empty" because they deliver energy (from added sugars, solid fats, or both) with little, or no, protein, vitamins, or minerals.

The concept of nutrient density is relatively simple when examining the contributions of one nutrient to a food or diet. With respect to calcium, milk ranks high and meats rank low. With respect to iron, meats rank high and milk ranks low. But it is a more complex task to answer the question, which food is more nutritious? To answer that question, we need to consider several nutrients—including both nutrients that may harm health as well as those that may be beneficial.[3] Ranking foods based on their overall nutrient composition is known as **nutrient profiling.**[4] Researchers have yet to agree on an ideal way to rate foods based on the nutrient profile, but when they do, nutrient profiling will be quite useful in helping consumers identify nutritious foods and plan healthy diets.[5]

Moderation **Moderation** contributes to adequacy, balance, and kcalorie control. Foods rich in fat and sugar often provide enjoyment and energy but relatively few nutrients; in addition, they promote weight gain when eaten in excess. A person practicing moderation eats such foods only on occasion and regularly selects foods low in **solid fats** and **added sugars**, a practice that automatically improves nutrient density. Returning to the example of cheddar cheese versus fat-free milk, the fat-free milk not only offers the same amount of calcium for less energy, but it also contains far less fat than the cheese.

Variety **Variety** improves nutrient adequacy. A diet may have all of the virtues just described and still lack variety, if a person eats the same foods day after day. People should select foods from each of the food groups daily and vary their choices within each food group from day to day for several reasons. First, different foods within the same group contain different arrays of nutrients. Among the fruits, for example, strawberries are especially rich in vitamin C while apricots are rich in vitamin A. Second, no food is guaranteed entirely free of substances that, in excess, could be harmful. The strawberries might contain trace amounts of one contaminant, the apricots another. By alternating fruit choices, a person will ingest very little of either contaminant. (Contamination of foods is discussed in Chapter 19.) Third, as the adage goes, variety is the spice of life. A person who eats beans frequently can enjoy pinto beans in Mexican burritos today, garbanzo beans in a Greek salad tomorrow, and baked beans with barbecued chicken on the weekend. Eating nutritious meals need never be boring.

Dietary Guidelines for Americans

What should a person eat to stay healthy? The answers can be found in the *Dietary Guidelines for Americans*. These guidelines translate the *nutrient* recommendations of the DRI (presented in Chapter 1) into *food* recommendations.[6] The result is evidence-based advice designed to help people attain and maintain a healthy weight, reduce the risk of chronic diseases, and promote overall health through diet and physical activity. In general, a healthy diet:

- Emphasizes a variety of fruits, vegetables, whole grains, and fat-free and low-fat milk products.
- Includes lean meats, poultry, seafood, legumes, eggs, seeds, and nuts.
- Is low in saturated and *trans* fats, cholesterol, salt (sodium), and added sugars.
- Stays within your daily energy needs for your recommended body weight.

Table 2-1 presents the key recommendations of the *Dietary Guidelines for Americans 2010*, clustered into four major topic areas. The first area focuses on balancing kcalories to manage a healthy body weight by improving eating habits and engaging in regular physical activity. The second area advises people to reduce their intakes of such foods and food components as sodium, solid fats (with their saturated fats, *trans* fats, and cholesterol), added sugars, refined grain products, and alcoholic beverages (for those who partake). The third area encourages people to consume a variety of fruits and vegetables, whole grains, and low-fat milk products and protein

empty-kcalorie foods: a popular term used to denote foods that contribute energy but lack protein, vitamins, and minerals.

nutrient profiling: ranking foods based on their nutrient composition.

moderation (dietary): providing enough but not too much of a substance.

solid fats: fats that are not usually liquid at room temperature; commonly found in most foods derived from animals and vegetable oils that have been hydrogenated. Solid fats typically contain more saturated and *trans* fats than most oils (Chapter 5 provides more details).

added sugars: sugars and other kcaloric sweeteners that are added to foods during processing, preparation, or at the table. Added sugars do not include the naturally occurring sugars found in fruits and milk products.

variety (dietary): eating a wide selection of foods within and among the major food groups.

TABLE 2-1 Key Recommendations of the *Dietary Guidelines for Americans 2010*

Balancing kCalories to Manage Weight

- Prevent and/or reduce overweight and obesity through improved eating and physical activity behaviors (see Chapter 9).
- Control total kcalorie intake to manage body weight. For people who are overweight or obese, this will mean consuming fewer kcalories from foods and beverages (see Chapter 8).
- Increase physical activity and reduce time spent in sedentary behaviors (see Chapter 14).
- Maintain appropriate kcalorie balance during each stage of life—childhood, adolescence, adulthood, pregnancy and breastfeeding, and older age (see Chapters 14–16).

Foods and Food Components to Reduce

- Reduce daily sodium intake to less that 2300 milligrams and further reduce intake to 1500 milligrams among persons who are 51 and older and those of any age who are African American or have hypertension, diabetes, or chronic kidney disease (see Chapter 12).
- Consume less than 10 percent of kcalories from saturated fatty acids by replacing them with monounsaturated and polyunsaturated fatty acids (see Chapter 5).
- Consume less than 300 milligrams per day of dietary cholesterol (see Chapter 5).
- Keep *trans* fatty acid consumption as low as possible by limiting foods that contain synthetic sources of *trans* fats, such as partially hydrogenated oils, and by limiting other solid fats (see Chapter 5).
- Reduce the intake of kcalories from solid fats and added sugars (see Chapters 4–5).
- Limit the consumption of foods that contain refined grains, especially refined grain foods that contain solid fats, added sugars, and sodium (see Chapters 4, 5, and 12).
- If alcohol is consumed it should be consumed in moderation—up to one drink per day for women and two drinks per day for men—and only by adults of legal drinking age (see Highlight 7).

Foods and Nutrients to Increase

- Increase vegetable and fruit intake.
- Eat a variety of vegetables, especially dark-green and red and orange vegetables and beans and peas.
- Consume at least half of all grains as whole grains. Increase whole-grain intake by replacing refined grains with whole grains.
- Increase intake of fat-free or low-fat milk and milk products, such as milk, yogurt, cheese, or fortified soy beverages.
- Choose a variety of protein foods, which include seafood, lean meat and poultry, eggs, beans and peas, soy products, and unsalted nuts and seeds.
- Increase the amount and variety of seafood consumed by choosing seafood in place of some meat and poultry.
- Replace protein foods that are higher in solid fats with choices that are lower in solid fats and kcalories and/or are sources of oils.
- Use oils to replace solid fats where possible (see Highlight 5).
- Choose foods that provide more potassium, dietary fiber, calcium, and vitamin D, which are nutrients of concern in American diets (see Chapters 4, 11, and 12). These foods include vegetables, fruits, whole grains, and milk and milk products.

Building Healthy Eating Patterns

- Select an eating pattern that meets nutrient needs over time at an appropriate kcalorie level.
- Account for all foods and beverages consumed and assess how they fit within a total healthy eating pattern.
- Follow food safety recommendations when preparing and eating foods to reduce the risk of foodborne illnesses (see Chapter 19).

© Cengage Learning 2013

NOTE: These guidelines are intended for adults and healthy children ages 2 and older.
SOURCE: The *Dietary Guidelines for Americans*, available at www.healthierus.gov/dietaryguidelines.

foods (including seafood). The fourth area helps consumers build healthy eating patterns that meet energy and nutrient needs while reducing the risk of foodborne illnesses. Together, the *Dietary Guidelines for Americans 2010* point the way toward longer, healthier, and more active lives. These key recommendations, along with additional recommendations for specific population groups, appear throughout the text as their subjects are discussed.

By law, the *Dietary Guidelines for Americans* are reviewed and revised as needed every five years. Each edition shares some similarities with previous editions but also sets precedent in new ways. Perhaps most noteworthy to the 2010 edition is



© AISPIX/Shutterstock.com

The *Dietary Guidelines* encourage Americans to increase the energy (kcalories) they expend through physical activity.

the overarching focus on curbing the obesity epidemic and improving the health of the American population.[7]

Some people might wonder why *dietary* guidelines include recommendations for physical activity. The simple answer is that most people who maintain a healthy body weight do more than eat right. They also exercise—the equivalent of 30 to 60 minutes or more of moderately intense physical activity on most days.[8] As you will see repeatedly throughout this text, food and physical activity choices are integral partners in supporting good health.

REVIEW IT Explain how each of the diet-planning principles can be used to plan a healthy diet.

A well-planned diet delivers adequate nutrients, a balanced array of nutrients, and an appropriate amount of energy. It is based on nutrient-dense foods, moderate in substances that can be detrimental to health, and varied in its selections. The *Dietary Guidelines* apply these principles, offering practical advice on how to eat for good health.

2.2 Diet-Planning Guides

LEARN IT Use the USDA Food Patterns to develop a meal plan within a specified energy allowance.

To plan a diet that achieves all of the dietary ideals just outlined, a person needs tools as well as knowledge. Among the most widely used tools for diet planning are **food group plans** that build a diet from clusters of foods that are similar in nutrient content. Thus each food group represents a set of nutrients that differs somewhat from the nutrients supplied by the other groups. Selecting foods from each of the groups eases the task of creating an adequate and balanced diet.

food group plans: diet-planning tools that sort foods into groups based on nutrient content and then specify that people should eat certain amounts of foods from each group.

USDA Food Patterns

The *Dietary Guidelines* encourage consumers to adopt a balanced eating pattern, using the USDA's Food Patterns. The USDA Food Patterns assign foods to five major groups ♦ and recommend daily amounts of foods from each group to meet nutrient needs. Figure 2-2 (pp. 42–43) presents the food groups, the most notable nutrients of each group, the serving equivalents, and the foods within each group. Chapter 16 provides a food guide for young children.

♦ Five food groups:
- Fruits
- Vegetables
- Grains
- Protein foods
- Milk and milk products

Recommended Amounts

All food groups offer valuable nutrients, and people should make selections from each group daily. Table 2-2 (p. 44) specifies the amounts of foods from each group needed daily to create a healthful diet for several energy (kcalorie) levels. A person needing 2000 kcalories a day, for example, would select 2 cups of fruit; 2½ cups of vegetables; 6 ounces of grain foods; 5½ ounces of protein foods; and 3 cups of milk or milk products.* Additionally, a small amount of unsaturated oil, such as vegetable oil, or the oils of nuts, olives, or fatty fish, is required to supply needed nutrients. Table 2-3 (p. 44) presents estimated daily kcalorie needs for adults.



> DIETARY GUIDELINES FOR AMERICANS 2010

Select an eating pattern that meets nutrient needs over time at an appropriate kcalorie level.

All vegetables provide an array of nutrients, but some vegetables are especially good sources of certain vitamins, minerals, and beneficial phytochemicals. For this reason, the vegetable group is sorted into five subgroups. The dark-green vegetables deliver the B vitamin folate; the red and orange vegetables provide

*Milk and milk products also can be referred to as dairy products.

vitamin A; legumes supply iron and protein; the starchy vegetables contribute carbohydrate energy; and the other vegetables fill in the gaps and add more of these same nutrients.

In a 2000-kcalorie diet, then, the recommended 2½ cups of daily vegetables should be varied among the subgroups over a week's time. In other words, consuming 2½ cups of potatoes or even nutrient-rich spinach every day for seven days does *not* meet the recommended amounts for vegetables. Potatoes and spinach make excellent choices when consumed in balance with vegetables from the other subgroups. One way to help ensure selections for all of the subgroups is to eat vegetables of various colors—for example, green broccoli, orange sweet potatoes, black beans, yellow corn, and white cauliflower. Intakes of vegetables are appropriately averaged over a week's time—it is not necessary to include every subgroup every day.

For similar reasons, the protein foods group is sorted into three subgroups. Perhaps most notably, each of these subgroups contributes a different assortment of fats. Table 2-4 (p. 44) presents the recommended *weekly* amounts for each of the subgroups for vegetables and protein foods.

Notable Nutrients As Figure 2-2 notes, each food group contributes key nutrients. This feature provides flexibility in diet planning because a person can select any food from a food group (or its subgroup) and receive similar nutrients. For example, a person can choose milk, cheese, or yogurt and receive the same key nutrients. Importantly, foods provide not only these key nutrients, but small amounts of other nutrients and phytochemicals as well.

Legumes contribute the same key nutrients—notably, protein, iron, and zinc—as meats, poultry, and seafood. They are also excellent sources of fiber, folate, and potassium, which are commonly found in vegetables. To encourage frequent consumption of these nutrient-rich foods, legumes are included as a subgroup of both the vegetable group and the protein foods group. Thus legumes can be counted in either the vegetable group or the protein foods group.[9] In general, people who regularly eat meat, poultry, and seafood count legumes as a vegetable, and vegetarians and others who seldom eat meat, poultry, or seafood count legumes in the protein foods group.

The USDA Food Patterns encourage greater consumption from certain food groups to provide the nutrients most often lacking in the diets of Americans. ♦ In general, most people need to eat:

- *More* vegetables, fruits, whole grains, seafood, and milk and milk products.
- *Less* sodium, saturated fat, *trans* fat, cholesterol, and *fewer* refined grains and foods and beverages with solid fats and added sugars.

♦ Nutrients of concern:
- Dietary fiber
- Vitamin D
- Calcium
- Potassium

Nutrient-Dense Choices A healthy eating pattern emphasizes nutrient-dense options within each food group. By consistently selecting nutrient-dense foods, a person can obtain all the nutrients needed and still keep kcalories under control. In contrast, eating foods that are low in nutrient density makes it difficult to get enough nutrients without exceeding energy needs and gaining weight. For this reason, consumers should select low-fat foods from each group and foods without solid fats or added sugars—for example, fat-free milk instead of whole milk, baked chicken without the skin instead of hot dogs, green beans instead of french fries, orange juice instead of fruit punch, and whole-wheat bread instead of biscuits. Notice that Figure 2-2 indicates which foods *within each group* contain solid fats and/or added sugars and therefore should be limited. Oil is a notable exception: even though oil is pure fat and therefore rich in kcalories, a small amount of oil from sources such as nuts, fish, or vegetable oils is necessary every day to provide nutrients lacking from other foods. Consequently, these high-fat foods are listed among the nutrient-dense foods (see Highlight 5 to learn why).



> DIETARY GUIDELINES FOR AMERICANS 2010

Consume foods from all food groups in nutrient-dense forms and in recommended amounts. Reduce the intake of kcalories from solid fats and added sugars.

legumes (lay-GYOOMS, LEG-yooms): plants of the bean and pea family, with seeds that are rich in protein compared with other plant-derived foods.

FIGURE 2-2 USDA Food Patterns: Food Groups and Subgroups



Fruits contribute folate, vitamin A, vitamin C, potassium, and fiber.

Consume a variety of fruits, and choose whole or cut-up fruits more often than fruit juice.

Apples, apricots, avocados, bananas, blueberries, cantaloupe, cherries, grapefruit, grapes, guava, honeydew, kiwi, mango, nectarines, oranges, papaya, peaches, pears, pineapples, plums, raspberries, strawberries, tangerines, watermelon; dried fruit (dates, figs, prunes, raisins); 100% fruit juices

Limit these fruits that contain solid fats and/or added sugars:
Canned or frozen fruit in syrup; juices, punches, ades, and fruit drinks with added sugars; fried plantains



Vegetables contribute folate, vitamin A, vitamin C, vitamin K, vitamin E, magnesium, potassium, and fiber.

Consume a variety of vegetables each day, and choose from all five subgroups several times a week.

Dark-green vegetables: Broccoli and leafy greens such as arugula, beet greens, bok choy, collard greens, kale, mustard greens, romaine lettuce, spinach, turnip greens, watercress

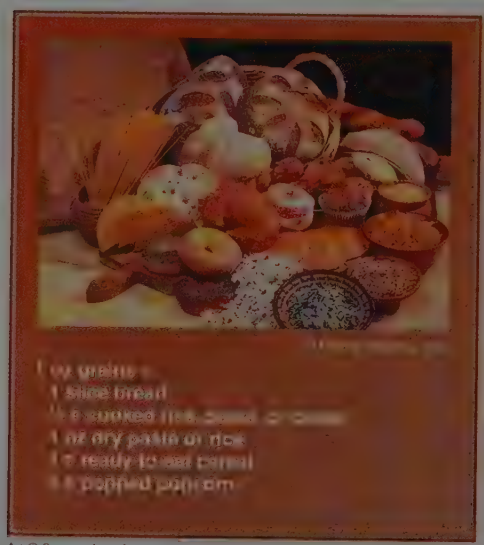
Red and orange vegetables: Carrots, carrot juice, pumpkin, red bell peppers, sweet potatoes, tomatoes, tomato juice, vegetable juice, winter squash (acorn, butternut)

Legumes: Black beans, black-eyed peas, garbanzo beans (chickpeas), kidney beans, lentils, navy beans, pinto beans, soybeans and soy products such as tofu, split peas, white beans

Starchy vegetables: Cassava, corn, green peas, hominy, lima beans, potatoes

Other vegetables: Artichokes, asparagus, bamboo shoots, bean sprouts, beets, brussels sprouts, cabbages, cactus, cauliflower, celery, cucumbers, eggplant, green beans, green bell peppers, iceberg lettuce, mushrooms, okra, onions, seaweed, snow peas, zucchini

Limit these vegetables that contain solid fats and/or added sugars:
Baked beans, candied sweet potatoes, coleslaw, french fries, potato salad, refried beans, scalloped potatoes, tempura vegetables



Grains contribute folate, niacin, riboflavin, thiamin, iron, magnesium, selenium, and fiber.

Make most (at least half) of the grain selections whole grains.

Whole grains: amaranth, barley, brown rice, buckwheat, bulgur, cornmeal, millet, oats, quinoa, rye, wheat, wild rice and whole-grain products such as breads, cereals, crackers, and pastas; popcorn

Enriched refined products: bagels, breads, cereals, pastas (couscous, macaroni, spaghetti), pretzels, white rice, rolls, tortillas

Limit these grains that contain solid fats and/or added sugars:
Biscuits, cakes, cookies, cornbread, crackers, croissants, doughnuts, fried rice, granola, muffins, pastries, pies, presweetened cereals, taco shells

Art © Cengage Learning 2013

> **FIGURE 2-2 USDA Food Patterns: Food Groups and Subgroups (*continued*)**



Protein foods contribute protein, essential fatty acids, niacin, thiamin, vitamin B_6, vitamin B_{12}, iron, magnesium, potassium, and zinc.

Choose a variety of protein foods from the three subgroups, including seafood in place of meat or poultry twice a week.

Seafood: Fish (catfish, cod, flounder, haddock, halibut, herring, mackerel, pollock, salmon, sardines, sea bass, snapper, trout, tuna), shellfish (clams, crab, lobster, mussels, oysters, scallops, shrimp)

Meats, poultry, eggs: Lean or low-fat meats (fat-trimmed beef, game, ham, lamb, pork, veal), poultry (no skin), eggs

Nuts, seeds, soy products: Unsalted nuts (almonds, cashews, filberts, pecans, pistachios, walnuts), seeds (flaxseeds, pumpkin seeds, sesame seeds, sunflower seeds), legumes, soy products (textured vegetable protein, tofu, tempeh), peanut butter, peanuts

Limit these protein foods that contain solid fats and/or added sugars:
Bacon; baked beans; fried meat, seafood, poultry, eggs, or tofu; refried beans; ground beef; hot dogs; luncheon meats; marbled steaks; poultry with skin; sausages; spare ribs

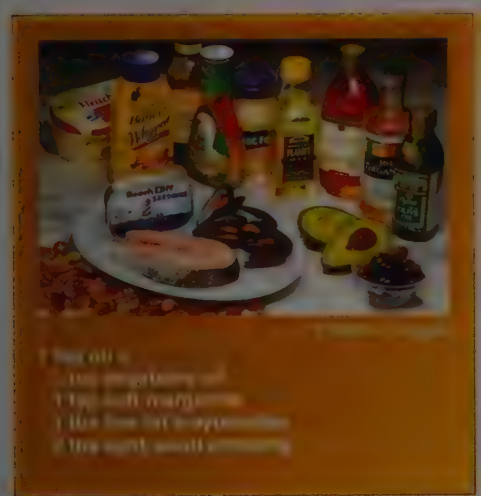


Milk and milk products contribute protein, riboflavin, vitamin B_{12}, calcium, potassium, and, when fortified, vitamin A and vitamin D.

Make fat-free or low-fat choices. Choose other calcium-rich foods if you don't consume milk.

Fat-free or 1% low-fat milk and fat-free or 1% low-fat milk products such as buttermilk, cheeses, cottage cheese, yogurt; fat-free fortified soy milk

Limit these milk products that contain solid fats and/or added sugars:
2% reduced-fat milk and whole milk; 2% reduced-fat and whole-milk products such as cheeses, cottage cheese, and yogurt; flavored milk with added sugars such as chocolate milk, custard, frozen yogurt, ice cream, milk shakes, pudding, sherbet; fortified soy milk



Oils are not a food group, but are featured here because they contribute vitamin E and essential fatty acids.

Use oils instead of solid fats, when possible.

Liquid vegetable oils such as canola, corn, flaxseed, nut, olive, peanut, safflower, sesame, soybean, sunflower oils; mayonnaise, oil-based salad dressing, soft *trans*-free margarine; unsaturated oils that occur naturally in foods such as avocados, fatty fish, nuts, olives, seeds (flaxseeds, sesame seeds), shellfish

Limit these solid fats:
Butter, animal fats, stick margarine, shortening

Art © Cengage Learning 2013

TABLE 2-2 USDA Food Patterns: Recommended Daily Amounts from Each Food Group

	1600 kcal	1800 kcal	2000 kcal	2200 kcal	2400 kcal	2600 kcal	2800 kcal	3000 kcal
Fruits	1½ c	1½ c	2 c	2 c	2 c	2 c	2½ c	2½ c
Vegetables	2 c	2½ c	2½ c	3 c	3 c	3½ c	3½ c	4 c
Grains	5 oz	6 oz	6 oz	7 oz	8 oz	9 oz	10 oz	10 oz
Protein foods	5 oz	5 oz	5½ oz	6 oz	6½ oz	6½ oz	7 oz	7 oz
Milk and milk products	3 c	3 c	3 c	3 c	3 c	3 c	3 c	3 c
Oils	5 tsp	5 tsp	6 tsp	6 tsp	7 tsp	8 tsp	8 tsp	10 tsp
Discretionary kcalories	121 kcal	161 kcal	258 kcal	266 kcal	330 kcal	362 kcal	395 kcal	459 kcal

© Cengage Learning 2013

TABLE 2-3 Estimated Daily kCalorie Needs for Adults

	Sedentary[a]	Active[b]
Women		
19–30 yr	1900	2400
31–50 yr	1800	2200
51+ yr	1600	2100
Men		
19–30 yr	2500	3000
31–50 yr	2300	2900
51+ yr	2100	2600

[a]Sedentary describes a lifestyle that includes only the activities typical of day-to-day life.
[b]Active describes a lifestyle that includes physical activity equivalent to walking more than 3 miles per day at a rate of 3 to 4 miles per hour, in addition to the activities typical of day-to-day life.
NOTE: kCalorie values reflect the midpoint of the range appropriate for age and gender, but within each group, older adults may need fewer kcalories and younger adults may need more. In addition to gender, age, and activity level, energy needs vary with height and weight (see Chapter 8 and Appendix F).

© Cengage Learning 2013

discretionary kcalories: the kcalories remaining in a person's energy allowance after consuming enough nutrient-dense foods to meet all nutrient needs for a day.

serving sizes: the standardized quantity of a food; such information allows comparisons when reading food labels and consistency when following the *Dietary Guidelines*.

Discretionary kCalories At each kcalorie level, people who consistently choose nutrient-dense foods may be able to meet most of their nutrient needs without consuming their full allowance of kcalories. The difference between the kcalories needed to supply nutrients and those needed to maintain weight might be considered **discretionary kcalories** (see Figure 2-3).

Discretionary kcalories allow a person to choose whether to:

- Eat additional nutrient-dense foods, such as an extra serving of skinless chicken or a second ear of corn.
- Select a few foods with fats or added sugars, such as reduced-fat milk or sweetened cereal.
- Add a little fat or sugar to foods, such as butter or jelly on toast.
- Consume some alcohol. (Highlight 7 explains why this may not be a good choice for some individuals.)

Alternatively, a person wanting to lose weight might choose to:

- *Not* use discretionary kcalories.



> DIETARY GUIDELINES FOR AMERICANS 2010
For most people, no more than about 5 to 15 percent of kcalories from solid fats and added sugars (empty kcalories) can be reasonably accommodated in the USDA Food Patterns, which are designed to meet nutrient needs within kcalorie limits.

Serving Equivalents Recommended serving amounts for fruits, vegetables, and milk are measured in cups, and those for grains and protein foods, in ounces. Figure 2-2 provides the **serving sizes** and equivalent measures for foods in each group specifying, for example, that 1 ounce of grains is equivalent to 1 slice of bread or ½ cup of cooked rice.

TABLE 2-4 USDA Food Patterns: Recommended Weekly Amounts from the Vegetable and Protein Foods Subgroups

Table 2-2 specifies the recommended amounts of total vegetables and protein foods per *day*. This table shows those amounts dispersed among five vegetable and three protein foods subgroups per *week*.

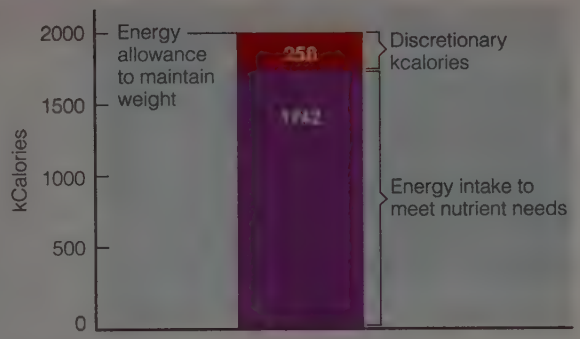
	1600 kcal	1800 kcal	2000 kcal	2200 kcal	2400 kcal	2600 kcal	2800 kcal	3000 kcal
Vegetable Subgroups								
Dark green	1½ c	1½ c	1½ c	2 c	2 c	2½ c	2½ c	2½ c
Red and orange	4 c	5½ c	5½ c	6 c	6 c	7 c	7 c	7½ c
Legumes	1 c	1½ c	1½ c	2 c	2 c	2½ c	2½ c	3 c
Starchy	4 c	5 c	5 c	6 c	6 c	7 c	7 c	8 c
Other	3½ c	4 c	4 c	5 c	5 c	5½ c	5½ c	7 c
Protein Foods Subgroups								
Seafood	8 oz	8 oz	8 oz	9 oz	10 oz	10 oz	11 oz	11 oz
Meats, poultry, eggs	24 oz	24 oz	26 oz	29 oz	31 oz	31 oz	34 oz	34 oz
Nuts, seeds, soy products	4 oz	4 oz	4 oz	4 oz	5 oz	5 oz	5 oz	5 oz

© Cengage Learning 2013

Consumers using the USDA Food Patterns can learn how standard serving sizes compare with their personal **portion sizes** ♦ by determining the answers to questions such as these: What portion of a cup is a small handful of raisins? Is a "helping" of mashed potatoes more or less than a half cup? How many ounces of cereal do you typically pour into the bowl? How many ounces is the steak at your favorite restaurant? How many cups of milk does your glass hold?

Ethnic Food Choices People can use the USDA Food Patterns and still enjoy a diverse array of culinary styles by sorting ethnic foods into their appropriate food groups. For example, a person eating Mexican foods would find tortillas in the grains group, jicama in the vegetable group, and guava in the fruit group. Table 2-5 (p. 46) features some ethnic food choices.

> **FIGURE 2-3 Discretionary kCalories in a 2000-kCalorie Diet**



Vegetarian Food Guide Vegetarian diets are plant-based eating patterns that rely mainly on grains, vegetables, legumes, fruits, seeds, and nuts. Some vegetarian diets include eggs, milk products, or both. People who do not eat meats or milk products can still use the USDA Food Patterns to create an adequate diet.[10] The subgroups for protein foods have been reorganized to eliminate meats, poultry, and seafood (see Table H2-1 on p. 64). The other food groups and the recommended daily amounts for each food group remain the same. Highlight 2 defines vegetarian terms and provides details on planning healthy vegetarian diets.

Mixtures of Foods Some foods—such as casseroles, soups, and sandwiches—fall into two or more food groups. With a little practice, consumers can learn to see these mixtures of foods as items from various food groups. For example, from the USDA Food Patterns point of view, a taco represents four different food groups: the taco shell from the grains group; the onions, lettuce, and tomatoes from the vegetables group; the ground beef from the protein foods group; and the cheese from the milk group.

MyPlate The USDA created an educational tool called MyPlate to illustrate the five food groups. Figure 2-4 (p. 46) shows the MyPlate icon, which was designed to remind consumers to make healthy food choices.

The MyPlate icon divides a plate into four sections, each representing a food group—fruits, vegetables, grains, and protein. The sections vary in size, indicating relative proportion each food group contributes to a healthy diet. A circle next to the plate represents the milk group (dairy).

The MyPlate icon does not stand alone as an educational tool. A wealth of information can be found at the website (**www.choosemyplate.gov**). Consumers can choose the kinds and amounts of foods they need to eat each day based on their height, weight, age, gender, and activity level. Information is also available for children, pregnant and lactating women, and for vegetarians. In addition to creating a personal plan, consumers can find daily tips to help them improve their diet and increase physical activity. A key message of the website is to enjoy food, but eat less by avoiding oversized portions.

Recommendations versus Actual Intakes The USDA Food Patterns and MyPlate were developed to help people choose a balanced and healthful diet. Are consumers actually eating according to these recommendations? The short answer is "not really." In general, consumers are not selecting the most nutrient-dense items from the food groups. Instead, they are consuming too many foods high in solid fats and added sugars—soft drinks, desserts, whole milk products, and fatty meats.[11] They are also not selecting the suggested quantities from each of the food groups, typically eating too few fruits, vegetables, whole grains, and milk products (see Figure 2-5, p. 47).

An assessment tool, called the **Healthy Eating Index**, can be used to measure how well a diet meets the recommendations of the *Dietary Guidelines*.[12] Various components of the diet are given scores that reflect the quantities consumed per

♦ For quick and easy estimates, visualize each portion as being about the size of a common object:

- 1 c fruit or vegetables = a baseball
- ¼ c dried fruit or nuts = a golf ball
- 3 oz meat = a deck of cards
- 2 tbs peanut butter = a ping pong ball
- 1 oz cheese = 4 stacked dice
- ½ c ice cream = a racquetball
- 4 small cookies = 4 poker chips


© Matthew Farruggio

Most bagels today weigh in at 4 ounces or more—meaning that a person eating one of these large bagels for breakfast is actually getting four or more grain servings, not one.

portion sizes: the quantity of a food served or eaten at one meal or snack; *not* a standard amount.

Healthy Eating Index: a measure that assesses how well a diet meets the recommendations of the *Dietary Guidelines for Americans*.

TABLE 2-5 Ethnic Food Choices

	Grains	Vegetables	Fruits	Protein Foods	Milk and Milk Products
Asian  © Josh Resnick/Shutterstock.com	Rice, noodles, millet	Amaranth, baby corn, bamboo shoots, chayote, bok choy, mung bean sprouts, sugar peas, straw mushrooms, water chestnuts, kelp	Carambola, guava, kumquat, lychee, persimmon, melons, mandarin orange	Soybeans and soy products such as soy milk and tofu, squid, duck eggs, pork, poultry, fish and other seafood, peanuts, cashews	Usually excluded
Mediterranean  © PhotoDisc/Getty Images	Pita pocket bread, pastas, rice, couscous, polenta, bulgur, focaccia, Italian bread	Eggplant, tomatoes, peppers, cucumbers, grape leaves	Olives, grapes, figs	Fish and other seafood, gyros, lamb, chicken, beef, pork, sausage, lentils, fava beans	Ricotta, provolone, parmesan, feta, mozzarella, and goat cheeses; yogurt
Mexican  © PhotoDisc/Getty Images	Tortillas (corn or flour), taco shells, rice	Chayote, corn, jicama, tomato salsa, cactus, cassava, tomatoes, yams, chilies	Guava, mango, papaya, avocado, plantain, bananas, oranges	Refried beans, fish, chicken, chorizo, beef, eggs	Cheese, custard

© Cengage Learning 2013

1000-kcalorie intake. For most components, higher intakes result in higher scores. For example, selecting at least 3 ounces of grains with at least half of them whole grains gives a score of 10 points, whereas selecting no grains gives a score of 0 points. For a few components, lower intakes provide higher scores. For example, less than 7 percent kcalories from saturated fat receives 10 points, but more than 15 percent gets 0 points. An assessment of recent nutrition surveys using the Healthy Eating Index reports that the American diet scores 58 out of a possible 100 points.[13] To improve this score, the American diet needs to decrease kcalories from solid fats and added sugars by about 60 percent; increase fruits by 100 percent and vegetables and milk products by 70 percent; maintain the quantity of grains but shift the quality to four times as many whole grains; and reduce salt by more than half.[14]

> **FIGURE 2-4 MyPlate**



SOURCE: USDA, www.choosemyplate.gov.

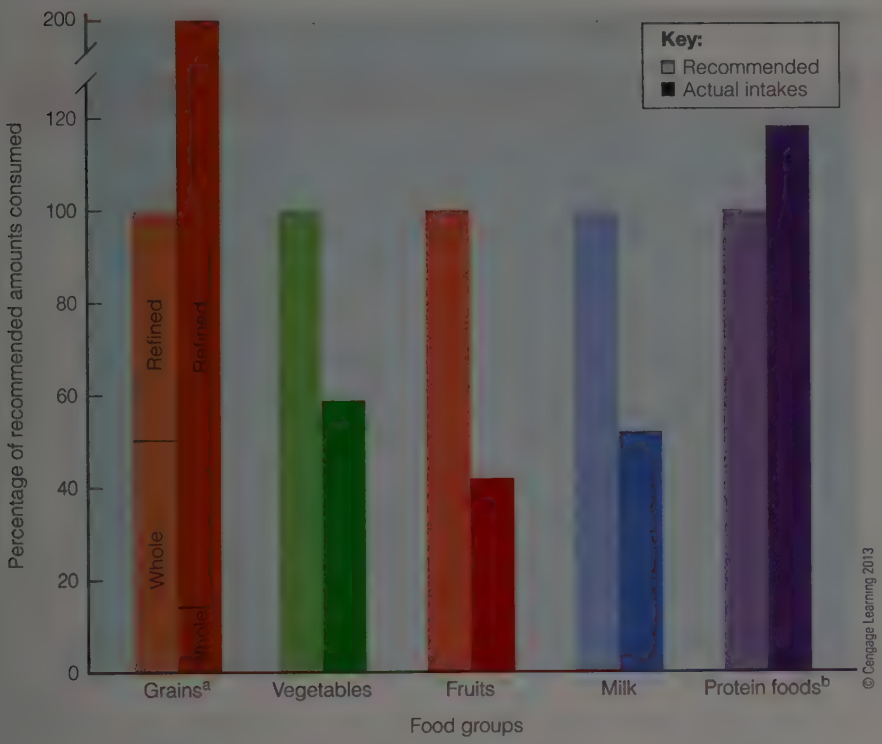
MyPlate Shortcomings MyPlate is not perfect and critics are quick to point out its flaws.[15] The first main criticism is that MyPlate fails to convey enough information to help consumers choose a healthy diet. MyPlate contains few words and depends on its website to provide key information—which is helpful for those who have Internet access and are willing to take the time to become familiar with its teachings. The second main criticism is that MyPlate fails to recognize that some foods within a food group are healthier choices than others. For example, MyPlate does not distinguish between fish sticks and salmon or between broccoli and french fries. Many of the upcoming chapters examine the links between diet and health, and Chapter 18 presents a complete summary, including a look at an alternative Healthy Eating Plate created by the faculty members in the Harvard School of Public Health.

Exchange Lists

Food group plans are particularly well suited to help a person achieve dietary adequacy, balance, and variety. **Exchange lists** provide additional help in achieving kcalorie control and moderation. Originally developed as a

exchange lists: diet-planning tools that organize foods by their proportions of carbohydrate, fat, and protein. Foods on any single list can be used interchangeably.

> **FIGURE 2-5 Recommended and Actual Intakes Compared**



[a]At least half of the grain selections should be whole grains.
[b]On average, actual intakes of all protein foods is close to recommended levels, but actual intakes of the seafood subgroup is only 44 percent of recommended levels.

meal planning guide for people with diabetes, exchange lists have proved useful for general diet planning as well.

Unlike the USDA Food Patterns, which sort foods primarily by their vitamin and mineral contents, the exchange system sorts foods according to their energy-nutrient contents. Consequently, foods do not always appear on the exchange list where you might first expect to find them. For example, cheeses are grouped with meats because, like meats, cheeses contribute energy from protein and fat but provide negligible carbohydrate. (In the USDA Food Patterns presented earlier, cheeses are grouped with milk because they are milk products with similar calcium contents.)

For similar reasons, starchy vegetables such as corn, green peas, and potatoes are listed with grains on the starch list in the exchange system, rather than with the vegetables. Likewise, olives are not classed as a "fruit" as a botanist would claim; they are classified as a "fat" because their fat content makes them more similar to oil than to berries. Cream cheese, bacon, and nuts are also on the fat list to remind users of their high fat content. These groupings highlight the characteristics of foods that are significant to energy intake. To learn more about this useful diet-planning tool, study Appendix G, which gives details of the exchange system used in the United States.

Putting the Plan into Action Familiarizing yourself with each of the food groups is the first step in diet planning. Table 2-6 (p. 48) shows how to use the 2000-kcalorie USDA Food Pattern to plan a diet. The amounts listed from each of the food groups (see the second column of the table) were taken from Table 2-2. The next step is to assign the food groups to meals (and snacks), as shown in the remaining columns of Table 2-6.

TABLE 2-6 Diet Planning Using the 2000-kCalorie USDA Food Pattern

This diet plan is one of many possibilities. It follows the amounts of foods suggested for a 2000-kcalorie diet as shown in Table 2-2 on p. 44 (with a little less oil).

Food Group	Amounts	Breakfast	Lunch	Snack	Dinner	Snack
Fruits	2 c	½ c		½ c	1 c	
Vegetables	2½ c		1 c		1½ c	
Grains	6 oz	1 oz	2 oz	½ oz	2 oz	½ oz
Protein foods	5½ oz		2 oz		3½ oz	
Milk and milk products	3 c	1 c		1 c		1 c
Oils	6 tsp		1½ tsp		4 tsp	

© Cengage Learning 2013

At this point, a person can begin to fill in a plan with real foods to create a menu. For example, the breakfast calls for 1 ounce grain, ½ cup fruit, and 1 cup milk. A person might select a bowl of cereal with banana slices and milk:

1 cup cereal = 1 ounce grain

½ large banana = ½ cup fruit

1 cup fat-free milk = 1 cup milk

Or ½ English muffin and a bowl of strawberries topped with yogurt:

½ English muffin = 1 ounce grain

½ cup strawberries = ½ cup fruit

1 cup fat-free plain yogurt = 1 cup milk

Then the person can continue to create a diet plan by creating menus for lunch, dinner, and snacks. The final menu might look like the one presented in Table 2-7.

TABLE 2-7 A Sample Menu

This sample menu provides about 1850 kcalories and meets the recommendations to provide 45 to 65 percent of kcalories from carbohydrate, 20 to 35 percent from fat, and 10 to 35 percent from protein.

Amounts	Sample Menu	Energy (kcal)
	Breakfast	
1 oz whole grains	1 c whole-grain cereal	108
1 c milk	1 c fat-free milk	100
½ c fruit	1 medium banana (sliced)	105
	Lunch	
2 oz meats, 2 oz whole grains	1 turkey sandwich on whole-wheat roll	272
1½ tsp oils	1½ tbs low-fat mayonnaise	71
1 c vegetables	1 c vegetable juice	50
	Snack	
½ oz whole grains	4 whole-wheat reduced-fat crackers	86
1 c milk	1½ oz low-fat cheddar cheese	74
½ c fruit	1 medium apple	72
	Dinner	
½ c vegetables	1 c raw spinach leaves	8
¼ c vegetables	¼ c shredded carrots	11
1 oz meats	¼ c garbanzo beans	71
2 tsp oils	2 tbs oil-based salad dressing and olives	76
¾ c vegetables, 2½ oz meat, 2 oz enriched grains	Spaghetti with meat and tomato sauce	425
½ c vegetables	½ c green beans	22
2 tsp oils	2 tsp soft margarine	67
1 c fruit	1 c strawberries	49
	Snack	
½ oz whole grains	3 graham crackers	90
1 c milk	1 c fat-free milk	100

© Cengage Learning 2013

As you can see, we all make countless food-related decisions daily—whether we have a plan or not. Following an eating pattern, such as the USDA Food Patterns, that incorporates health recommendations and diet-planning principles helps a person make wise nutrition decisions.

From Guidelines to Groceries Dietary recommendations emphasize nutrient-rich foods such as whole grains, fruits, vegetables, lean meats, poultry, seafood, and low-fat milk products. You can design such a diet for yourself, but how do you begin? Start with the foods you regularly enjoy eating and then try to make a few improvements.[16] For most people that will mean eating less red meat, cheeses, and salted snacks and more fruits, vegetables, whole grains, legumes, nuts, milk products, and seafood. Such small changes can dramatically improve the diet. When shopping, think of the food groups, and choose nutrient-dense foods within each group.

Be aware that many of the tens of thousands of food options available today are **processed foods** that have lost valuable nutrients and gained sugar, fat, and salt as they were transformed from farm-fresh foods to those found in the bags, boxes, and cans that line grocery-store shelves. Their value in the diet depends on the original food and how it was prepared or processed. By eating more fresh foods and fewer processed foods, consumers can reduce their intakes of added sugars, solid fats, and sodium for relatively little effort. Sometimes processed foods have been **fortified** to improve their nutrient contents, which can be helpful in increasing dietary intake of specific vitamins and minerals.

Grains When shopping for grain products, you will find them described as *refined, enriched,* or *whole grain*. These terms refer to the milling process and the making of grain products, and they have different nutrition implications (see Figure 2-6, p. 50). **Refined** grains have lost many nutrients during processing; **enriched** grains have had some nutrients added back; and **whole-grain** products have all the nutrients and fiber found in the original grain. As such, whole-grain products support good health and should account for at least half of the grains daily. Adding more whole grains to the diet can be as easy as eating oatmeal for breakfast and popcorn for a snack or substituting brown rice for white rice and whole-wheat bread for enriched white bread. To find whole-grain products, read food labels and select those that name a whole-grain ♦ first in the ingredient list. Products described as "multi-grain," "stone-ground," or "100% wheat" are usually *not* whole-grain products. Brown color is also not a useful hint, but fiber content often is.

When it became a common practice to refine the wheat flour used for bread by milling it and throwing away the bran and the germ, consumers suffered a tragic loss of many nutrients. As a consequence, in the early 1940s Congress passed legislation requiring that all grain products that cross state lines be enriched with iron, thiamin, riboflavin, and niacin. In 1996 this legislation was amended to include folate, a vitamin considered essential in the prevention of some birth defects. Most grain products that have been refined, such as rice, pastas such as macaroni and spaghetti, and cereals (both cooked and ready-to-eat types), have subsequently been enriched. ♦ Food labels must specify that products have been enriched and include the enrichment nutrients in the ingredients list.

♦ Examples of whole grains:

- Amaranth
- Barley
- Buckwheat
- Bulgur
- Corn (and popcorn)
- Millet
- Oats (and oatmeal)
- Quinoa
- Rice (brown or wild)
- Whole rye
- Whole wheat

♦ Grain enrichment nutrients:

- Iron
- Thiamin
- Riboflavin
- Niacin
- Folate

processed foods: foods that have been treated to change their physical, chemical, microbiological, or sensory properties.

fortified: the addition to a food of nutrients that were either not originally present or present in insignificant amounts. Fortification can be used to correct or prevent a widespread nutrient deficiency or to balance the total nutrient profile of a food.

refined: the process by which the coarse parts of a food are removed. When wheat is refined into flour, the bran, germ, and husk are removed, leaving only the endosperm.

enriched: the addition to a food of specific nutrients to replace losses that occur during processing so that the food will meet a specified standard.

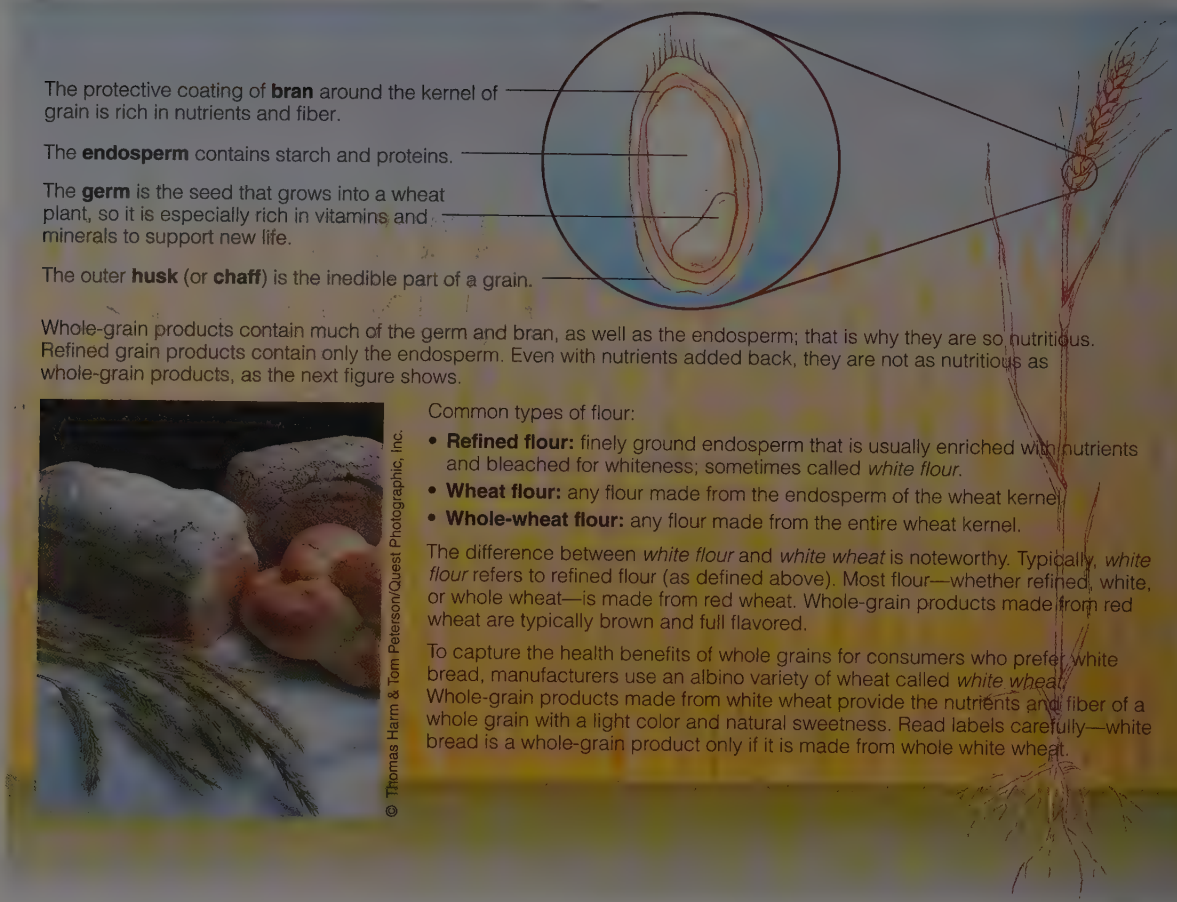
whole grain: a grain that maintains the same relative proportions of starchy endosperm, germ, and bran as the original (all but the husk); not refined.



When shopping for bread, look for the descriptive words *whole grain* or *whole wheat* and check the fiber content on the Nutrition Facts panel of the label—the more fiber, the more likely the bread is a whole-grain product.

© Roman Barnes Photo Research

> **FIGURE 2-6 A Wheat Plant**



Whole-grain products contain much of the germ and bran, as well as the endosperm; that is why they are so nutritious. Refined grain products contain only the endosperm. Even with nutrients added back, they are not as nutritious as whole-grain products, as the next figure shows.

© Thomas Harm & Tom Peterson/Quest Photographic, Inc.

Common types of flour:

- **Refined flour:** finely ground endosperm that is usually enriched with nutrients and bleached for whiteness; sometimes called *white flour.*
- **Wheat flour:** any flour made from the endosperm of the wheat kernel.
- **Whole-wheat flour:** any flour made from the entire wheat kernel.

The difference between *white flour* and *white wheat* is noteworthy. Typically, *white flour* refers to refined flour (as defined above). Most flour—whether refined, white, or whole wheat—is made from red wheat. Whole-grain products made from red wheat are typically brown and full flavored.

To capture the health benefits of whole grains for consumers who prefer white bread, manufacturers use an albino variety of wheat called *white wheat.* Whole-grain products made from white wheat provide the nutrients and fiber of a whole grain with a light color and natural sweetness. Read labels carefully—white bread is a whole-grain product only if it is made from whole white wheat.

© Cengage Learning 2013

Enrichment doesn't make a slice of bread rich in these added nutrients, but people who eat several slices a day obtain significantly more of these nutrients than they would from unenriched bread. Even though the enrichment of flour helps to prevent deficiencies of these nutrients, it fails to compensate for losses of many other nutrients and fiber. As Figure 2-7 (p. 51) shows, whole-grain items deliver many more nutrients than the enriched ones. Only *whole-grain* flour contains all of the nutritive portions of the grain. Whole-grain products, such as brown rice and oatmeal, provide more nutrients and fiber and contain less salt, sugar, and fat than refined grain products. This helps to explain why diet quality tends to be better for consumers who eat more whole grains.[17]



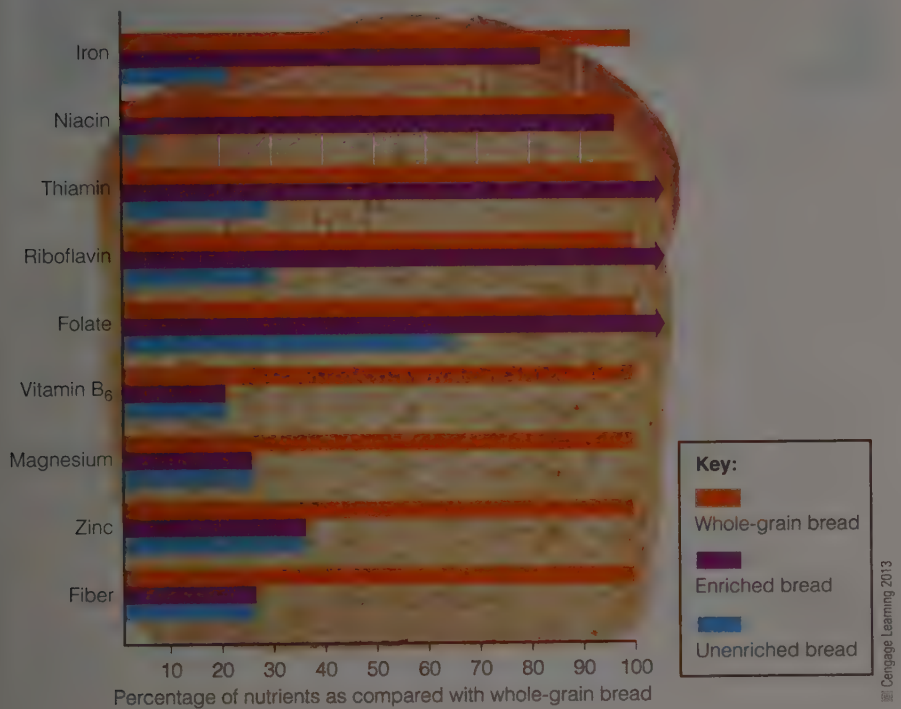
> DIETARY GUIDELINES FOR AMERICANS 2010

Increase whole-grain intake. Consume at least half of all grains as whole grains. Whenever possible, replace refined grains with whole grains.

Speaking of processed foods, ready-to-eat breakfast cereals are the most highly fortified foods on the market. Like an enriched food, a *fortified* food has had nutrients added during processing, but in a fortified food, the added nutrients may not have been present in the original product. (The terms *fortified* and *enriched* may be used interchangeably.[18]) Some breakfast cereals made from refined flour and fortified with high doses of vitamins and minerals are actually more like dietary supplements disguised as cereals than they are like whole grains. They may be nutritious—with respect to the nutrients added—but they still may fail to convey the full spectrum of nutrients that a whole-grain food or a mixture of

> FIGURE 2-7 Nutrients in Bread

Whole-grain bread is more nutritious than other breads, even enriched bread. For iron, thiamin, riboflavin, niacin, and folate, enriched bread provides about the same quantities as whole-grain bread and significantly more than unenriched bread. For fiber and the other nutrients (those shown here as well as those not shown), enriched bread provides less than whole-grain bread.



© Cengage Learning 2013

such foods might provide. Still, fortified foods help people meet their vitamin and mineral needs.[19]

Vegetables Posters in the produce section of grocery stores encourage consumers to "think variety, think color." Such efforts are part of a national educational campaign to increase fruit and vegetable consumption.

Choose fresh vegetables often, especially dark-green leafy and red and orange vegetables such as spinach, broccoli, tomatoes, and sweet potatoes. Cooked or raw, vegetables are good sources of vitamins, minerals, and fiber. Frozen and canned vegetables without added salt are acceptable alternatives to fresh. To control fat, energy, and sodium intakes, limit butter and salt on vegetables.

Choose often from the variety of legumes available. ♦ They are an economical, low-fat, nutrient- and fiber-rich food choice. Combining legumes with foods from other food groups creates delicious meals.

♦ Legumes include a variety of beans and peas:

- Adzuki beans
- Black beans
- Black-eyed peas
- Fava beans
- Garbanzo beans
- Great northern beans
- Kidney beans
- Lentils
- Lima beans
- Navy beans
- Peanuts
- Pinto beans
- Soybeans
- Split peas



> DIETARY GUIDELINES FOR AMERICANS 2010

Increase vegetable intake. Eat recommended amounts of vegetables and include a variety of vegetables, especially dark-green vegetables, red and orange vegetables, and legumes.

Fruit Choose fresh fruits often. Frozen, dried, and canned fruits without added sugar are acceptable alternatives to fresh. Fruits supply valuable vitamins, minerals, fibers, and



© iStockphoto.com/Kelly Cline

Consumers can remember to eat a variety of fruits and vegetables every day by selecting from each of five colors.



© PhotoDisc/Getty Images

Add rice to red beans for a hearty meal.



© Felicia Martinez, Photo Edit

Enjoy a Greek salad topped with garbanzo beans for a little ethnic diversity.



© Michael Newman/PhotoEdit

A bit of meat and lots of spices turn kidney beans into chili con carne.

phytochemicals. They add flavors, colors, and textures to meals, and their natural sweetness makes them enjoyable as snacks or desserts.

Fruit juices are healthy beverages but contain little dietary fiber compared with whole fruits. Whole fruits satisfy the appetite better than juices, thereby helping people to limit food energy intakes. For people who need extra food energy, though, 100 percent fruit juices are a good choice. Be aware that sweetened fruit "drinks" or "ades" contain mostly water, sugar, and a little juice for flavor. Some may have been fortified with vitamin C or calcium but lack any other significant nutritional value.



> DIETARY GUIDELINES FOR AMERICANS 2010

Increase fruit intake. Eat recommended amounts of fruits and choose a variety of fruits. Choose whole or cut-up fruits more often than fruit juice.

Protein Foods Protein foods include seafood, meats, poultry, eggs, legumes, soy products, nuts, and seeds. In addition to protein, these foods provide B vitamins, vitamin E, iron, zinc, and magnesium. To buy and prepare these foods without adding excess energy, fat, and sodium takes a little knowledge and planning.

When shopping in the meat department, choose lean cuts of beef and pork named "round" or "loin" (as in top round or pork tenderloin). As a guide, "prime" and "choice" cuts generally have more fat than "select" cuts. Restaurants usually serve prime cuts. Ground beef, even "lean" ground beef, derives most of its food energy from fat. Have the butcher trim and grind a lean round steak instead. Alternatively, soy products such as **textured vegetable protein** can be used instead of ground beef in a casserole, spaghetti sauce, or chili, saving fat kcalories. Because nuts and seeds are energy dense, they need to be consumed in small quantities and in place of—not in addition to—other protein foods. To lower sodium intake, choose unsalted nuts and seeds.

Serving sizes for meats, poultry, and seafood reflect weight after cooking and without bones. In general, 4 ounces of raw meat is equal to about 3 ounces of cooked meat. Some examples of 3-ounce portions include 1 medium pork chop, ½ chicken breast, or 1 steak or fish filet about the size of a deck of cards. To keep fat intake moderate, bake, roast, broil, grill, or braise meats, poultry, and seafood (but do not fry them in fat); remove the skin from poultry after cooking; trim visible fat before cooking; and drain fat after cooking. Chapter 5 offers many additional strategies for moderating fat intake.



> DIETARY GUIDELINES FOR AMERICANS 2010

Choose a variety of protein foods, which include seafood, lean meats and poultry, eggs, legumes, soy products, and unsalted nuts and seeds. Increase the amount and variety of seafood consumed by choosing seafood in place of some meat and poultry.

textured vegetable protein: processed soybean protein used in vegetarian products such as soy burgers.

Milk and Milk Products Shoppers find a variety of fortified foods in the dairy case. Examples are milk, to which vitamins A and D have been added, and soy milk, to which calcium, vitamin D, and vitamin B_{12} have been added. Be aware that not all soy beverages have been fortified. Read labels carefully.

In addition, shoppers may find **imitation foods** (such as cheese products), **food substitutes** (such as egg substitutes), and functional foods (such as margarine with added plant sterols). As food technology advances, many such foods offer alternatives to traditional choices that may help people reduce their saturated fat and cholesterol intakes. Chapter 5 provides other examples.

When shopping, choose fat-free ♦ or low-fat milk, yogurt, and cheeses. Such selections help consumers meet their vitamin and mineral needs within their energy and fat allowances. Milk products are important sources of calcium but can provide too much sodium and fat if not selected with care.

♦ Milk descriptions:
- Fat-free milk = nonfat, skim, zero-fat, or no-fat
- Low-fat milk = 1% milk
- Reduced-fat milk = 2% milk or less-fat



> DIETARY GUIDELINES FOR AMERICANS 2010

Increase intake of fat-free or low-fat milk and milk products—such as milk, yogurt, cheese, or fortified soy milk—and replace whole milk products with fat-free or low-fat options.

REVIEW IT Use the USDA Food Patterns to develop a meal plan within a specified energy allowance.

Food group plans such as the USDA Food Patterns help consumers select the types and amounts of foods to provide adequacy, balance, and variety in the diet. They make it easier to plan a diet that includes a balance of grains, vegetables, fruits, protein foods, and milk and milk products. In making any food choice, remember to view the food in the context of the total diet. The combination of many different foods provides the array of nutrients that is so essential to a healthy diet.

2.3 Food Labels

LEARN IT Compare and contrast the information on food labels to make selections that meet specific dietary and health goals.

Many consumers, especially those interested in preventing chronic diseases, read food labels to help them make healthy choices.[20] Food labels appear on virtually all packaged foods, and posters or brochures provide similar nutrition information for fresh meats, fruits, and vegetables (see Figure 2-8, p. 54). A few foods need not carry nutrition labels: those contributing few nutrients, such as plain coffee, tea, and spices; those produced by small businesses; and those prepared and sold in the same establishment. Producers of some of these items, however, voluntarily use food labels. Even markets selling nonpackaged items voluntarily present nutrient information, either in brochures or on signs posted at the point of purchase.

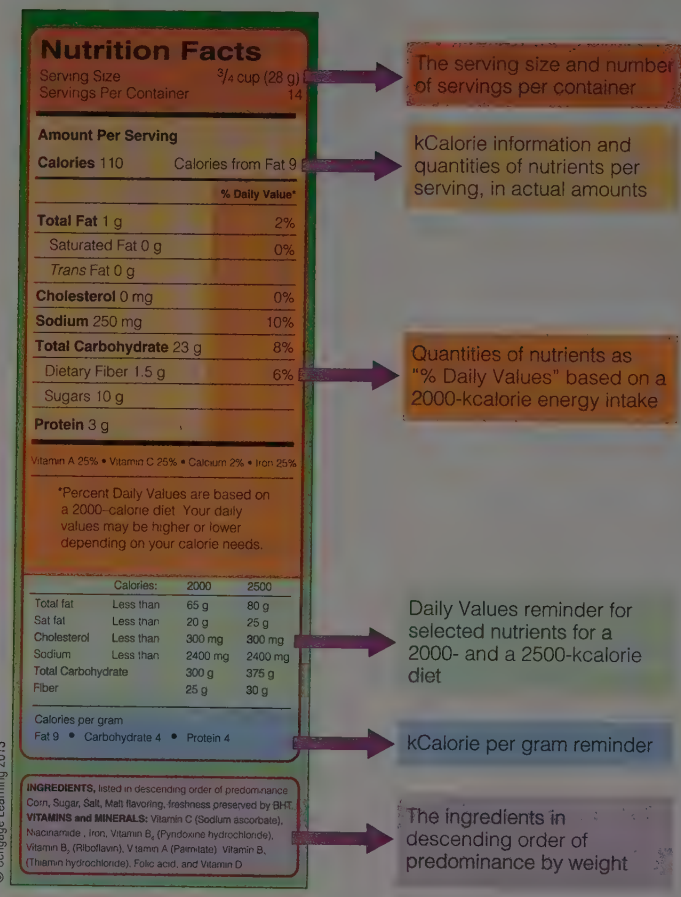
Restaurants with 20 or more locations must provide menu listings of an item's kcalories, grams of saturated fat, and milligrams of sodium.[21] Other restaurants need not supply nutrition information for menu items unless claims such as "low-fat" or "heart healthy" have been made. When ordering such items, keep in mind that restaurants tend to serve extra-large portions—two to three times standard serving sizes. A "low-fat" ice cream, for example, may have only 3 grams of fat per ½ cup, but you may be served 2 cups for a total of 12 grams of fat and all their accompanying kcalories.

The Ingredient List *All* packaged foods must list *all* ingredients—including additives used to preserve or enhance foods, such as vitamins and minerals added to enrich or fortify products. The ingredients are listed on the label in descending order of predominance by weight. Knowing that the first ingredient predominates

imitation foods: foods that substitute for and resemble another food, but are nutritionally inferior to it with respect to vitamin, mineral, or protein content. If the substitute is not inferior to the food it resembles and if its name provides an accurate description of the product, it need not be labeled "imitation."

food substitutes: foods that are designed to replace other foods.

> **FIGURE 2-8** Example of a Food Label



© Cengage Learning 2013

by weight, consumers can glean much information. Compare these products, for example:

- A beverage powder that contains "sugar, citric acid, natural flavors . . ." versus a juice that contains "water, tomato concentrate, concentrated juices of carrots, celery . . ."
- A cereal that contains "puffed milled corn, sugar, corn syrup, molasses, salt . . ." versus one that contains "100 percent rolled oats"
- A canned fruit that contains "sugar, apples, water" versus one that contains simply "apples, water"

In each of these comparisons, consumers can see that the second product is more nutrient dense.

Nutrition Facts Panel The FDA requires labels to include key nutrition facts. The Nutrition Facts panel provides such information as serving sizes, nutrient quantities, and Daily Values.

Serving Sizes Because labels present nutrient information based on one serving, they must identify the size of the serving. The Food and Drug Administration (FDA) has established specific serving sizes for various foods and requires that all labels for a given product use the same serving size. For example, the standard serving size for all ice creams is ½ cup and for all beverages it is 8 fluid ounces. This facilitates comparison shopping. Consumers can see at a glance which brand has more or fewer kcalories or grams of fat, for example. Standard serving sizes are expressed in both common household measures, ♦ such as cups, and metric measures, such as milliliters, to accommodate users of both types of measures.

♦ Household and metric measures:
- 1 teaspoon (tsp) = 5 milliliters (mL)
- 1 tablespoon (tbs) = 15 mL
- 1 cup (c) = 240 mL
- 1 fluid ounce (fl oz) = 30 mL
- 1 ounce (oz) = 28 grams (g)

When examining the nutrition facts on a food label, consumers need to compare the serving size on the label with how much they actually eat and adjust their calculations accordingly. For example, if the serving size is four cookies and you eat only two, then you need to cut the nutrient and kcalorie values in half; similarly, if you eat eight cookies, then you need to double the values. Notice, too, that small bags or individually wrapped items, such as chips or candy bars, may contain more than a single serving. The total number of servings per container is listed just below the serving size.

Be aware that serving sizes on food labels are not always the same as those of the USDA Food Patterns. For example, a serving of rice on a food label is 1 cup, whereas in the USDA Food Patterns it is ½ cup. Unfortunately, this discrepancy, coupled with each person's own perception (oftentimes misperception) of standard serving sizes, sometimes creates confusion for consumers trying to follow recommendations.

Nutrient Quantities In addition to the serving size and the servings per container, the FDA requires that the Nutrition Facts panel on food labels present nutrient information in two ways—in quantities (such as grams) and as percentages of standards called the **Daily Values.** The Nutrition Facts panel must provide the nutrient amount, **percent Daily Value,** or both for the following:

- Total food energy (kcalories)
- Food energy from fat (kcalories)
- Total fat (grams and percent Daily Value)
- Saturated fat (grams and percent Daily Value)

Daily Values (DV): reference values developed by the FDA specifically for use on food labels.

percent Daily Value (%DV): the percentage of a Daily Value recommendation found in a specified serving of food for key nutrients based on a 2000-kcalorie diet.

- *Trans* fat (grams)
- Cholesterol (milligrams and percent Daily Value)
- Sodium (milligrams and percent Daily Value)
- Total carbohydrate, which includes starch, sugar, and fiber (grams and percent Daily Value)
- Dietary fiber (grams and percent Daily Value)
- Sugars, which includes both those naturally present in and those added to the food (grams)
- Protein (grams)

The labels must also present nutrient content information as a percent Daily Value for the following vitamins and minerals:

- Vitamin A
- Vitamin C
- Iron
- Calcium



© Daniel Grill/Jupiterimages

Consumers read food labels to learn about the nutrient contents of a food or to compare similar foods.

The Daily Values Table 2-8 presents the Daily Value standards for nutrients that are required to provide this information. Food labels list the amount of some nutrients in a product as a percentage of its Daily Value, which makes the numbers more meaningful to consumers. A person reading a food label might wonder, for example, whether 1 milligram of iron or calcium is a little or a lot. As Table 2-8 shows, the Daily Value for iron is 18 milligrams, so 1 milligram of iron is enough to notice—it is more than 5 percent, and that is what the food label will say. But because the Daily Value for calcium on food labels is 1000 milligrams, 1 milligram of calcium is insignificant, and the food label will read "0%."

The Daily Values reflect dietary recommendations for nutrients and dietary components that have important relationships with health. For example, for heart health, consumers are advised to limit saturated fat to 10 percent of energy intake. For a 2000-kcalorie diet, 10 percent is 200 kcalories, or 22 grams of fat. (Remember that fats deliver 9 kcalories per gram.) As Table 2-8 shows, the Daily Value for saturated fat has been rounded down to 20 grams.

The "% Daily Value" column on a label provides a ballpark estimate of how individual foods contribute to the total diet. It compares key nutrients in a serving of food with the goals of a person consuming 2000 kcalories per day. A 2000-kcalorie diet is considered about right for sedentary younger women, active older women, and sedentary older men. Young children and sedentary older women may need fewer kcalories. Most labels list, at the bottom, Daily Values for both a 2000-kcalorie and a 2500-kcalorie diet, but the "% Daily Value" column on all labels applies only to a 2000-kcalorie diet. A 2500-kcalorie diet is considered about right for many men, teenage boys, and active younger women. People who are exceptionally active may have still higher energy needs. Labels may also provide a reminder of the kcalories in a gram of carbohydrate, fat, and protein just below the Daily Value information (review Figure 2-8).

People who consume 2000 kcalories a day can simply add up all of the "% Daily Values" for a particular nutrient to see if their diet for the day fits recommendations. People who require more or less than 2000 kcalories daily must do some calculations to see how foods compare with their personal nutrition goals. Those interested can use the Calculation Factors column in Table 2-8 or the suggestions presented in the "How To" feature on p. 56.

TABLE 2-8 Daily Values for Food Labels

Food labels must present the "% Daily Value" for these nutrients.

Food Component	Daily Value	Calculation Factors
Fat	65 g	30% of kcalories
Saturated fat	20 g	10% of kcalories
Cholesterol	300 mg	—
Carbohydrate (total)	300 g	60% of kcalories
Fiber	25 g	11.5 g per 1000 kcalories
Protein	50 g	10% of kcalories
Sodium	2400 mg	—
Potassium	3500 mg	—
Vitamin C	60 mg	—
Vitamin A	1500 µg	—
Calcium	1000 mg	—
Iron	18 mg	—

NOTE: Daily Values were established for adults and children more than 4 years old. The values for energy-yielding nutrients are based on 2000 kcalories a day. For fiber, the Daily Value was rounded up from 23.

© Cengage Learning 2013

>How To

Calculate Personal Daily Values

The Daily Values on food labels are designed for a 2000-kcalorie intake, but you can calculate a personal set of Daily Values based on your energy allowance. Consider a 1500-kcalorie intake, for example. To calculate a daily goal for fat, multiply energy intake by 30 percent:

1500 kcal × 0.30 kcal from fat
= 450 kcal from fat

The "kcalories from fat" are listed on food labels, so you can add all the "kcalories from fat" values for a day, using 450 as an upper limit. A person who prefers to count grams of fat can divide this 450 kcalories from fat by 9 kcalories per gram to determine the goal in grams:

450 kcal from fat ÷ 9 kcal/g = 50 g fat

Alternatively, a person can calculate that 1500 kcalories is 75 percent of the 2000-kcalorie intake used for Daily Values:

1500 kcal ÷ 2000 kcal = 0.75
0.75 × 100 = 75%

Then, instead of trying to achieve 100 percent of the Daily Value, a person consuming 1500 kcalories will aim for 75 percent. Similarly, a person consuming 2800 kcalories would aim for 140 percent:

2800 kcal ÷ 2000 kcal = 1.40 or 140%

Table 2-8 includes a calculation column that can help you estimate your personal daily value for several nutrients.

TRY IT Calculate the Daily Values for a 1800-kcalorie diet and revise the Daily Value percentages on the cereal label found on p. 54.

♦ % Daily Values:
- ≥20% = high or excellent source
- 10–19% = good source
- < 5% = low source

Daily Values help consumers readily see whether a food contributes "a little" or "a lot" of a nutrient. ♦ For example, the "% Daily Value" column on a package of frozen macaroni and cheese may say 20 percent for fat. This tells the consumer that each serving of this food contains about 20 percent of the day's allotted 65 grams of fat. Be aware that for some nutrients (such as fat and sodium) you will want to select foods with a low "% Daily Value" and for others (such as calcium and fiber) you will want a high "% Daily Value." To determine whether a particular food is a wise choice, a consumer needs to consider its place in the diet among all the other foods eaten during the day.

Daily Values also make it easy to compare foods. For example, a consumer might discover that frozen macaroni and cheese has a Daily Value for fat of 20 percent, whereas macaroni and cheese prepared from a boxed mix has a Daily Value of 15 percent. By comparing labels, consumers who are concerned about their fat intakes can make informed decisions.

Claims on Labels In addition to the Nutrition Facts panel, consumers may find various claims on labels. These claims include nutrient claims, health claims, and structure-function claims.

Nutrient Claims Have you noticed phrases such as "good source of fiber" on a box of cereal or "rich in calcium" on a package of cheese? These and other **nutrient claims** may be used on labels so long as they meet FDA definitions, which include the conditions under which each term can be used. For example, in addition to having less than 2 milligrams of cholesterol, a "cholesterol-free" product may not contain more than 2 grams of saturated fat and *trans* fat combined per serving. The accompanying glossary defines nutrient terms on food labels, including criteria for foods described as "low," "reduced," and "free." When nutrients have been added to enriched or fortified products, they must appear in the ingredients list.

nutrient claims: statements that characterize the quantity of a nutrient in a food.

Some descriptions *imply* that a food contains, or does not contain, a nutrient. Implied claims are prohibited unless they meet specified criteria. For example, a claim that a product "contains no oil" *implies* that the food contains no fat. If the product is truly fat-free, then it may make the no-oil claim, but if it contains another source of fat, such as butter, it may not.

Health Claims **Health claims** describe a relationship between a food (or food component) and a disease or health-related condition. In some cases, the FDA authorizes health claims based on an extensive review of the scientific literature.[22] For example, the health claim that "Diets low in sodium may reduce the risk of high blood pressure" is based on enough scientific evidence to establish a clear link between diet and health. In cases where there is emerging—but not established—evidence for a relationship between a food or food component and disease, the FDA allows the use of *qualified* health claims that must use specific language indicating that the evidence supporting the claim is limited. A qualified health claim might claim that "Very limited and preliminary research suggests that eating one-half to one cup of tomatoes and/or tomato sauce a week may reduce the risk of prostate cancer. The FDA concludes that there is little scientific evidence supporting the claim."

Structure-Function Claims Unlike health claims, which require food manufacturers to collect scientific evidence and petition the FDA, **structure-function claims** can be made without any FDA approval. Product labels can claim to "slow aging," "improve memory," and "build strong bones" without any proof. The only

health claims: statements that characterize the relationship between a nutrient or other substance in a food and a disease or health-related condition.

structure-function claims: statements that characterize the relationship between a nutrient or other substance in a food and its role in the body.

GLOSSARY OF TERMS ON FOOD LABELS

GENERAL TERMS

free: "nutritionally trivial" and unlikely to have a physiological consequence; synonyms include *without, no,* and *zero.* A food that does not contain a nutrient naturally may make such a claim, but only as it applies to all similar foods (for example, "applesauce, a fat-free food").

good source of: the product provides between 10 and 19 percent of the Daily Value for a given nutrient per serving.

healthy: a food that is low in fat, saturated fat, cholesterol, and sodium and that contains at least 10 percent of the Daily Values for vitamin A, vitamin C, iron, calcium, protein, or fiber.

high: 20 percent or more of the Daily Value for a given nutrient per serving; synonyms include *rich in* or *excellent source.*

less: at least 25 percent less of a given nutrient or kcalories than the comparison food (see individual nutrients); synonyms include *fewer* and *reduced.*

light or **lite:** one-third fewer kcalories than the comparison food; 50 percent or less of the fat or sodium than the comparison food; any use of the term other than as defined must specify what it is referring to (for example, "light in color" or "light in texture").

low: an amount that would allow frequent consumption of a food without exceeding the Daily Value for the nutrient. A food that is naturally low in a nutrient may make such a claim, but only as it applies to all similar foods (for example, "fresh cauliflower, a low-sodium food"); synonyms include *little, few,* and *low source of.*

more: at least 10 percent more of the Daily Value for a given nutrient than the comparison food; synonyms include *added* and *extra.*

organic: on food labels, that at least 95 percent of the product's ingredients have been grown and processed according to USDA regulations defining the use of fertilizers, herbicides, insecticides, fungicides, preservatives, and other chemical ingredients (see Chapter 19).

ENERGY

kcalorie-free: fewer than 5 kcalories per serving.

low kcalorie: 40 kcalories or less per serving.

reduced kcalorie: at least 25 percent fewer kcalories per serving than the comparison food.

FAT AND CHOLESTEROL*

percent fat-free: may be used only if the product meets the definition of *low fat* or *fat-free* and must reflect the amount of fat in 100 grams (for example, a food that contains 2.5 grams of fat per 50 grams can claim to be "95 percent fat-free").

fat-free: less than 0.5 gram of fat per serving (and no added fat or oil); synonyms include *zero-fat, no-fat,* and *nonfat.*

low fat: 3 grams or less fat per serving.

less fat: 25 percent or less fat than the comparison food.

saturated fat-free: less than 0.5 gram of saturated fat and 0.5 gram of *trans* fat per serving.

low saturated fat: 1 gram or less saturated fat and less than 0.5 gram of *trans* fat per serving.

less saturated fat: 25 percent or less saturated fat and *trans* fat combined than the comparison food.

***trans* fat-free:** less than 0.5 gram of *trans* fat and less than 0.5 gram of saturated fat per serving.

cholesterol-free: less than 2 milligrams cholesterol per serving and 2 grams or less saturated fat and *trans* fat combined per serving.

low cholesterol: 20 milligrams or less cholesterol per serving and 2 grams or less saturated fat and *trans* fat combined per serving.

less cholesterol: 25 percent or less cholesterol than the comparison food (reflecting a reduction of at least 20 milligrams per serving), and 2 grams or less saturated fat and *trans* fat combined per serving.

extra lean: less than 5 grams of fat, 2 grams of saturated fat and *trans* fat combined, and 95 milligrams of cholesterol per serving and per 100 grams of meat, poultry, and seafood.

lean: less than 10 grams of fat, 4.5 grams of saturated fat and *trans* fat combined, and 95 milligrams of cholesterol per serving and per 100 grams of meat, poultry, and seafood. For mixed dishes such as burritos and sandwiches, less than 8 grams of fat, 3.5 grams of saturated fat, and 80 milligrams of cholesterol per reference amount customarily consumed.

CARBOHYDRATES: FIBER AND SUGAR

high fiber: 5 grams or more of fiber per serving. A high-fiber claim made on a food that contains more than 3 grams of fat per serving and per 100 grams of food must also declare total fat.

sugar-free: less than 0.5 gram of sugar per serving.

SODIUM

sodium-free and salt-free: less than 5 milligrams of sodium per serving.

low sodium: 140 milligrams or less per serving.

very low sodium: 35 milligrams or less per serving.

*Foods containing more than 13 grams total fat per serving or per 50 grams of food must indicate those contents immediately after a cholesterol claim. As you can see, all cholesterol claims are prohibited when the food contains more than 2 grams saturated fat and *trans* fat combined per serving.

> FIGURE 2-9 **Label Claims**

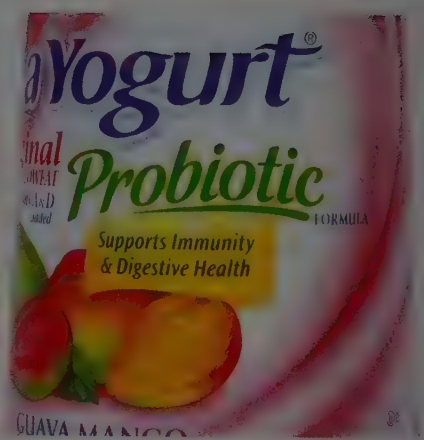


© Sam Kolich/Bill Smith Group/Cengage Learning

Nutrient claims characterize the level of a nutrient in the food—for example, "fat free" or "less sodium."



Health claims characterize the relationship of a food or food component to a disease or health-related condition—for example, "soluble fiber from oatmeal daily in a diet low in saturated fat and cholesterol may reduce the risk of heart disease" or "a diet low in total fat may reduce the risk of some cancers."



Structure/function claims describe the effect that a substance has on the structure or function of the body and do not make reference to a disease—for example, "supports immunity and digestive health" or "calcium builds strong bones."

criterion for a structure-function claim is that it must not mention a disease or symptom. Unfortunately, structure-function claims can be deceptively similar to health claims, and most consumers do not distinguish between these two types of claims. Consider these statements:

- "May reduce the risk of heart disease"
- "Promotes a healthy heart"

The first is a health claim that requires FDA approval and the second is an unproven, but legal, structure-function claim. Figure 2-9 compares label claims.

Consumer Education Food labels are a primary source of information for consumers trying to make healthy diet choices, but label messages are often confusing.[23] Because labels are valuable only if people know how to use them, the FDA has designed several programs to educate consumers. Consumers who understand how to read labels are best able to apply the information to achieve and maintain healthful dietary practices. Table 2-9 shows how the messages from the *Dietary Guidelines*, the USDA Food Patterns, and food labels coordinate with one another.

REVIEW IT Compare and contrast the information on food labels to make selections that meet specific dietary and health goals.

Food labels provide consumers with information they need to select foods that will help them meet their nutrition and health goals. When labels contain relevant information presented in a standardized, easy-to-read format, consumers are well prepared to plan and create healthful diets.

This chapter provides the links to go from dietary guidelines to buying groceries and offers helpful tips for selecting nutritious foods. For additional information on foods, including organic foods, irradiated foods, genetically modified foods, and more, turn to Chapter 19.

TABLE 2-9 From Guidelines to Groceries

Dietary Guidelines	USDA Food Patterns/MyPlate	Food Labels
Balancing kcalories to manage weight	Enjoy your food, but eat less. Select the recommended amounts from each food group at the energy level appropriate for your energy needs; meet, but do not exceed, energy needs. Limit foods and beverages with solid fats and added sugars. Use appropriate portion sizes; avoid oversized portions. Increase physical activity and reduce time spent in sedentary behaviors.	Read the Nutrition Facts to see how many kcalories are in a serving and the number of servings that are in a package. Look for foods that describe their kcalorie contents as *free, low, reduced, light*, or *less*.
Foods and food components to reduce	Choose foods within each group that are low in salt or sodium. Choose foods within each group that are lean, low fat, or fat free and have little solid fat (sources of saturated and *trans* fats); use unsaturated oils instead of solid fats whenever possible. Choose foods and beverages within each group that have little added sugars; drink water instead of sugary beverages. If alcohol is consumed by adults, use in moderation (no more than one drink a day for women and two drinks a day for men).	Read the Nutrition Facts to see how much sodium, saturated fat, *trans* fat, and cholesterol is in a serving of food. Look for foods that describe their salt and sodium contents as *free, low*, or *reduced*; foods that describe their fat, saturated fat, *trans* fat, and cholesterol contents as *free, less, low, light, reduced, lean*, or *extra lean*; foods that describe their sugar contents as *free* or *reduced*. Look for foods that provide no more than 5 percent of the Daily Value for sodium, fat, saturated fat, and cholesterol. A food may be high in solid fats if its ingredients list begins with or contains several of the following: *beef fat (tallow, suet), butter, chicken fat, coconut oil, cream, hydrogenated oils, palm kernel oil, palm oil, partially hydrogenated oils, pork fat (lard), shortening*, or *stick margarine*. A food most likely contains *trans* fats if its ingredients list includes: *partially hydrogenated oils*. A food may be high in added sugars if its ingredients list begins with or contains several of the following: *brown sugar, confectioner's powdered sugar, corn syrup, dextrin, fructose, high-fructose corn syrup, honey, invert sugar, lactose, malt syrup, maltose, molasses, nectars, sucrose, sugar*, or *syrup*. Light beverages contain fewer kcalories and less alcohol than regular versions.
Foods and nutrients to increase	Make half your plate fruits and vegetables. Choose a variety of vegetables from all five subgroups (dark green, red and orange, legumes, starchy vegetables, and other vegetables) several times a week. Choose a variety of fruits; consume whole or cut-up fruits more often than fruit juice. Choose potassium-rich foods such as fruits and vegetables often. Choose fiber-rich fruits, vegetables, and whole grains often. Choose whole grains; make at least half of the grain selections whole grains by replacing refined grains with whole grains whenever possible. Choose fat-free or low-fat milk and milk products. Choose a variety of protein foods; increase the amount and variety of seafood by choosing seafood in place of some meat and poultry.	Look for foods that describe their fiber, calcium, potassium, and vitamin D contents as *good, high*, or *excellent*. Look for foods that provide at least 10 percent of the Daily Value for fiber, calcium, potassium, and vitamin D from a variety of sources. A food may be a good source of whole grains if its ingredients list begins with or contains several of the following: *barley, brown rice, buckwheat, bulgur, corn, millet, oatmeal, popcorn, quinoa, rolled oats, rye, sorghum, triticale, whole wheat*, or *wild rice*.
Building healthy eating patterns	Select nutrient-dense foods and beverages within and among the food groups. Keep food safe.	Look for foods that describe their vitamin, mineral, or fiber contents as a *good source* or *high*. Follow the *safe handling instructions* on packages of meat and other safety instructions, such as *keep refrigerated*, on packages of perishable foods.

© Cengage Learning 2013

Nutrition Portfolio

The secret to making healthy food choices is learning to incorporate the *Dietary Guidelines for Americans* and the USDA Food Patterns into your decision-making process.

Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Choose the MyPlate Report and, looking at it, record in your journal the answers to the following:

- How do the foods you consumed on the day you have chosen stack up with the daily goals (the percentages) in the MyPlate breakdown? Which food groups are over- or under-represented?
- Think about your choices within each food group for the day you recorded. Are they typical of the foods you choose from day to day? Are there simple and realistic ways to enhance the variety in your diet?
- Write yourself a letter describing the dietary changes you can make to improve your chances of enjoying good health.

Diet Analysis PLUS

To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. Position of the American Dietetic Association: Total diet approach to communicating food and nutrition information, *Journal of the American Dietetic Association* 107 (2007): 1224–1232.
2. Practice paper of the American Dietetic Association: Nutrient density: Meeting nutrient goals within calorie needs, *Journal of the American Dietetic Association* 107 (2007): 860–869.
3. G. D. Miller and coauthors, It is time for a positive approach to dietary guidance using nutrient density as a basic principle, *Journal of Nutrition* 139 (2009): 1198–1202.
4. A. Drewnowski and V. Fulgoni III, Nutrient profiling of foods: Creating a nutrient-rich food index, *Nutrition Reviews* 66 (2008): 23–39.
5. The science behind current nutrition profiling systems to promote consumer intake of nutrient-dense foods, *American Journal of Clinical Nutrition* 91 (2010): entire supplement; N. Darmon and coauthors, Nutrient profiles discriminate between foods according to their contribution to nutritionally adequate diets: A validation study using linear programming and the SAIN, LIM system, *American Journal of Clinical Nutrition* 89 (2009): 1227–1236; E. Kennedy, Food rating systems, diet quality, and health, *Nutrition Reviews* 66 (2008): 21–22.
6. D. Mozaffarian and D. S. Ludwig, Dietary Guidelines in the 21st century: A time for food, *Journal of the American Medical Association* 304 (2010): 681–682.
7. *L. V. Horn, Development of the 2010 US Dietary Guidelines Advisory Committee Report: Perspectives from a registered dietitian, *Journal of the American Dietetic Association* 110 (2010): 1638–1645.
8. US Department of Health and Human Services, *2008 Physical Activity Guidelines for Americans*, www.health.gov/paguidelines; US Department of Agriculture and US Department of Health and Human Services, *Dietary Guidelines for Americans, 2010*, www.dietaryguidelines.gov.
9. www.choosemyplate.gov/food-groups/vegetables-beans-peas.html, accessed February 15, 2012.
10. Position of the American Dietetic Association: Vegetarian diets, *Journal of the American Dietetic Association* 109 (2009): 1266–1282.
11. J. L. Bachman and coauthors, Sources of food group intakes among the US population, 2001–2002, *Journal of the American Dietetic Association* 108 (2008): 804–814.
12. P. M. Guenther, J. Reedy, and S. M. Krebs-Smith, Development of the Healthy Eating Index—2005, *Journal of the American Dietetic Association* 108 (2008): 1896–1901; Center for Nutrition Policy and Promotion, Healthy Eating Index—2005, fact sheet revised June 2008, www.cnpp.usda.gov.
13. Center for Nutrition Policy and Promotion, Diet quality of Americans in 1994–1996 and 2001–02 as measured by the Healthy Eating Index—2005, nutrition insight 37 revised August 2008, www.cnpp.usda.gov.
14. S. M. Krebs-Smith, J. Reedy, and C. Bosire, Healthfulness of the US food supply: Little improvement despite decades of dietary guidance, *American Journal of Preventive Medicine* 38 (2010): 472–477.
15. Harvard School of Public Health, *The Nutrition Source: Healthy Eating Plate vs. USDA's MyPlate*, www.hsph.harvard.edu, accessed October 4, 2011.
16. M. Maillot and coauthors, Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices, *American Journal of Clinical Nutrition* 91 (2010): 421–430.
17. C. E. O'Neil and coauthors, Whole-grain consumption is associated with diet quality and nutrient intake in adults: The National Health and Nutrition Examination Survey, 1999–2004, *Journal of the American Dietetic Association* 110 (2010): 1461–1468.
18. As cited in 21 Code of Federal Regulations—Food and Drugs, Section 104.20, 45 *Federal Register* 6323, January 25, 1980, as amended in 58 *Federal Register* 2228, January 6, 1993.
19. Position of the American Dietetic Association: Fortification and nutritional supplements, *Journal of the American Dietetic Association* 105 (2005): 1300–1311.
20. J. E. Lewis and coauthors, Food label use and awareness of nutritional information and recommendations among persons with chronic disease, *American Journal of Clinical Nutrition* 90 (2009):1351–1357; C. L. Taylor and

V. L. Wilkening, How the nutrition food label was developed, part 1: The nutrition facts panel, *Journal of the American Dietetic Association* 108 (2008): 437–442.

21. L. Marr, National restaurant menu labeling legislation: Public nutrition education and professional opportunities, *Journal of the American Dietetic Association* 111 (2011): S7; K. Stein, A national approach to restaurant menu labeling: The Patient Protection and Affordable Health Care Act, section 4205, *Journal of the American Dietetic Association* 110 (2010): 1280–1286.
22. C. L. Taylor and V. L. Wilkening, How the nutrition food label was developed, part 2: The purpose and promise of nutrition claims, *Journal of the American Dietetic Association* 108 (2008): 618–623.
23. N. J. Ollberding, R. L. Wolf, and I. Contento, Food label use and its relation to dietary intake among US adults, *Journal of the American Dietetic Association* 111 (2011): S47–S51; J. M. Wills and coauthors, Exploring global consumer attitudes toward nutrition information on food labels, *Nutrition Reviews* 67 (2009): S102–S106.

Vegetarian Diets


© Polara Studios, Inc.

The waiter presents this evening's specials: a fresh spinach salad topped with mandarin oranges, raisins, and sunflower seeds, served with a bowl of pasta smothered in a mushroom and tomato sauce and topped with grated parmesan cheese. Then this one: a salad made of chopped parsley, scallions, celery, and tomatoes mixed with bulgur wheat and dressed with olive oil and lemon juice, served with a spinach and feta cheese pie. Do these meals sound good to you? Or is something missing . . . a pork chop or chicken breast, perhaps?

Would vegetarian fare be acceptable to you some of the time? Most of the time? Ever? The health benefits of a primarily vegetarian diet seem to have encouraged many people to eat more plant-based meals. The popular press sometimes refers to individuals who eat small amounts of meat, seafood, or poultry from time to time as "flexitarians."

People who choose to exclude meat and other animal-derived foods from their diets today do so for many of the same reasons the Greek philosopher Pythagoras cited in the sixth century B.C.: physical health, ecological responsibility, and philosophical concerns. They might also cite world hunger issues, economic reasons, ethical concerns, or religious beliefs as motivating factors. Whatever their reasons—and even if they don't have a particular reason—people who exclude meat will be better prepared to plan well-balanced meals if they understand the nutrition and health implications of their choices.

Vegetarians generally are categorized, not by their motivations but by the foods they choose to exclude (see the accompanying glossary). Some people exclude red meat only; some also exclude poultry or seafood; others also exclude eggs; and still others exclude milk and milk products as well. In fact, finding agreement on the definition of the term *vegetarian* is a challenge.

As you will see, though, the foods a person *excludes* are not nearly as important as the foods a person *includes* in the diet. Vegetarian diets that include a variety of whole grains, vegetables, legumes, fruits, and nuts and seeds offer abundant complex carbohydrates and fibers, an assortment of vitamins and minerals, a mixture of phytochemicals, and little fat—characteristics that reflect current dietary recommendations aimed at maintaining good health and an appropriate body weight. Each of these foods—whole grains, vegetables, legumes, fruits, and nuts and seeds—independently reduces the risk for several chronic diseases. This highlight examines the health benefits and potential problems of vegetarian diets and shows how to plan a well-balanced vegetarian diet. Highlight 20 includes a discussion of the environmental benefits of a plant-based diet.[1]

Health Benefits of Vegetarian Diets

Research findings suggest that well-planned vegetarian diets offer sound nutrition and health benefits to adults.[2] Eating patterns that include very little, if any, meat may even increase life expectancy.

Obesity

Vegetarians tend to maintain a lower and healthier body weight than nonvegetarians. In general, those who eat meat have higher energy intakes and body weights.[3] Vegetarians' lower body weights correlate with their high intakes of fiber and low intakes of fat. Because obesity impairs health in a number of ways, this gives vegetarians a health advantage.

GLOSSARY

lactovegetarians: people who include milk and milk products, but exclude meat, poultry, seafood, and eggs from their diets.
- **lacto** = milk

lacto-ovo-vegetarians: people who include milk, milk products, and eggs, but exclude meat, poultry, and seafood from their diets.
- **ovo** = egg

macrobiotic diet: a philosophical approach of eating mostly plant-based foods such as whole grains, legumes, and vegetables, with small amounts of fish, fruits, nuts, and seeds.
- **macro** = large, great
- **biotic** = life

meat replacements: products formulated to look and taste like meat, seafood, or poultry; usually made of textured vegetable protein.

omnivorous: an eating pattern that includes foods derived from both animals and plants.
- **omni** = all
- **vores** = to eat

tempeh (TEM-pay): a fermented-soybean food, rich in protein and fiber.

plant-based diets: an eating pattern that derives most of its protein from plant products (although some animal products may be included).

tofu (TOE-foo): a curd made from soybeans, rich in protein and often fortified with calcium; used in many Asian and vegetarian dishes in place of meat.

vegans (VEE-gans): people who exclude all animal-derived foods (including meat, poultry, fish, eggs, and dairy products); also called *pure vegetarians, strict vegetarians,* or *total vegetarians.*

vegetarians: a general term used to describe people who exclude meat, poultry, fish, or other animal-derived foods from their diets.

Diabetes

Obesity and weight gains are strong risk factors for diabetes, which partially explains why **omnivorous** diets are more often associated with diabetes than vegetarian diets.[4] Even when body weight and lifestyle factors are taken into account, vegetarian eating patterns seem to protect against diabetes.[5]

Hypertension

Vegetarians tend to have lower blood pressure and lower rates of hypertension than nonvegetarians. Appropriate body weight helps to maintain a healthy blood pressure, as does a diet low in total fat and saturated fat and high in fiber, fruits, vegetables, and soy protein. Lifestyle factors also influence blood pressure: smoking and alcohol intake raise blood pressure, and physical activity lowers it.

Heart Disease

The incidence of heart disease and related deaths and the concentrations of blood cholesterol are lower for vegetarians than for nonvegetarians, which can partly be explained by their avoidance of meat.[6] The dietary factor most directly related to heart disease is saturated animal fat, and in general, vegetarian diets are lower in total fat, saturated fat, and cholesterol than typical meat-based diets. The fats common in **plant-based diets**—the monounsaturated fats of olives, seeds, and nuts and the polyunsaturated fats of vegetable oils—are associated with a decreased risk of heart disease. Furthermore, vegetarian diets are generally higher in dietary fiber, antioxidant vitamins, and phytochemicals—all factors that help control blood lipids and protect against heart disease.

Many vegetarians include soy products such as **tofu** in their diets. Soy products—with their polyunsaturated fats, fibers, vitamins, and minerals, and little saturated fat—may help to protect against heart disease.[7]

Cancer

Vegetarians have a lower rate of some cancers than the general population. Their low cancer rates may be due to their high intakes of fruits and vegetables (as Highlight 11 explains). In fact, the ratio of vegetables to meat may be the most relevant dietary factor responsible for cancer prevention.

Some scientific findings indicate that vegetarian diets are associated not only with lower cancer mortality in general, but also with lower incidence of cancer at specific sites as well, most notably, colon cancer. People with colon cancer seem to eat more meat. Some cancer experts recommend limiting "consumption of red meat to no more than 11 ounces a week, with very little (if any) processed meat."[8]

Other Diseases

In addition to obesity, diabetes, hypertension, heart disease, and some cancers, vegetarian diets may help prevent osteoporosis, diverticular disease, gallstones, cataracts, and rheumatoid arthritis. Health benefits of a vegetarian diet depend on wise diet planning.

Vegetarian Diet Planning

The vegetarian has the same meal-planning task as everyone else—using a variety of foods to deliver all the needed nutrients within an energy allowance that maintains a healthy body weight (as discussed in Chapter 2). Vegetarians who include milk, milk products, and eggs can meet recommendations for most nutrients about as easily as nonvegetarians. Such eating patterns may rely on some fortified foods, but generally provide enough energy, protein, and other nutrients to support the health of adults and the growth of children and adolescents. The USDA Food Patterns for vegetarians are flexible enough that a variety of people can use it: people who have adopted various vegetarian diets, those who want to make the transition to a vegetarian diet, and those who simply want to include more plant-based meals in their diets.

Vegans who exclude milk, milk products, and eggs can select protein foods such as legumes, nuts, and seeds as well as foods made from them, such as peanut butter, **tempeh**, and tofu. Those who do not use milk can use soy "milk"—a product made from soybeans that provides similar nutrients if fortified with calcium, vitamin D, and vitamin B_{12} (see Figure H2-1). Similarly, "milks" made from rice, almonds, and oats are reasonable alternatives, if adequately fortified. Vegan eating patterns must include fortified foods or supplements to provide adequate intakes of all essential nutrients.

MyPlate includes tips for planning vegetarian diets using an adaptation of the USDA Food Patterns. The recommended daily amounts

> FIGURE H2-1 Low-Fat Milk and Soy Milk Compared

A comparison of low-fat milk and enriched soy milk shows that they provide similar amounts of key nutrients.

Low-Fat Milk

Nutrition Facts

Serving Size 1 cup (240mL)
Servings Per Container About 8

Amount Per Serving	
Calories 110	Calories from Fat 25
	% Daily Value*
Total Fat 2.5g	4%
Saturated Fat 1.5g	8%
Trans Fat 0g	
Polyunsaturated Fat 0.5g	
Monounsaturated Fat 0.5g	
Cholesterol 15mg	4%
Sodium 130mg	5%
Potassium 380mg	11%
Total Carbohydrate 13g	4%
Dietary Fiber 0g	0%
Sugars 12g	
Protein 8g	
Vitamin A 10% • Vitamin C 0%	
Calcium 30% • Iron 0%	
Vitamin D 25%	

Soy Milk

Nutrition Facts

Serving Size 1 cup (240mL)
Servings Per Container About 8

Amount Per Serving	
Calories 100	Calories from Fat 35
	% Daily Value*
Total Fat 4g	6%
Saturated Fat 0.5g	3%
Trans Fat 0g	
Polyunsaturated Fat 2.5g	
Monounsaturated Fat 1g	
Cholesterol 0mg	0%
Sodium 120mg	5%
Potassium 300mg	8%
Total Carbohydrate 8g	3%
Dietary Fiber 1g	4%
Sugars 6g	
Protein 7g	
Vitamin A 10% • Vitamin C 0%	
Calcium 30% • Iron 6%	
Vitamin D 30% • Riboflavin 30%	
Folate 6% • Vitamin B12 50%	

© Cengage Learning 2013

TABLE H2-1 USDA Food Patterns: Recommended Weekly Amounts of Protein Foods for Vegetarians and Vegans

The daily amounts for protein foods is the same for both vegetarians and nonvegetarians, but the subgroups and weekly amounts for protein foods differ. The recommended daily amounts from each of the other food groups—fruits, vegetables, grains, and milk products—is the same (see Table 2-2).

Protein Foods	1600 kcal	1800 kcal	2000 kcal	2200 kcal	2400 kcal	2600 kcal	2800 kcal	3000 kcal
Daily Amounts	5 oz	5 oz	5½ oz	6 oz	6½ oz	6½ oz	7 oz	7 oz
Vegetarian Subgroups								
Eggs	4 oz	4 oz	4 oz	4 oz	5 oz	5 oz	5 oz	5 oz
Legumes	9 oz	9 oz	10 oz	10 oz	11 oz	11 oz	12 oz	12 oz
Soy products	11 oz	11 oz	12 oz	13 oz	14 oz	14 oz	15 oz	15 oz
Nuts and seeds	12 oz	12 oz	13 oz	15 oz	16 oz	16 oz	17 oz	17 oz
Vegan Subgroups								
Legumes	12 oz	12 oz	13 oz	15 oz	16 oz	16 oz	17 oz	17 oz
Soy products	9 oz	9 oz	10 oz	11 oz	11 oz	11 oz	12 oz	12 oz
Nuts and seeds	14 oz	14 oz	15 oz	17 oz	18 oz	18 oz	20 oz	20 oz

NOTE: Total recommended amounts for legumes include the sum of both the vegetables and protein foods. An ounce-equivalent of legumes in the protein foods group is ¼ cup. For a 2000-kcal vegan diet, that's 3¼ cups legumes for protein foods plus 1½ cups legumes for vegetables (see Table 2-4), or about almost 5 cups legumes weekly.

© Cengage Learning 2013

from the food groups is the same for both vegetarians and nonvegetarians (see Table 2-2 on p. 44). Selections from within the food groups may differ, of course. For example, the milk group features fortified soy milks for those who do not use milk, cheese, or yogurt. When selecting from the vegetable and fruit groups, vegetarians may want to emphasize particularly good sources of calcium and iron. Green leafy vegetables provide almost five times as much calcium per serving as other vegetables. Similarly, dried fruits deserve special notice in the fruit group because they deliver six times as much iron as other fruits. The protein foods group includes eggs (for those who use them), legumes, soy products, and nuts and seeds. Table H2-1 provides recommended *weekly* amounts of protein food subgroups for both vegetarians and vegans. The use of vegetable oils rich in unsaturated fats provides essential omega-3 fatty acids.

Most vegetarians easily obtain large quantities of the nutrients that are abundant in plant foods, including carbohydrate, fiber, thiamin, folate, vitamin B_6, vitamin C, vitamin A, and vitamin E. Well-planned vegetarian eating patterns help to ensure adequate intakes of the nutrients vegetarian diets might otherwise lack, including protein, iron, zinc, calcium, vitamin B_{12}, vitamin D, and omega-3 fatty acids. Table H2-2 presents good vegetarian sources of these key nutrients.

Protein

The protein RDA for vegetarians is the same as for others, although some have suggested that it should be higher because plant proteins are not digested as completely. **Lacto-ovo-vegetarians**, who use animal-derived foods such as milk and eggs, receive high-quality proteins and are likely to meet their protein needs. Even those who adopt only plant-based diets are likely to meet protein needs provided that their energy intakes are adequate and the protein sources varied.[9] The proteins of whole grains, vegetables, legumes, and nuts and seeds can provide adequate amounts of all the amino acids. An advantage of many vegetarian sources of protein is that they are generally lower in saturated fat than meats and are often higher in fiber and richer in some vitamins and minerals.

Vegetarians sometimes use **meat replacements** made of textured vegetable protein (soy protein). These foods are formulated to look and taste like meat, seafood, or poultry. Many of these products are fortified to provide the vitamins and minerals found in animal sources of protein. Some may be high in salt, sugars, and saturated fats. A wise vegetarian learns to read labels and use a variety of whole, unrefined foods often and commercially prepared foods less frequently. Vegetarians may also use soy products such as tofu to bolster protein intake.

Iron

Getting enough iron can be a problem even for meat eaters, and those who eat no meat must pay special attention to their iron intake. The iron in plant foods such as legumes, dark-green leafy vegetables, iron-fortified cereals, and whole-grain breads and cereals is poorly absorbed. Because iron absorption from a vegetarian diet is low, the iron RDA for vegetarians is higher than for others (see Chapter 13 for more details).

Fortunately, the body seems to adapt to a low-iron vegetarian diet by increasing iron absorption and decreasing iron losses. Furthermore, iron absorption is enhanced by vitamin C, and vegetarians typically eat many vitamin C–rich fruits and vegetables. Consequently, vegetarians are no more iron deficient than other people.

Zinc

Zinc is similar to iron in that meat is its richest food source, and zinc from plant sources is not well absorbed. In addition, phytates, fiber, and calcium, which are common in vegetarian diets, interfere with zinc absorption. Nevertheless, most vegetarian adults are not zinc

TABLE H2-2 Good Vegetarian Sources of Key Nutrients

Nutrients	Grains	Vegetables	Fruits	Protein Foods	Milk	Oils
Protein	Whole grains[a]			Legumes, seeds, nuts, soy products (tempeh, tofu, veggie burgers)[a] Eggs (for ovo-vegetarians)	Milk, cheese, yogurt (for lactovegetarians)	
Iron	Fortified cereals, enriched and whole grains	Dark green leafy vegetables (spinach, turnip greens)	Dried fruits (apricots, prunes, raisins)	Legumes (black-eyed peas, kidney beans, lentils)		
Zinc	Fortified cereals, whole grains			Legumes (garbanzo beans, kidney beans, navy beans), nuts, seeds (pumpkin seeds)	Milk, cheese, yogurt (for lactovegetarians)	
Calcium	Fortified cereals	Dark green leafy vegetables (bok choy, broccoli, collard greens, kale, mustard greens, turnip greens, watercress)	Fortified juices, figs	Fortified soy products, nuts (almonds), seeds (sesame seeds)	Milk, cheese, yogurt (for lactovegetarians) Fortified soy milk	
Vitamin B_{12}	Fortified cereals			Eggs (for ovo-vegetarians) Fortified soy products	Milk, cheese, yogurt (for lactovegetarians) Fortified soy milk	
Vitamin D					Milk, cheese, yogurt (for lactovegetarians) Fortified soy milk	
Omega-3 fatty acids				Flaxseed, walnuts, soybeans		Flaxseed oil, walnut oil, soybean oil

© Cengage Learning 2013

[a]As Chapter 6 explains, many plant proteins do not contain all the essential amino acids in the amounts and proportions needed by human beings. To improve protein quality, vegetarians can eat grains and legumes together, for example, although it is not necessary if protein intake is varied and energy intake is sufficient.

deficient. Perhaps the best advice to vegetarians regarding zinc is to eat a variety of nutrient-dense foods; include whole grains, nuts, and legumes such as black-eyed peas, pinto beans, and kidney beans; and maintain an adequate energy intake. For those who include seafood in their diets, oysters, crabmeat, and shrimp are rich in zinc.

Calcium

The calcium intakes of **lactovegetarians** are similar to those of the general population, but vegans who use no milk or milk products may risk inadequate intakes. To ensure adequate intakes, vegans can select calcium-rich foods, such as calcium-fortified juices, soy milk, and breakfast cereals, in ample quantities regularly. This advice is especially important for children and adolescents. Soy formulas for infants are fortified with calcium and can be used in cooking, even for adults. Other good calcium sources include figs, some legumes, some green vegetables such as broccoli and turnip greens, some nuts such as almonds, certain seeds such as sesame seeds, and calcium-set tofu.* The choices should be varied because calcium absorption from some plant foods may be limited (as Chapter 12 explains).

*Calcium salts are often added during processing to coagulate the tofu.

Vitamin B_{12}

The requirement for vitamin B_{12} is small, but this vitamin is found only in animal-derived foods. Consequently, vegetarians, in general, and vegans who eat no foods of animal original, in particular, may not get enough vitamin B_{12} in their diets.[10] Fermented soy products such as tempeh may contain some vitamin B_{12} from the bacteria, but unfortunately, much of the vitamin B_{12} found in these products may be an inactive form. Seaweeds such as nori and chlorella supply some vitamin B_{12}, but not much, and excessive intakes of these foods can lead to iodine toxicity. To defend against vitamin B_{12} deficiency, vegans must rely on vitamin B_{12}-fortified sources (such as soy milk or breakfast cereals) or supplements. Without vitamin B_{12}, the nerves suffer damage, leading to such health consequences as loss of vision.

Vitamin D

The vitamin D status of vegetarians is similar to that of nonvegetarians.[11] People who do not use vitamin D–fortified foods and do not receive enough exposure to sunlight to synthesize adequate vitamin D may need supplements to defend against bone loss. This is particularly

important for infants, children, and older adults. In northern climates during winter months, young children on vegan diets can readily develop rickets, the vitamin D–deficiency disease.

Omega-3 Fatty Acids

Both Chapter 5 and Highlight 5 describe the health benefits of unsaturated fats, most notably the omega-3 fatty acids commonly found in fatty fish. A diet that includes some meat, fish, and eggs provides much more omega-3 fatty acids than a vegetarian diet, but the *blood* differences between those eating fish and others is relatively small.[12] Researchers speculate that the smaller-than-expected differences may reflect a more efficient conversion of plant-derived fats to omega-3 fats in non–fish eaters. Vegetarians can obtain sufficient amounts of omega-3 fatty acids from plant sources such as flaxseed, walnuts, soy, and canola oil.[13]

Healthy Food Choices

Later chapters provide details on how vegetarian diets can meet nutrient needs for various stages of the life cycle, including pregnancy, lactation, infancy, childhood, and adolescence. In general, well-planned vegetarian eating patterns may lower the risk of mortality and several chronic diseases, including obesity, diabetes, high blood pressure, heart disease, and some cancers.[14] But there is nothing mysterious or magical about a vegetarian eating pattern. The quality of the diet depends not on whether it includes meat but on whether the other food choices are nutritionally sound. A plant-based eating pattern that includes ample fruits, vegetables, whole grains, legumes, nuts, and seeds is higher in fiber, antioxidant vitamins, and phytochemicals and lower in saturated fats and cholesterol than meat-based diets. Variety is key to nutritional adequacy in a vegetarian diet. Restrictive plans that limit selections to a few grains and vegetables cannot possibly deliver a full array of nutrients.

Vegetarianism is not a religion like Buddhism or Hinduism, but merely an eating pattern that selects plant foods to deliver needed nutrients. That said, some vegetarians choose to follow a **macrobiotic diet.** Those following a macrobiotic diet select natural, organic foods and embrace a Zen-like spirituality. In other words, a macrobiotic diet represents a way of life, not just a meal plan. A macrobiotic diet emphasizes whole grains, legumes, and vegetables, with small amounts of fish, fruits, nuts, and seeds. Practices include selecting locally grown foods, eating foods in their most natural state, and balancing cold, sweet, and passive foods with hot, salty, and aggressive ones. Some items, such as processed foods, alcohol, hot spices, and potatoes are excluded from the diet. Early versions of the macrobiotic diet followed a progression that ended with the "ultimate" diet of brown rice and water—a less-than nutritiously balanced diet. Today's version reflects a modified vegetarian approach with an appreciation of how foods can enhance health. With careful planning, a macrobiotic diet can provide an array of nutrients that support good health.

If not properly balanced, any diet—vegetarian, macrobiotic, or otherwise—can lack nutrients. Poorly planned vegetarian diets typically lack iron, zinc, calcium, vitamin B_{12}, and vitamin D; without planning, meat-based diets may lack vitamin A, vitamin C, folate, and fiber, among others. Quite simply, the negative health aspects of any diet, including vegetarian diets, reflect poor diet planning. Careful attention to energy intake and specific nutrients of concern can ensure adequacy.

Keep in mind, too, that diet is only one factor influencing health. Whatever a diet consists of, its context is also important: no smoking, alcohol consumption in moderation (if at all), regular physical activity, adequate rest, and medical attention when needed all contribute to good health. Establishing these healthy habits early in life seems to be the most important step one can take to reduce the risks of chronic diseases later in life (as Highlight 16 explains).

REFERENCES

1. B. M. Popkin, Reducing meat consumption has multiple benefits for the world's health, *Archives of Internal Medicine* 169 (2009): 543–545.
2. D. R. Jacobs and coauthors, Food, plant food, and vegetarian diets in the US dietary guidelines: Conclusions of an expert panel, *American Journal of Clinical Nutrition* 89 (2009): 1549S–1552S; S. E. Berkow and N. Barnard, Vegetarian diets and weight status, *Nutrition Review* 64 (2006): 175–188; T. J. Key, P. N. Appleby, and M. S. Rosell, Health effects of vegetarian and vegan diets, *Proceedings of the Nutrition Society* 65 (2006): 35–41; Position of the American Dietetic Association: Vegetarian diets, *Journal of the American Dietetic Association* 109 (2009): 1266–1282.
3. Y. Wang and M. A. Beydoun, Meat consumption is associated with obesity and central obesity among US adults, *International Journal of Obesity* 33 (2009): 621-628; S. Tonstad and coauthors, Type of vegetarian diet, body weight, and prevalence of type 2 diabetes, *Diabetes Care* 32 (2009): 791–796.
4. A. Vang and coauthors, Meats, processed meats, obesity, weight gain and occurrence of diabetes among adults: Findings from Adventist Health Studies, *Annals of Nutrition and Metabolism* 52 (2008): 96–104.
5. S. Tonstad and coauthors, Type of vegetarian diet, body weight, and prevalence of type 2 diabetes, *Diabetes Care* 32 (2009): 791–796.
6. H. R. Ferdowsian and N. D. Barnard, Effects of plant-based diets on plasma lipids, *American Journal of Cardiology* 104 (2009): 947–956.
7. M. Messina, Insights gained from 20 years of soy research, *Journal of Nutrition* 140 (2010): 2289S–2295S.
8. World Cancer Research Fund/American Institute for Cancer Research, *Policy and Action for Cancer Prevention. Food, Nutrition, and Physical Activity: A Global Perspective* (Washington, D.C.: AICR, 2009), p. 26.
9. Position of the American Dietetic Association, 2009.
10. I. Elmadfa and I. Singer, Vitamin B-12 and homocysteine status among vegetarians: A global perspective, *American Journal of Clinical Nutrition* 89 (2009): 1693S–1698S.
11. J. Chan, K. Jaceldo-Siegl, and Gary E. Fraser, Serum 25-hydroxyvitamin D status of vegetarians, partial vegetarians, and nonvegetarians: The Adventist Health Study, *American Journal of Clinical Nutrition* 89 (2009): 1686S–1692S.
12. A. A. Welch and coauthors, Dietary intake and status of n-3 polyunsaturated fatty acids in a population of fish-eating and

non-fish-eating meat-eaters, vegetarians, and vegans and the precursor-product ratio of α-linolenic acid to long-chain n-3 polyunsaturated fatty acids: Results from the EPIC-Norfolk cohort, *American Journal of Clinical Nutrition* 92 (2010): 1040–1051.

13. I. Mangat, Do vegetarians have to eat fish for optimal cardiovascular protection? *American Journal of Clinical Nutrition* 89 (2009): 1597S–1601S.

14. W. J. Craig, Nutrition concerns and health effects of vegetarian diets, *Nutrition in Clinical Practice* 25 (2010): 613–620; G. E. Fraser, Vegetarian diets: What do we know of their effects on common chronic diseases? *American Journal of Clinical Nutrition* 89 (2009): 1607S–1612S.



CENGAGE LEARNING'S NUTRITION GLOBAL NUTRITION RESOURCE CENTER

Probiotics offer a wide array of digestive benefits, but some studies suggest the benefits may go beyond the GI tract. Go to Nutrition Basics and Tools → Probiotics to learn more about the ways probiotics support good health.

3 Digestion, Absorption, and Transport

LEARNING GPS

3.1 Digestion 69

LEARN IT Explain how foods move through the digestive system, describing the actions of the organs, muscles, and digestive secretions along the way.

- Anatomy of the Digestive Tract 70
- The Muscular Action of Digestion 72
- The Secretions of Digestion 73
- The Final Stage 75

3.2 Absorption 77

LEARN IT Describe the anatomical details of the intestinal cells that facilitate nutrient absorption.

- Anatomy of the Absorptive System 77
- A Closer Look at the Intestinal Cells 79

3.3 The Circulatory Systems 80

LEARN IT Explain how nutrients are routed in the circulatory systems from the GI tract into the body and identify which nutrients enter the blood directly and which must first enter the lymph.

- The Vascular System 80
- The Lymphatic System 82

3.4 The Health and Regulation of the GI Tract 82

LEARN IT Describe how bacteria, hormones, and nerves influence the health and activities of the GI tract

- Gastrointestinal Bacteria 82
- Gastrointestinal Hormones and Nerve Pathways 83
- The System at Its Best 85

Highlight 3 Common Digestive Problems 88

LEARN IT Outline strategies to prevent or alleviate common GI problems.

Nutrition in Your Life

Have you ever wondered what happens to the food you eat after you swallow it? Or how your body extracts nutrients from food? Have you ever marveled at how it all just seems to happen? Follow foods as they travel through the digestive system. Learn how a healthy digestive system takes whatever food you give it—whether sirloin steak and potatoes or tofu and brussels sprouts—and extracts the nutrients that will nourish the cells of your body. In the Nutrition Portfolio at the end of the chapter, you can determine whether your current eating habits are supporting a healthy digestive system.

This chapter follows the journey that breaks down foods into the nutrients featured in the later chapters. Then it follows the nutrients as they travel through the intestinal cells and into the body to do their work. This introduction presents a general overview of the processes common to all nutrients; later chapters discuss the specifics of digesting and absorbing individual nutrients.

3.1 Digestion

LEARN IT Explain how foods move through the digestive system, describing the actions of the organs, muscles, and digestive secretions along the way.

Digestion is the body's ingenious way of breaking down foods into nutrients in preparation for **absorption.** In the process, the body overcomes many challenges without any conscious effort. Consider these challenges:

1. Human beings breathe, eat, and drink through their mouths. Air taken in through the mouth must go to the lungs; food and liquid must go to the stomach. The throat must be arranged so that swallowing and breathing don't interfere with each other.
2. Below the lungs lies the diaphragm, a dome of muscle that separates the upper half of the major body cavity from the lower half. The body needs a

digestion: the process by which food is broken down into absorbable units.

- **digest** = take apart

absorption: the uptake of nutrients by the cells of the small intestine for transport into either the blood or the lymph.

- **absorb** = suck in



© Morgan Lane Photography/Shutterstock.com

The process of digestion breaks down all kinds of *foods* into *nutrients*.

passageway that will allow food from the mouth to pass through the diaphragm to reach the stomach below.

3. The contents of the digestive tract should be kept moving forward, slowly but steadily, at a pace that permits all reactions to reach completion.
4. To move through the system, food must be lubricated with fluids. Too much would form a liquid that would flow too rapidly; too little would form a paste too dry and compact to move at all. The amount of fluids must be regulated to keep the intestinal contents at the right consistency to move along smoothly.
5. For digestive enzymes to work, foods must be broken down into small particles and suspended in enough liquid so that every particle is accessible. Once digestion is complete and nutrients have been absorbed from the GI tract into the body, the remaining waste must be excreted. Excreting all the water along with the solid residue, however, would be both wasteful and messy. Some water must be withdrawn, leaving a solid waste product that is easy to pass.
6. The digestive enzymes are designed to digest carbohydrate, fat, and protein. The cells of the GI tract are also made of carbohydrate, fat, and protein. These cells must be protected against the powerful digestive juices that they secrete.
7. Once waste matter has reached the end of the GI tract, it must be excreted, but it would be inconvenient and embarrassing if this function occurred continuously. Evacuation needs to occur periodically.

The following sections show how the body elegantly and efficiently handles these challenges. Each section follows the GI tract from one end to the other—first describing its anatomy, then its muscular actions, and finally its secretions.

Anatomy of the Digestive Tract

The **gastrointestinal (GI) tract** is a flexible muscular tube that extends from the mouth, through the esophagus, stomach, small intestine, large intestine, and rectum to the anus. Figure 3-1 traces the path followed by food from one end to the other. In a sense, the human body surrounds the GI tract. The inner space within the GI tract, called the **lumen,** is continuous from one end to the other. (GI anatomy terms appear in boldface type and are defined in the accompanying glossary.) Only when a nutrient or other substance finally penetrates the GI tract's wall does it enter the body proper; many materials pass through the GI tract without being digested or absorbed.

gastrointestinal (GI) tract: the digestive tract. The principal organs are the stomach and intestines.

- **gastro** = stomach
- **intestinalis** = intestine

GLOSSARY OF GI ANATOMY TERMS

anus (AY-nus): the terminal outlet of the GI tract.

appendix: a narrow blind sac extending from the beginning of the colon that contains bacteria and lymph cells.

duodenum (doo-oh-DEEN-um, doo-ODD-num): the top portion of the small intestine (about "12 fingers' breadth" long in ancient terminology).

- **duodecim** = twelve

epiglottis (epp-ih-GLOTT-iss): cartilage in the throat that guards the entrance to the trachea and prevents fluid or food from entering it when a person swallows.

- **epi** = upon (over)
- **glottis** = back of tongue

esophageal (ee -SOF-ah-GEE-al) **sphincter:** a sphincter muscle at the upper or lower end of the esophagus. The *lower esophageal sphincter* is also called the *cardiac sphincter* because of its proximity to the heart.

esophagus (ee-SOFF-ah-gus): the food pipe; the conduit from the mouth to the stomach.

gallbladder: the organ that stores and concentrates bile. When it receives the signal that fat is present in the duodenum, the gallbladder contracts and squirts bile through the bile duct into the duodenum.

ileocecal (ill-ee-oh-SEEK-ul) **valve:** the sphincter separating the small and large intestines.

ileum (ILL-ee-um): the last segment of the small intestine.

jejunum (je-JOON-um): the first two-fifths of the small intestine beyond the duodenum.

large intestine or colon (COAL-un): the lower portion of intestine that completes the digestive process. Its segments are the *ascending colon*, the *transverse colon*, the *descending colon*, and the *sigmoid colon*.

- **sigmoid** = shaped like the letter S (sigma in Greek)

lumen (LOO-men): the space within a vessel, such as the intestine.

mouth: the oral cavity containing the tongue and teeth.

pancreas: a gland that secretes digestive enzymes and juices into the duodenum. (The pancreas also secretes hormones into the blood that help to maintain glucose homeostasis.)

pharynx (FAIR-inks): the passageway leading from the nose and mouth to the larynx and esophagus, respectively.

pyloric (pie-LORE-ic) **sphincter:** the circular muscle that separates the stomach from the small intestine and regulates the flow of partially digested food into the small intestine; also called *pylorus* or *pyloric valve*.

- **pylorus** = gatekeeper

rectum: the muscular terminal part of the intestine, extending from the sigmoid colon to the anus.

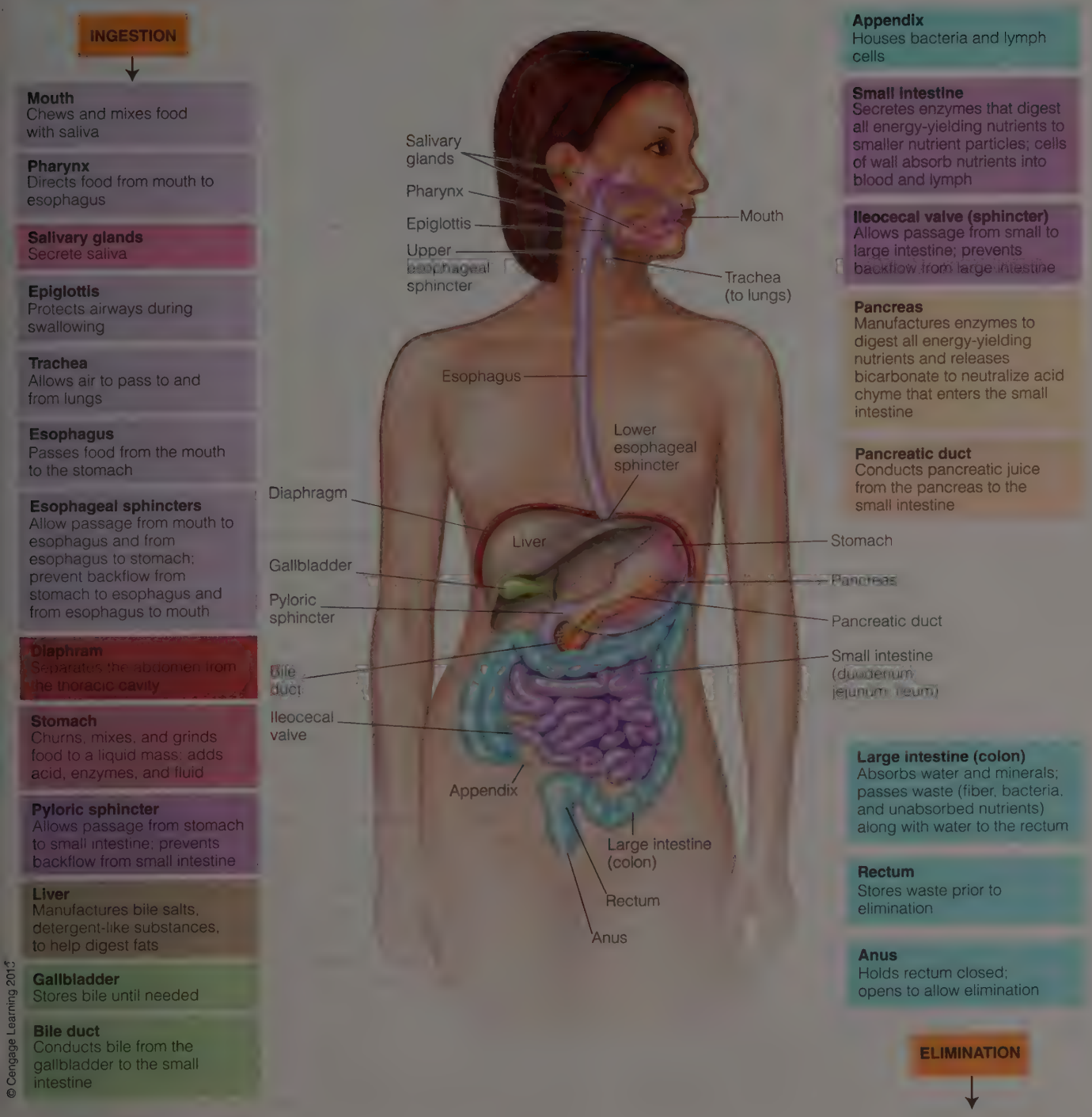
small intestine: a 10-foot length of small-diameter intestine that is the major site of digestion of food and absorption of nutrients. Its segments are the *duodenum, jejunum,* and *ileum*.

sphincter (SFINK-ter): a circular muscle surrounding, and able to close, a body opening. Sphincters are found at specific points along the GI tract and regulate the flow of food particles.

- **sphincter** = band (binder)

stomach: a muscular, elastic, saclike portion of the digestive tract that grinds and churns swallowed food, mixing it with acid and enzymes to form chyme.

FIGURE 3-1 The Gastrointestinal Tract



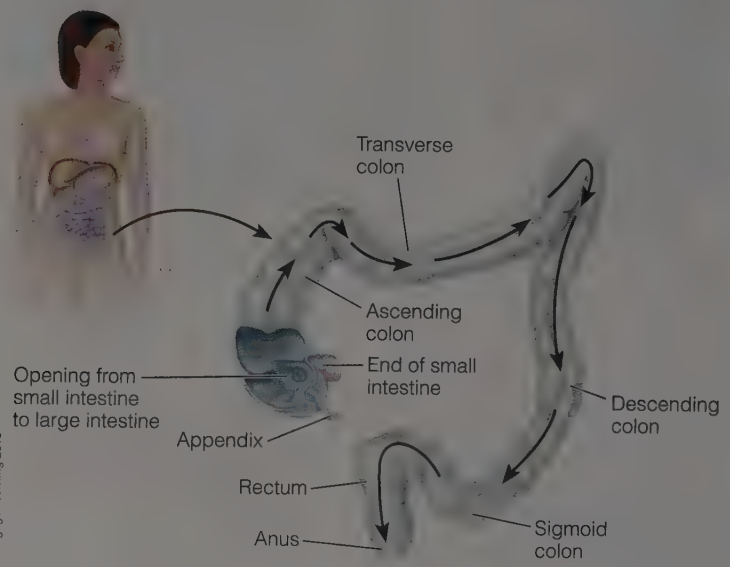
© Cengage Learning 2013

Mouth The process of digestion begins in the **mouth.** During chewing, teeth crush large pieces of food into smaller ones, and fluids from foods, beverages, and salivary glands blend with these pieces to ease swallowing.* Fluids also help dissolve the food so that the tongue can taste it; only particles in solution can react with taste buds. When stimulated, the taste buds detect one, or a combination, of the four basic taste sensations: sweet, sour, bitter, and salty. Some scientists also include the flavor associated with monosodium glutamate, sometimes called

*The process of chewing is called *mastication* (mass-tih-KAY-shun).

> FIGURE 3-2 The Colon

The colon begins with the ascending colon rising upward toward the liver. It becomes the transverse colon as it turns and crosses the body toward the spleen. The descending colon turns downward and becomes the sigmoid colon, which extends to the rectum. Along the way, the colon mixes the intestinal contents, absorbs water and salts, and forms stools.



© Cengage Learning 2013

savory or its Asian name, *umami* (oo-MOM-ee).[1] In addition to these chemical triggers, aroma, appearance, texture, and temperature also affect a food's flavor.

The tongue provides taste sensations and moves food around the mouth, facilitating chewing and swallowing. When a mouthful of food is swallowed, it passes through the **pharynx**, a short tube that is shared by both the **digestive system** and the respiratory system. To bypass the entrance to the lungs, the **epiglottis** closes off the airway so that choking doesn't occur when swallowing, thus resolving the first challenge. (Choking is discussed on pp. 88–89.) After a mouthful of food has been chewed and swallowed, it is called a **bolus.**

Esophagus The **esophagus** has a **sphincter** muscle at each end. During a swallow, the upper **esophageal sphincter** opens. The bolus then slides down the esophagus, which passes through a hole in the diaphragm (challenge 2) to the stomach. The lower esophageal sphincter at the entrance to the stomach closes behind the bolus so that it proceeds forward and doesn't slip back into the esophagus (challenge 3).

Stomach The **stomach** retains the bolus for a while in its upper portion. Little by little, the stomach transfers the food to its lower portion, adds juices to it, and grinds it to a semiliquid mass called **chyme.** Then, bit by bit, the stomach releases the chyme through the **pyloric sphincter,** which opens into the **small intestine** and then closes behind the chyme.

Small Intestine At the beginning of the small intestine, the chyme bypasses the opening from the common bile duct, which is dripping fluids (challenge 4) into the small intestine from two organs outside the GI tract—the **gallbladder** and the **pancreas.** The chyme travels on down the small intestine through its three segments—the **duodenum,** the **jejunum,** and the **ileum**—almost 10 feet of tubing coiled within the abdomen.*

Large Intestine (Colon) Having traveled the length of the small intestine, the remaining contents arrive at another sphincter (challenge 3 again): the **ileocecal valve,** located at the beginning of the **large intestine (colon)** in the lower right side of the abdomen. Upon entering the colon, the contents pass another opening. Should any intestinal contents slip into this opening, it would end up in the **appendix,** a blind sac about the size of your little finger. Normally, the contents bypass this opening, however, and travel along the large intestine up the right side of the abdomen, across the front to the left side, down to the lower left side, and finally below the other folds of the intestines to the back of the body, above the **rectum** (see Figure 3-2).

As the intestinal contents pass to the rectum, the colon withdraws water, leaving semisolid waste (challenge 5). The strong muscles of the rectum and anal canal hold back this waste until it is time to defecate. Then the rectal muscles relax (challenge 7), and the two sphincters of the **anus** open to allow passage of the waste.

The Muscular Action of Digestion

In the mouth, chewing, the addition of saliva, and the action of the tongue transform food into a coarse mash that can be swallowed. After swallowing, all the activity that follows occurs without much conscience thought. As is the case with so much else that happens in the body, the muscles of the digestive tract meet internal needs without any concerted effort on

digestive system: all the organs and glands associated with the ingestion and digestion of food.

bolus (BOH-lus): a portion; with respect to food, the amount swallowed at one time.

- **bolos** = lump

chyme (KIME): the semiliquid mass of partly digested food expelled by the stomach into the duodenum.

- **chymos** = juice

*The small intestine is almost two and a half times shorter in living adults than it is at death, when muscles are relaxed and elongated.

your part. They keep things moving at just the right pace, slow enough to get the job done and fast enough to make progress.*

Peristalsis The entire GI tract is ringed with circular muscles. Surrounding these rings of muscle are longitudinal muscles. When the rings tighten and the long muscles relax, the tube is constricted. When the rings relax and the long muscles tighten, the tube bulges. This action—called **peristalsis**—occurs continuously and pushes the intestinal contents along (challenge 3 again). (If you have ever watched a lump of food pass along the body of a snake, you have a good picture of how these muscles work.)

The waves of contraction normally ripple along the GI tract at varying rates and intensities depending on the part of the GI tract and on whether food is present. Factors such as stress, medicines, and medical conditions may interfere with normal GI tract contractions.[2]

Stomach Action The stomach has the thickest walls and strongest muscles of all the GI tract organs. In addition to the circular and longitudinal muscles, it has a third layer of diagonal muscles that also alternately contract and relax (see Figure 3-3). These three sets of muscles work to force the chyme downward, but the pyloric sphincter usually remains tightly closed, preventing the chyme from passing into the duodenum of the small intestine. As a result, the chyme is churned and forced down, hits the pyloric sphincter, and remains in the stomach. Meanwhile, the stomach wall releases gastric juices. When the chyme is completely liquefied with gastric juices, the pyloric sphincter opens briefly, about three times a minute, to allow small portions of chyme to pass through. At this point, the chyme no longer resembles food in the least.

Segmentation The circular muscles of the intestines rhythmically contract and squeeze their contents. These contractions, called **segmentation**, mix the chyme and promote close contact with the digestive juices and the absorbing cells of the intestinal walls before letting the contents move slowly along.

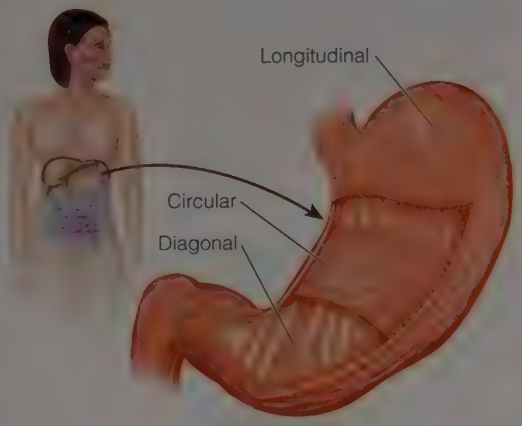
Sphincter Contractions Sphincter muscles periodically open and close, allowing the contents of the GI tract to move along at a controlled pace (challenge 3 again). At the top of the esophagus, the upper esophageal sphincter opens in response to swallowing. At the bottom of the esophagus, the lower esophageal sphincter (sometimes called the cardiac sphincter because of its proximity to the heart) prevents **reflux** of the stomach contents. At the bottom of the stomach, the pyloric sphincter, which stays closed most of the time, holds the chyme in the stomach long enough for it to be thoroughly mixed with gastric juice and liquefied. The pyloric sphincter also prevents the intestinal contents from backing up into the stomach. At the end of the small intestine, the ileocecal valve performs a similar function, allowing the contents of the small intestine to empty into the large intestine. Finally, the tightness of the rectal muscle acts as a kind of safety device; together with the two sphincters of the anus, it prevents continuous elimination (challenge 7). Figure 3-4 illustrates how sphincter muscles contract and relax to close and open passageways.

The Secretions of Digestion

The breakdown of food into nutrients requires secretions from five different organs: the salivary glands, the stomach, the pancreas, the liver (via the gallbladder), and the small

*The ability of the GI tract muscles to move is called *motility* (moh-TIL-ih-tee).

> **FIGURE 3-3 Stomach Muscles**
The stomach has three layers of muscles.



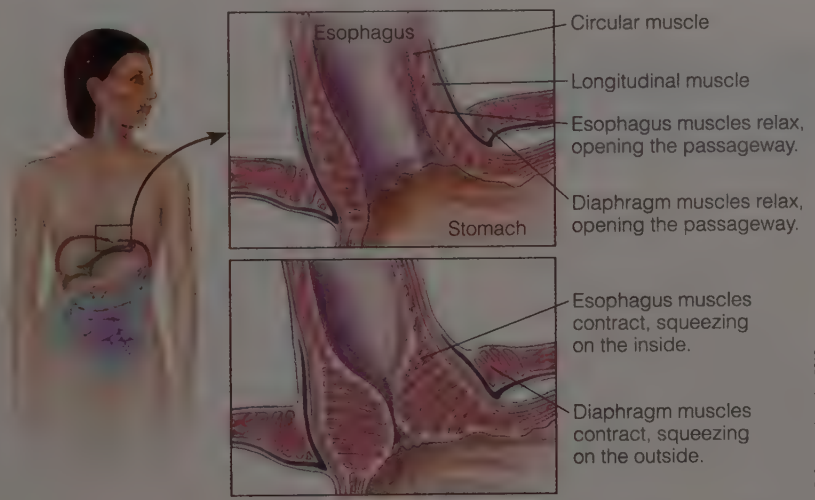
© Cengage Learning 2013

peristalsis (per-ih-STALL-sis): wavelike muscular contractions of the GI tract that push its contents along.
- **peri** = around
- **stellein** = wrap

segmentation (SEG-men-TAY-shun): a periodic squeezing or partitioning of the intestine at intervals along its length by its circular muscles.

reflux: a backward flow.
- **re** = back
- **flux** = flow

> **FIGURE 3-4 An Example of a Sphincter Muscle**
When the circular muscles of a sphincter contract, the passage closes; when they relax, the passage opens.



© Cengage Learning 2013

GLOSSARY OF DIGESTIVE ENZYMES

-ase (ACE): a word ending denoting an enzyme. The word beginning often identifies the compounds the enzyme works on. Examples include:

- *carbohydrase* (KAR-boe-HIGH-drase), an enzyme that hydrolyzes carbohydrates.
- *lipase* (LYE-pase), an enzyme that hydrolyzes lipids (fats).
- *protease* (PRO-tee-ase), an enzyme that hydrolyzes proteins.

digestive enzymes: proteins found in digestive juices that act on food substances, causing them to break down into simpler compounds.

hydrolysis (high-DROL-ih-sis): a chemical reaction in which one molecule is split into two molecules, with hydrogen (H) added to one and a hydroxyl group (OH) to the other (from water, H_2O). (The noun is *hydrolysis;* the verb is *hydrolyze.*)

- **hydro** = water
- **lysis** = breaking

FIGURE 3-5 The Salivary Glands

The salivary glands secrete enzyme-rich saliva into the mouth and begin the digestive process. Given the short time food is in the mouth, salivary enzymes contribute little to digestion.



© Cengage Learning 2013

catalyst (CAT-uh-list): a compound that facilitates chemical reactions without itself being changed in the process.

intestine. These secretions enter the GI tract at various points along the way, bringing an abundance of water (challenge 4) and a variety of enzymes.

Enzymes are formally introduced in Chapter 6, but for now a simple definition will suffice. An enzyme is a protein that facilitates a chemical reaction—making a molecule, breaking a molecule apart, changing the arrangement of a molecule, or exchanging parts of molecules. As a **catalyst**, the enzyme itself remains unchanged. The enzymes involved in digestion facilitate a chemical reaction known as **hydrolysis**—the addition of water *(hydro)* to break *(lysis)* a molecule into smaller pieces. The glossary above describes how to identify some of the common **digestive enzymes** and related terms; later chapters introduce specific enzymes. When learning about enzymes, it helps to know that the word ending ***-ase*** denotes an enzyme. Enzymes are often identified by the organ they come from and the compounds they work on. *Gastric lipase,* for example, is a stomach enzyme that acts on lipids, whereas *pancreatic lipase* comes from the pancreas (and also works on lipids).

Saliva The **salivary glands,** shown in Figure 3-5, squirt just enough **saliva** to moisten each mouthful of food so that it can pass easily down the esophagus (challenge 4). (Digestive **glands** and their secretions are defined in the glossary below.) The saliva contains water, salts, mucus, and enzymes that initiate the digestion of carbohydrates. Saliva also protects the teeth and the linings of the mouth, esophagus, and stomach from substances that might cause damage.

Gastric Juice In the stomach, **gastric glands** secrete **gastric juice,** a mixture of water, enzymes, and **hydrochloric acid,** which acts primarily in protein digestion. The acid is so strong that it causes the sensation of heartburn if it happens to reflux into the esophagus. Highlight 3, following this chapter, discusses heartburn, ulcers, and other common digestive problems.

The strong acidity of the stomach prevents bacterial growth and kills most bacteria that enter the body with food. It would destroy the cells of the stomach as well, but for their natural defenses. To protect themselves from gastric juice, the cells of

GLOSSARY OF DIGESTIVE GLANDS AND THEIR SECRETIONS

bicarbonate: an alkaline compound with the formula HCO_3 that is secreted from the pancreas as part of the pancreatic juice. (Bicarbonate is also produced in all cell fluids from the dissociation of carbonic acid to help maintain the body's acid-base balance.)

bile: an emulsifier that prepares fats and oils for digestion; an exocrine secretion made by the liver, stored in the gallbladder, and released into the small intestine when needed.

emulsifier (ee-MUL-sih-fire): a substance with both water-soluble and fat-soluble portions that promotes the mixing of oils and fats in a watery solution.

gastric glands: exocrine glands in the stomach wall that secrete gastric juice into the stomach.

- **gastro** = stomach

gastric juice: the digestive secretion of the gastric glands of the stomach.

glands: cells or groups of cells that secrete materials for special uses in the body. Glands may be *exocrine* (EKS-oh-crin) *glands,* secreting their materials "out" (into the digestive tract or onto the surface of the skin), or *endocrine* (EN-doe-crin) *glands,* secreting their materials "in" (into the blood).

- **exo** = outside
- **endo** = inside
- **krine** = to separate

hydrochloric acid: an acid composed of hydrogen and chloride atoms (HCl) that is normally produced by the gastric glands.

liver: the organ that manufactures bile. (The liver's many other functions are described in Chapter 7.)

mucus (MYOO-kus): a slippery substance secreted by cells of the GI lining (and other body linings) that protects the cells from exposure to digestive juices (and other destructive agents). The lining of the GI tract with its coat of mucus is a *mucous membrane.* (The noun is *mucus;* the adjective is *mucous.*)

pancreatic (pank-ree-AT-ic) **juice:** the exocrine secretion of the pancreas that contains both enzymes for the digestion of carbohydrate, fat, and protein as well as bicarbonate, a neutralizing agent. The juice flows from the pancreas into the small intestine through the pancreatic duct. (The pancreas also has an endocrine function, the secretion of insulin and other hormones.)

saliva: the secretion of the salivary glands. Its principal enzyme begins carbohydrate digestion.

salivary glands: exocrine glands that secrete saliva into the mouth.

the stomach wall (in fact, of the entire gastrointestinal lining) secrete **mucus**, a thick, slippery, white substance that coats the cells, protecting them from the acid, enzymes, and disease-causing bacteria that might otherwise cause harm (challenge 6).

Figure 3-6 shows how the strength of acids is measured—in pH units. Note that the acidity of gastric juice registers below 2 on the pH scale—stronger than vinegar. The stomach enzymes work most efficiently in the stomach's strong acid, but the salivary enzymes, which are swallowed with food, do not work in acid this strong. Consequently, the salivary digestion of carbohydrates gradually ceases when the stomach acid penetrates each newly swallowed bolus of food. Once in the stomach, salivary enzymes simply become other proteins to be digested.

Pancreatic Juice and Intestinal Enzymes By the time food leaves the stomach, digestion of all three energy nutrients (carbohydrates, fats, and proteins) has begun, and the action gains momentum in the small intestine. There the pancreas contributes digestive juices by way of ducts leading into the duodenum. The **pancreatic juice** contains enzymes that act on all three energy nutrients, and the cells of the intestinal wall also possess digestive enzymes on their surfaces.

In addition to enzymes, the pancreatic juice contains sodium **bicarbonate**, which is basic or alkaline—the opposite of the stomach's acid (review Figure 3-6). The pancreatic juice thus neutralizes the acidic chyme arriving in the small intestine from the stomach. From this point on, the chyme remains at a neutral or slightly alkaline pH. The enzymes of both the intestine and the pancreas work best in this environment.

Bile **Bile** also flows into the duodenum. The **liver** continuously produces bile, which is then concentrated and stored in the gallbladder. The gallbladder squirts bile into the duodenum of the small intestine when fat arrives there. Bile is not an enzyme; it is an **emulsifier** that brings fats into suspension in water so that enzymes can break them down into their component parts. A summary of digestive secretions and their actions is presented in Table 3-1.

The Final Stage

At this point, the three energy-yielding nutrients—carbohydrate, fat, and protein—have been digested and are ready to be absorbed. Some vitamins and minerals are altered slightly during digestion, but most are absorbed as they are. Undigested residues, such as some fibers, are not absorbed. Instead, they continue through the digestive tract, carrying some minerals, bile acids, additives, and contaminants out of the body. This semisolid mass helps exercise the GI muscles and keep them strong enough to perform peristalsis efficiently. Fiber also retains water, accounting for the consistency of **stools**.

TABLE 3-1 Summary of Digestive Secretions and Their Major Actions

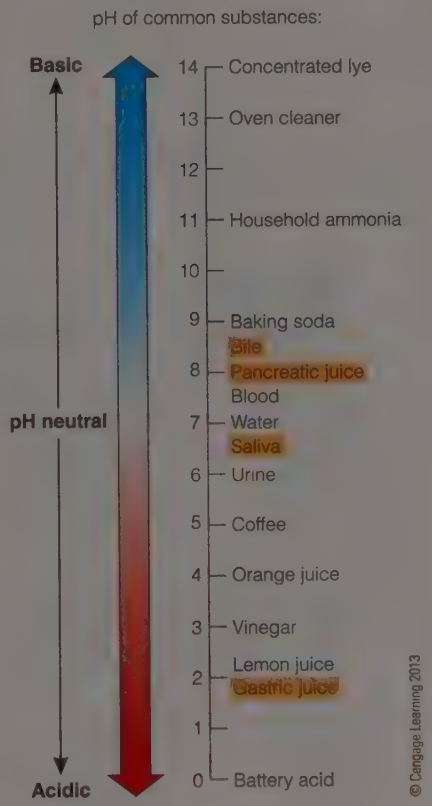
Organ or Gland	Target Organ	Secretion	Action
Salivary glands	Mouth	Saliva	Fluid eases swallowing; salivary enzyme breaks down some **carbohydrate.***
Gastric glands	Stomach	Gastric juice	Fluid mixes with bolus; hydrochloric acid uncoils **proteins;** enzymes break down proteins; mucus protects stomach cells.*
Pancreas	Small intestine	Pancreatic juice	Bicarbonate neutralizes acidic gastric juices; pancreatic enzymes break down **carbohydrates, fats,** and **proteins.**
Liver	Gallbladder	Bile	Bile is stored until needed.
Gallbladder	Small intestine	Bile	Bile emulsifies **fat** so that enzymes can have access to break it down.
Intestinal glands	Small intestine	Intestinal juice	Intestinal enzymes break down **carbohydrate, fat,** and **protein** fragments; mucus protects the intestinal wall.

*Saliva and gastric juice also contain lipases, but most fat breakdown occurs in the small intestine.

© Cengage Learning 2013

> FIGURE 3-6 The pH Scale

A substance's acidity or alkalinity is measured in pH units. The pH is the negative logarithm of the hydrogen ion concentration. Each increment represents a tenfold increase in concentration of hydrogen ions, meaning, for example, that a pH of 2 is 1000 times stronger than a pH of 5.



pH: the unit of measure expressing a substance's acidity or alkalinity. The lower the pH, the higher the H^+ ion concentration and the stronger the acid. A pH above 7 is alkaline, or base (a solution in which OH^- ions predominate).

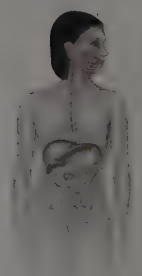
stools: waste matter discharged from the colon; also called *feces* (FEE-seez).

By the time the contents of the GI tract reach the end of the small intestine, little remains but water, a few dissolved salts and body secretions, and undigested materials such as fiber (with some fat, cholesterol, and a few minerals bound to it). All of this remaining matter enters the large intestine (colon).

In the colon, intestinal bacteria ferment some fibers, producing water, gas, and small fragments of fat that provide energy for the cells of the colon. The colon itself retrieves all materials that the body can recycle—water and dissolved salts. The waste that is finally excreted has little or nothing of value left in it. The body has extracted all that it can use from the food. Figure 3-7 summarizes digestion by following a sandwich through the GI tract and into the body.

> FIGURE 3-7 ***Animated*** **The Digestive Fate of a Sandwich**

To review the digestive processes, follow a peanut butter and banana sandwich on whole-wheat, sesame seed bread through the GI tract. As the graph on the right illustrates, digestion of the energy nutrients begins in different parts of the GI tract, but all are ready for absorption by the time they reach the end of the small intestine.



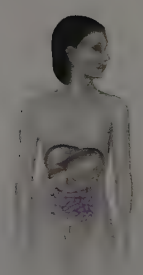
MOUTH: CHEWING AND SWALLOWING, WITH LITTLE DIGESTION

Carbohydrate digestion begins as the salivary enzyme starts to break down the starch from bread and peanut butter.
Fiber covering on the sesame seeds is crushed by the teeth, which exposes the nutrients inside the seeds to the upcoming digestive enzymes.
Fat digestion is minimal. Some hard fats begin to melt as they reach body temperature.
Protein foods are moistened by saliva.



STOMACH: COLLECTING AND CHURNING, WITH SOME DIGESTION

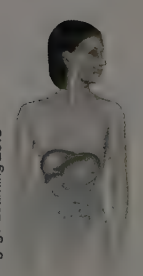
Carbohydrate digestion continues until the mashed sandwich has been mixed with the gastric juices; the stomach acid of the gastric juices inactivates the salivary enzyme, and carbohydrate digestion ceases.
Proteins from the bread, seeds, and peanut butter begin to uncoil when they mix with the gastric acid, making them available to the gastric protease enzymes that begin to digest proteins.
Fat from the peanut butter and seeds forms a separate layer on top of the watery mixture.



SMALL INTESTINE: DIGESTING AND ABSORBING

Carbohydrate digestion picks up when the pancreas sends pancreatic enzymes to the small intestine via the pancreatic duct to break down starch. Enzymes on the surfaces of the small intestinal cells complete the process of breaking down starch into small fragments that can be absorbed through the intestinal cell walls and into the hepatic portal vein. Sugars from the banana require so little digestion that they begin to traverse the intestinal cells immediately on contact.
Fat from the peanut butter and seeds is emulsified with the watery digestive fluids by bile. Now the pancreatic and intestinal lipases can begin to break down the fat to smaller fragments that can be absorbed through the cells of the small intestinal wall and into the lymph.
Protein digestion depends on the pancreatic and intestinal proteases. Small fragments of protein are liberated and absorbed through the cells of the small intestinal wall and into the hepatic portal vein.
Vitamins and minerals are absorbed.

Note: Sugars and starches are members of the carbohydrate family.



LARGE INTESTINE: ABSORBING AND ELIMINATING

Fluids and some minerals are absorbed.
Some fibers from the seeds, whole-wheat bread, peanut butter, and banana are partly digested by the bacteria living in the large intestine, and some of these products are absorbed.
Most fibers pass through the large intestine and are excreted as feces; some fat, cholesterol, and minerals bind to fiber and are also excreted.



© Cengage Learning 2013

REVIEW IT Explain how foods move through the digestive system, describing the actions of the organs, muscles, and digestive secretions along the way.

As Figure 3-1 shows, food enters the mouth and travels down the esophagus and through the upper and lower esophageal sphincters to the stomach, then through the pyloric sphincter to the small intestine, on through the ileocecal valve to the large intestine, past the appendix to the rectum, ending at the anus. The wavelike contractions of peristalsis and the periodic squeezing of segmentation keep things moving at a reasonable pace. Along the way, secretions from the salivary glands, stomach, pancreas, liver (via the gallbladder), and small intestine deliver fluids and digestive enzymes.

3.2 Absorption

LEARN IT Describe the anatomical details of the intestinal cells that facilitate nutrient absorption.

Within three or four hours after a person has eaten a dinner of beans and rice (or spinach lasagna, or steak and potatoes) with vegetable, salad, beverage, and dessert, the body must find a way to absorb the molecules derived from carbohydrate, protein, and fat digestion—and the vitamin and mineral molecules as well. Most absorption takes place in the small intestine, one of the most elegantly designed organ systems in the body. Within its 10-foot length, which provides a surface area equivalent to a tennis court, the small intestine traps and absorbs the nutrient molecules. To remove the absorbed molecules rapidly and provide room for more to be absorbed, a rush of circulating blood continuously washes the underside of this surface, carrying the absorbed nutrients away to the liver and other parts of the body. Figure 3-8 describes how most nutrients are absorbed by simple diffusion, facilitated diffusion, or active transport. Later chapters provide details on specific nutrients. Before following nutrients through the body, we must look more closely at the anatomy of the absorptive system.



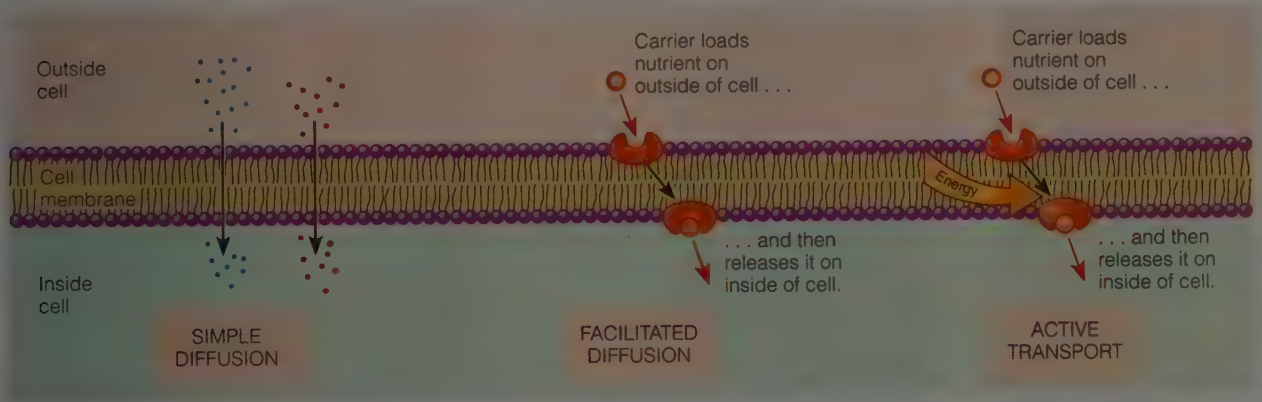
© Amana Images/Jupiterimages.com

Foods must first be digested and nutrients must be absorbed before the body can use them.

Anatomy of the Absorptive System The inner surface of the small intestine looks smooth and slippery, but when viewed through a microscope, it turns out to be wrinkled into hundreds of folds. Each fold is contoured into thousands

> FIGURE 3-8 Absorption of Nutrients

Absorption of nutrients into intestinal cells typically occurs by simple diffusion, facilitated diffusion, or active transport. Occasionally, a large molecule is absorbed by *endocytosis*—a process in which the cell membrane engulfs the molecule, forming a sac that separates from the membrane and moves into the cell.



Some nutrients (such as water and small lipids) are absorbed by simple diffusion. They cross into intestinal cells freely.

Some nutrients (such as the water-soluble vitamins) are absorbed by facilitated diffusion. They need a specific carrier to transport them from one side of the cell membrane to the other. (Alternatively, facilitated diffusion may occur when the carrier changes the cell membrane in such a way that the nutrients can pass through.)

Some nutrients (such as glucose and amino acids) must be absorbed actively. These nutrients move against a concentration gradient, which requires energy.

© Cengage Learning 2013

villi (VILL-ee, VILL-eye): fingerlike projections from the folds of the small intestine; singular *villus*.

microvilli (MY-cro-VILL-ee, MY-cro-VILL-eye): tiny, hairlike projections on each cell of every villus that can trap nutrient particles and transport them into the cells; singular *microvillus*.

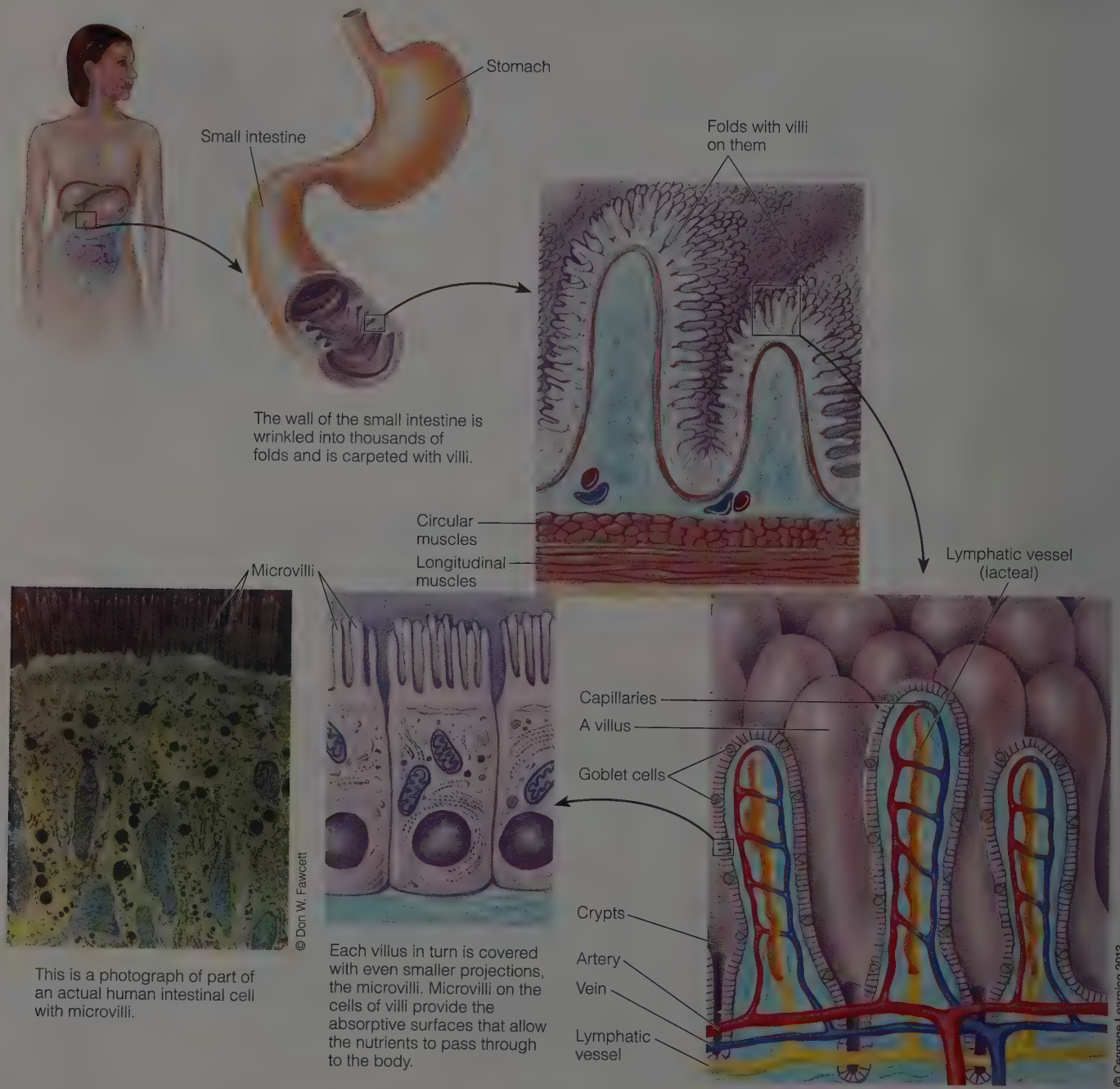
crypts (KRIPTS): tubular glands that lie between the intestinal villi and secrete intestinal juices into the small intestine.

goblet cells: cells of the GI tract (and lungs) that secrete mucus.

of fingerlike projections, as numerous as the hairs on velvet fabric. These small intestinal projections are called **villi**. A single villus, magnified still more, turns out to be composed of hundreds of cells, each covered with its own microscopic hairs, called **microvilli** (see Figure 3-9). In the crevices between the villi lie the **crypts**—tubular glands that secrete the intestinal juices into the small intestine. Nearby **goblet cells** secrete mucus.

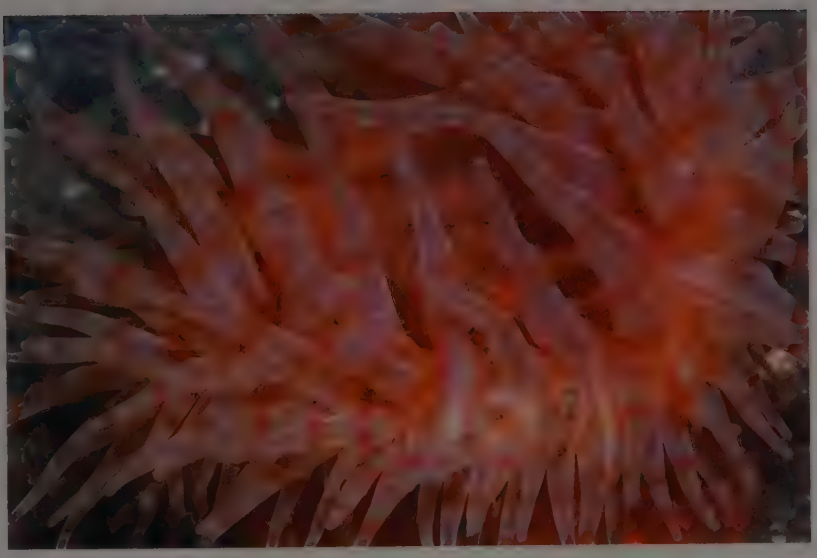
The villi are in constant motion. Each villus is lined by a thin sheet of muscle, so it can wave, squirm, and wriggle like the tentacles of a sea anemone. Any nutrient molecule small enough to be absorbed is trapped among the microvilli and then drawn into the cells. Some partially digested nutrients are caught in the microvilli, digested further by enzymes there, and then absorbed into the cells.

> FIGURE 3-9 The Small Intestinal Villi



A Closer Look at the Intestinal Cells

The cells of the villi are among the most amazing in the body, for they recognize and select the nutrients the body needs and regulate their absorption. As already described, each cell of a villus is coated with thousands of microvilli, which project from the cell's membrane (review Figure 3-9). In these microvilli, and in the membrane, lie hundreds of different kinds of enzymes and "pumps," which recognize and act on different nutrients. Descriptions of specific enzymes and "pumps" for each nutrient are presented in later chapters where appropriate; the point here is that the cells are equipped to handle all kinds and combinations of foods and their nutrients.



© Undersea Discoveries/Shutterstock.com

If you have ever watched a sea anemone with its fingerlike projections in constant motion, you have a good picture of how the intestinal villi move.

Specialized Cells A further refinement of the system is that the cells of successive portions of the intestinal tract are specialized to absorb different nutrients. The nutrients that are ready for absorption early are absorbed near the top of the GI tract; those that take longer to be digested are absorbed farther down. Registered dietitians and medical professionals who treat digestive disorders learn the specialized absorptive functions of different parts of the GI tract so that if one part becomes dysfunctional, the diet can be adjusted accordingly.

Food Combining The idea that people should not eat certain food combinations (for example, fruit and meat) at the same meal, because the digestive system cannot handle more than one task at a time, is a myth. The art of "food combining"—which actually emphasizes "food separating"—is based on this myth, and it represents faulty logic and a gross underestimation of the body's capabilities. In fact, the contrary is often true; foods eaten together can enhance each other's use by the body. For example, vitamin C in a pineapple or other citrus fruit can enhance the absorption of iron from a meal of chicken and rice or other iron-containing foods. Many other instances of mutually beneficial interactions are presented in later chapters.

Preparing Nutrients for Transport When a nutrient molecule has crossed the cell of a villus, it enters either the bloodstream or the lymphatic system. Both transport systems supply vessels to each villus, as shown in Figure 3-9. The water-soluble nutrients and the smaller products of fat digestion are released directly into the bloodstream and guided directly to the liver where their fate and destination will be determined.

The larger fats and the fat-soluble vitamins are insoluble in water, however, and blood is mostly water. The intestinal cells assemble many of the products of fat digestion into larger molecules. These larger molecules cluster together with special proteins, forming chylomicrons. Chylomicrons (kye-lo-MY-cronz) are defined and described in more detail in Chapter 5. For now, keep in mind that because chylomicrons carry fats, they are released into the lymphatic system. They move through the lymph until they can enter the bloodstream at a point near the heart. Consequently, chylomicrons bypass the liver at first. Details follow.

REVIEW IT Describe the anatomical details of the intestinal cells that facilitate nutrient absorption.

The many folds and villi of the small intestine dramatically increase its surface area, facilitating nutrient absorption. Nutrients pass through the cells of the villi and enter either the blood (if they are water soluble or small fat fragments) or the lymph (if they are fat soluble).

3.3 The Circulatory Systems

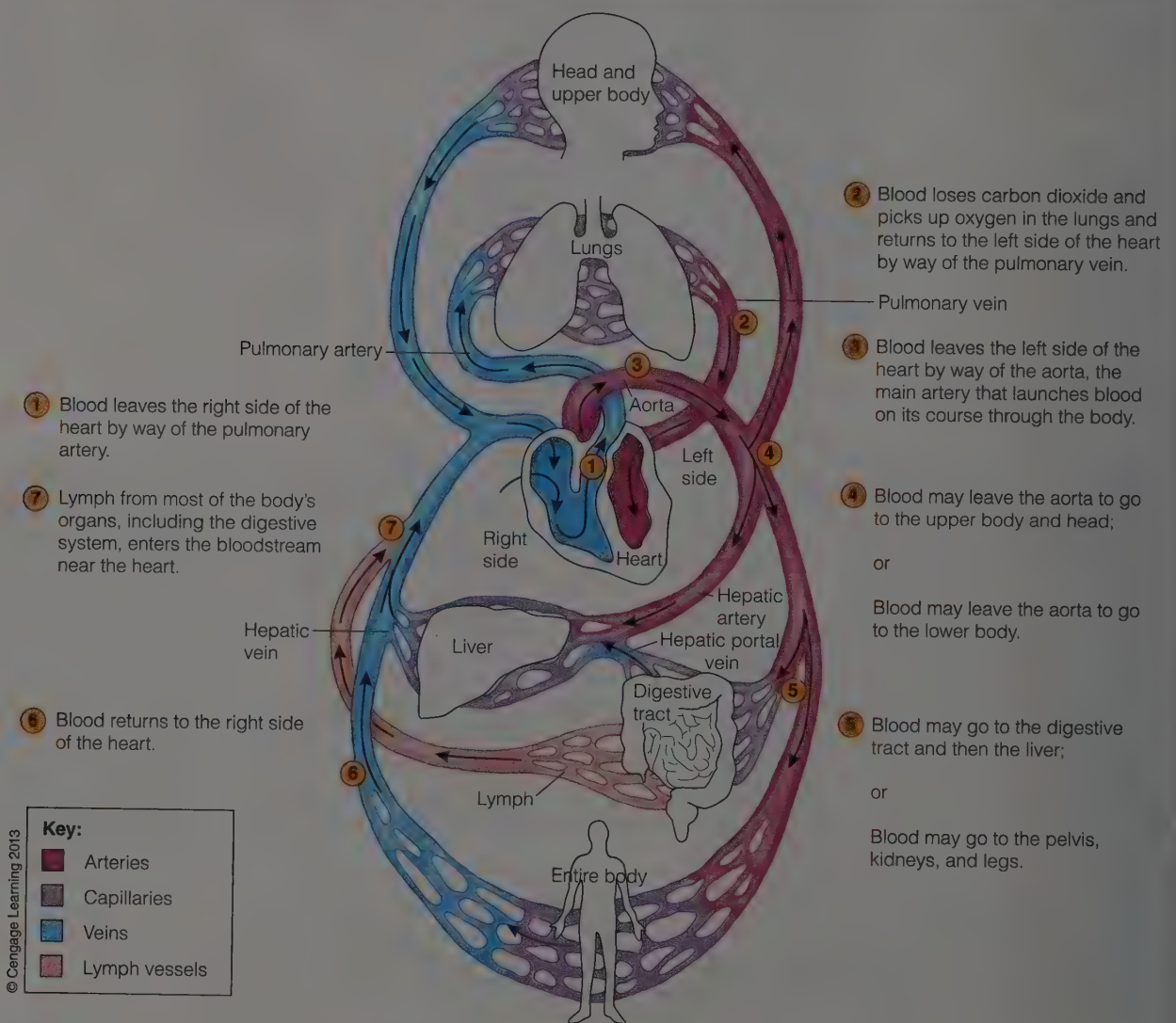
LEARN IT Explain how nutrients are routed in the circulatory systems from the GI tract into the body and identify which nutrients enter the blood directly and which must first enter the lymph.

Once a nutrient has entered the bloodstream, it may be transported to any of the cells in the body, from the tips of the toes to the roots of the hair. The circulatory systems deliver nutrients wherever they are needed.

The Vascular System The vascular, or blood circulatory, system is a closed system of vessels through which blood flows continuously, with the heart serving as the pump (see Figure 3-10). As the blood circulates through this system, it picks up and delivers materials as needed.

All the body tissues derive nutrients and oxygen from the blood and deposit carbon dioxide and other wastes back into the blood. The digestive system supplies the nutrients. The lungs exchange oxygen (which enters the blood to be delivered to all cells) and carbon dioxide (which leaves the blood to be exhaled). The kidneys filter wastes other than carbon dioxide out of the blood to be excreted in the urine.

> **FIGURE 3-10** *Animated* **The Vascular System**



© Cengage Learning 2013

Blood leaving the right side of the heart circulates through the lungs and then back to the left side of the heart. The left side of the heart then pumps the blood out of the **aorta** through **arteries** to all systems of the body. The blood circulates in the **capillaries**, where it exchanges material with the cells and then collects into **veins**, which return it again to the right side of the heart. In short, blood travels this simple route:

Heart to arteries to capillaries to veins to heart

The routing of the blood leaving the digestive system has a special feature. The blood is carried to the digestive system (as to all organs) by way of an artery, which (as in all organs) branches into capillaries to reach every cell. Blood leaving the digestive system, however, goes by way of a vein. The **hepatic portal vein** directs blood not back to the heart but to another organ, the liver. This vein branches into a network of large capillaries so that every cell of the liver has access to the blood. Blood leaving the liver then collects into the **hepatic vein**, which returns blood to the heart. The route is:

Heart to arteries to capillaries (in intestines) to hepatic portal vein to capillaries (in liver) to hepatic vein to heart

Figure 3-11 shows the liver's key position in nutrient transport. An anatomist studying this system knows there must be a reason for this special arrangement. The liver's placement ensures that it will be first to receive the nutrients absorbed from the GI tract. In fact, the liver has many jobs to do in preparing the absorbed nutrients for use by the body. Of all the body's organs, the liver is the most metabolically active.

aorta (ay-OR-tuh): the large, primary artery that conducts blood from the heart to the body's smaller arteries.

arteries: vessels that carry blood from the heart to the tissues.

capillaries (CAP-ill-aries): small vessels that branch from an artery. Capillaries connect arteries to veins. Exchange of oxygen, nutrients, and waste materials takes place across capillary walls.

veins (VANES): vessels that carry blood to the heart.

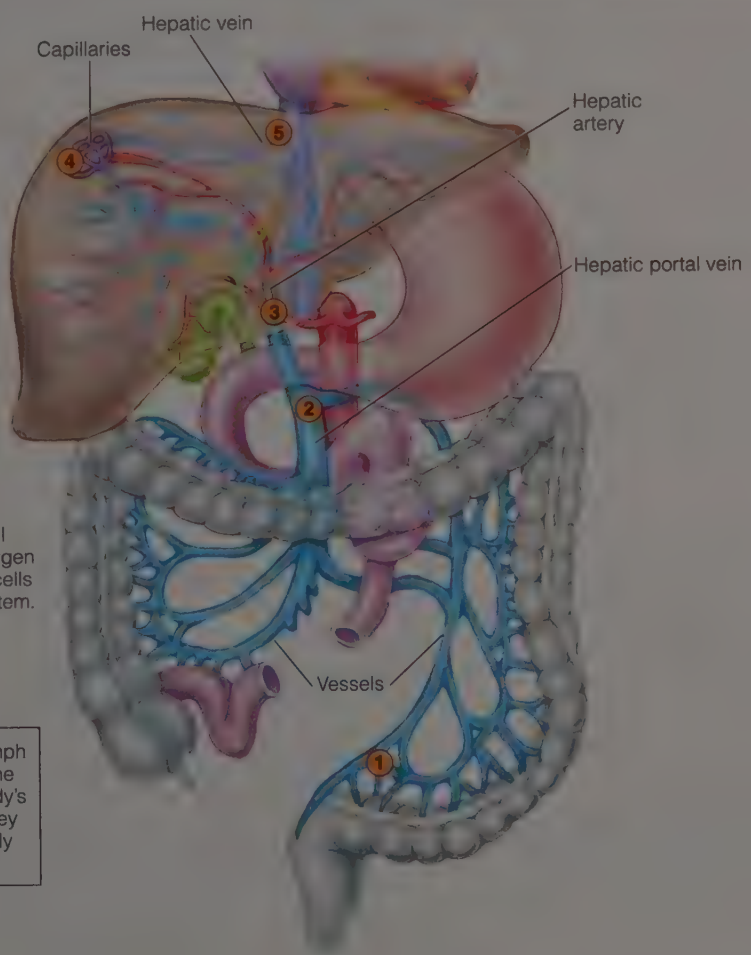
hepatic portal vein: the vein that collects blood from the GI tract and conducts it to the liver.

- **portal** = gateway

hepatic vein: the vein that collects blood from the liver and returns it to the heart.

- **hepatic** = liver

> FIGURE 3-11 The Liver



1. Vessels gather up nutrients from the digestive tract.

Not shown here:
Parallel to these vessels (veins) are other vessels (arteries) that carry oxygen-rich blood from the heart to the intestines.

2. The vessels merge into the hepatic portal vein, which conducts all absorbed materials to the liver.

3. The hepatic artery brings a supply of freshly oxygenated blood (not loaded with nutrients) from the lungs to supply oxygen to the liver's own cells.

4. A network of large capillaries branch all over the liver, making nutrients and oxygen available to all its cells and giving the cells access to blood from the digestive system.

5. The hepatic vein gathers up blood in the liver and returns it to the heart.

In contrast, nutrients absorbed into lymph do not go to the liver first. They go to the heart, which pumps them to all the body's cells. The cells remove the nutrients they need, and the liver then has to deal only with the remnants.

© Cengage Learning 2013

In addition, the liver defends the body by detoxifying substances that might cause harm and preparing waste products for excretion. This is why, when people ingest poisons that succeed in passing the first barrier (the intestinal cells), the liver quite often suffers the damage—from viruses such as hepatitis, from drugs such as barbiturates or alcohol, from toxins such as pesticide residues, and from contaminants such as mercury. Perhaps, in fact, you have been undervaluing your liver, not knowing what heroic tasks it quietly performs for you.

The Lymphatic System The **lymphatic system** provides a one-way route for fluid from the tissue spaces to enter the blood. Unlike the vascular system, the lymphatic system has no pump; instead, **lymph** circulates *between* the cells of the body and collects into tiny vessels. The fluid moves from one portion of the body to another as muscles contract and create pressure here and there. Ultimately, much of the lymph collects in the **thoracic duct** behind the heart. The thoracic duct opens into the **subclavian vein**, where the lymph enters the bloodstream. Thus nutrients from the GI tract that enter lymphatic vessels (large fats and fat-soluble vitamins) ultimately enter the bloodstream, circulating through arteries, capillaries, and veins like the other nutrients, with a notable exception—they bypass the liver at first.*

Once inside the vascular system, the nutrients can travel all over the body where they can be taken into cells and used as needed. What becomes of them is described in later chapters.

REVIEW IT Explain how nutrients are routed in the circulatory systems from the GI tract into the body and identify which nutrients enter the blood directly and which must first enter the lymph.

Nutrients leaving the digestive system via the blood are routed directly to the liver before being transported to the body's cells. Those leaving via the lymphatic system (large fats and fat-soluble vitamins) eventually enter the vascular system but bypass the liver at first.

3.4 The Health and Regulation of the GI Tract

LEARN IT Describe how bacteria, hormones, and nerves influence the health and activities of the GI tract.

This section describes the bacterial conditions and hormonal regulation of a healthy GI tract, but many factors can influence normal GI function. For example, peristalsis and sphincter action are poorly coordinated in newborns, so infants tend to "spit up" during the first several months of life. Older adults often experience constipation, in part because the intestinal wall loses strength and elasticity with age, which slows GI motility. Diseases can also interfere with digestion and absorption and often lead to malnutrition. Lack of nourishment, in general, and lack of certain dietary constituents such as fiber, in particular, alter the structure and function of GI cells. Quite simply, GI tract health depends on adequate nutrition.

Gastrointestinal Bacteria An estimated 10 trillion bacteria representing some 400 or more different species and subspecies live in a healthy GI tract.** The prevalence of different bacteria in various parts of the GI tract depends on such factors as pH, peristalsis, diet, and other microorganisms.[3] Relatively few microorganisms can live in the low pH of the stomach with its relatively rapid peristalsis, whereas the neutral pH and slow peristalsis of the lower small intestine and the large intestine permit the growth of a diverse and abundant bacterial population.

Most bacteria in the GI tract are not harmful; in fact, they are actually beneficial.[4] Provided that the normal intestinal **flora** are thriving, infectious bacteria have a hard time establishing themselves to launch an attack on the system.

lymphatic (lim-FAT-ic) **system:** a loosely organized system of vessels and ducts that convey fluids toward the heart. The GI part of the lymphatic system carries the products of fat digestion into the bloodstream.

lymph (LIMF): a clear yellowish fluid that is similar to blood except that it contains no red blood cells or platelets. Lymph from the GI tract transports fat and fat-soluble vitamins to the bloodstream via lymphatic vessels.

thoracic (thor-ASS-ic) **duct:** the main lymphatic vessel that collects lymph and drains into the left subclavian vein.

subclavian (sub-KLAY-vee-an) **vein:** the vein that provides passageway from the lymphatic system to the vascular system.

flora: bacteria in the intestines.

*The lymphatic vessels of the intestine that take up nutrients and pass them to the lymph circulation are called *lacteals* (LACK-tee-als).

**Bacteria in the intestines are sometimes referred to as *flora*.

Diet is one of several factors that influence the body's bacterial population and environment. Consider **yogurt**, for example. Yogurt contains *Lactobacillus* and other living bacteria. These microorganisms are considered **probiotics** because they change the conditions and native bacterial colonies in the GI tract in ways that seem to benefit health.[5] The potential GI health benefits of probiotics include helping to alleviate diarrhea, constipation, inflammatory bowel disease, ulcers, allergies, lactose intolerance, and infant colic; enhance immune function; and protect against colon cancer. Some probiotics may have adverse effects under certain circumstances.[6] Research studies continue to explore how diet influences GI bacteria and which foods—with their probiotics—affect GI health. In addition, research studies are beginning to reveal several health benefits beyond the GI tract—such as improving blood pressure and immune responses.[7]

GI bacteria also digest fibers and complex proteins. These food components are called **prebiotics** because they encourage the growth and activity of bacteria. In the process, the bacteria produce nutrients such as short fragments of fat that the cells of the colon use for energy. Bacteria in the GI tract also produce several vitamins, ♦ although the amount is insufficient to meet the body's total need for these vitamins.


© Polara Studios Inc

Eaten regularly, yogurt can alleviate common digestive problems.

♦ Vitamins produced by bacteria include:
- Biotin
- Folate
- Pantothenic acid
- Riboflavin
- Thiamin
- Vitamin B_6
- Vitamin B_{12}
- Vitamin K

Gastrointestinal Hormones and Nerve Pathways

The ability of the digestive tract to handle its ever-changing contents illustrates an important physiological principle that governs the way all living things function—the principle of **homeostasis.** Simply stated, survival depends on body conditions staying about the same; if they deviate too far from the norm, the body must "do something" to bring them back to normal. The body's regulation of digestion is one example of homeostatic regulation. The body also regulates its temperature, its blood pressure, and all other aspects of its blood chemistry in similar ways.

Two intricate and sensitive systems coordinate all the digestive and absorptive processes: the hormonal (or endocrine) system and the nervous system. Even before the first bite of food is taken, the mere thought, sight, or smell of food can trigger a response from these systems. Then, as food travels through the GI tract, it either stimulates or inhibits digestive secretions by way of messages that are carried from one section of the GI tract to another by both **hormones** and nerve pathways. (Appendix A presents a brief summary of the body's hormonal system and nervous system.)

Notice that the kinds of regulation described next are all examples of *feedback* mechanisms. A certain condition demands a response. The response changes that condition, and the change then cuts off the response. Thus the system is self-correcting. Examples follow:

- *The stomach normally maintains a pH between 1.5 and 1.7. How does it stay that way?* Food entering the stomach stimulates cells in the stomach wall to release the hormone **gastrin.** Gastrin, in turn, stimulates the stomach glands to secrete the components of hydrochloric acid. When pH 1.5 is reached, the acid itself turns off the gastrin-producing cells; they stop releasing gastrin, and the glands stop producing hydrochloric acid. Thus the system adjusts itself, as Figure 3-12 (p. 84) shows.

Nerve receptors in the stomach wall also respond to the presence of food and stimulate the gastric glands to secrete juices and the muscles to contract. As the stomach empties, the receptors are no longer stimulated, the flow of juices slows, and the stomach quiets down.

- *The pyloric sphincter opens to let out a little chyme, then closes again. How does it know when to open and close?* When the pyloric sphincter relaxes, acidic chyme slips through. The cells of the pyloric muscle on the intestinal side sense the acid, causing the pyloric sphincter to close tightly. Only after the chyme has been neutralized by pancreatic bicarbonate and the juices surrounding the pyloric sphincter have become alkaline can the muscle relax again. This process ensures that the chyme will be released slowly enough to be neutralized as it flows through the

yogurt: milk product that results from the fermentation of lactic acid in milk by *Lactobacillus bulgaricus* and *Streptococcus thermophilus.*

probiotics: living microorganisms found in foods and dietary supplements that, when consumed in sufficient quantities, are beneficial to health.
- **pro** = for
- **bios** = life

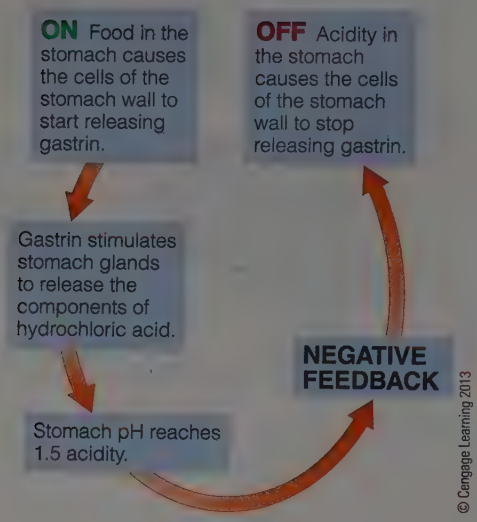
prebiotics: food components (such as fibers) that are not digested by the human body but are used as food by the GI bacteria to promote their growth and activity.

homeostasis (HOME-ee-oh-STAY-sis): the maintenance of constant internal conditions (such as blood chemistry, temperature, and blood pressure) by the body's control systems. A homeostatic system is constantly reacting to external forces to maintain limits set by the body's needs.
- **homeo** = the same
- **stasis** = staying

hormones: chemical messengers. Hormones are secreted by a variety of glands in response to altered conditions in the body. Each hormone travels to one or more specific target tissues or organs, where it elicits a specific response to maintain homeostasis.

gastrin: a hormone secreted by cells in the stomach wall. Target organ: the glands of the stomach. Response: secretion of gastric acid.

> **FIGURE 3-12 An Example of a Negative Feedback Loop**



© Cengage Learning 2013

small intestine. This is important because the small intestine has less of a mucous coating than the stomach does and so is not as well protected from acid.

- *As the chyme enters the small intestine, the pancreas adds bicarbonate to it so that the intestinal contents always remain at a slightly alkaline pH. How does the pancreas know how much to add?* The presence of chyme stimulates the cells of the duodenum wall to release the hormone **secretin** into the blood. When secretin reaches the pancreas, it stimulates the pancreas to release its bicarbonate-rich juices. Thus, whenever the duodenum signals that acidic chyme is present, the pancreas responds by sending bicarbonate to neutralize it. When the need has been met, the cells of the duodenum wall are no longer stimulated to release secretin, the hormone no longer flows through the blood, and the pancreas no longer receives the message and stops sending pancreatic juice. Nerves also regulate pancreatic secretions.

- *Pancreatic secretions contain a mixture of enzymes to digest carbohydrate, fat, and protein. How does the pancreas know how much of each type of enzyme to provide?* This is one of the most interesting questions physiologists have asked. Clearly, the pancreas does know what its owner has been eating, and it secretes enzyme mixtures tailored to handle the food mixtures that have been arriving recently (over the last several days). Enzyme activity changes proportionately in response to the amounts of carbohydrate, fat, and protein in the diet. If a person has been eating mostly carbohydrates, the pancreas makes and secretes mostly carbohydrases; if the person's diet has been high in fat, the pancreas produces more lipases; and so forth. Hormones from the GI tract, secreted in response to meals, keep the pancreas informed as to its digestive tasks. The day or two lag between the time a person's diet changes dramatically and the time digestion of the new diet becomes efficient explains why dietary changes can "upset digestion" and should be made gradually.

- *Why don't the digestive enzymes damage the pancreas?* The pancreas protects itself from harm by producing an inactive form of the enzymes.* It releases these proteins into the small intestine, where they are activated to become enzymes. In pancreatitis, the digestive enzymes become active within the infected pancreas, causing inflammation and damaging the delicate pancreatic tissues.

- *When fat is present in the intestine, the gallbladder contracts to squirt bile into the intestine to emulsify the fat. How does the gallbladder get the message that fat is present?* Fat in the intestine stimulates cells of the intestinal wall to release the hormone **cholecystokinin (CCK).** This hormone travels by way of the blood to the gallbladder and stimulates it to contract, which releases bile into the small intestine. Cholecystokinin also travels to the pancreas and stimulates it to secrete its juices, which releases bicarbonate and enzymes into the small intestine. Once the fat in the intestine is emulsified and enzymes have begun to work on it, the fat no longer provokes release of the hormone, and the message to contract is canceled. (By the way, fat emulsification can continue even after a diseased gallbladder has been surgically removed because the liver can deliver bile directly to the small intestine.)

- *Fat and protein take longer to digest than carbohydrate does. When fat or protein is present, intestinal motility slows to allow time for its digestion. How does the intestine know when to slow down?* Cholecystokinin is released in response to fat or protein in the small intestine. In addition to its role in fat emulsification and digestion, cholecystokinin slows GI tract motility. Slowing the digestive process helps to maintain a pace that allows all reactions to reach completion. Hormonal and nervous mechanisms like these account for much of the body's ability to adapt to changing conditions.

Table 3-2 summarizes the actions of these three GI hormones. Gastrin, secretin, and cholecystokinin are among the most studied GI hormones, but the GI tract releases more than 20 hormones. In addition to assisting with

secretin (see-CREET-in): a hormone produced by cells in the duodenum wall. Target organ: the pancreas. Response: secretion of bicarbonate-rich pancreatic juice.

cholecystokinin (COAL-ee-SIS-toe-KINE-in), or **CCK**: a hormone produced by cells of the intestinal wall. Target organ: the gallbladder. Response: release of bile and slowing of GI motility.

*The inactive precursor of an enzyme is called a *zymogen* (ZYE-mo-jen).

TABLE 3-2 The Primary Actions of Selected GI Hormones

Hormone	Responds to	Secreted from	Stimulates	Response
Gastrin	Food in the stomach	Stomach wall	Stomach glands	Hydrochloric acid secreted into the stomach
Secretin	Acidic chyme in the small intestine	Duodenal wall	Pancreas	Bicarbonate-rich juices secreted into the small intestine
Cholecystokinin	Fat or protein in the small intestine	Intestinal wall	Gallbladder	Bile secreted into the duodenum
			Pancreas	Bicarbonate- and enzyme-rich juices secreted into the small intestine

© Cengage Learning 2013

digestion and absorption, many of these hormones regulate food intake and influence satiation—the feeling of satisfaction and fullness that occurs during a meal and halts eating. Current research is focusing on the roles these hormones may play in the development of obesity and its treatments (more details provided in Chapter 9).

Discovering the answers to questions like these has led some people to devote their whole lives to the study of physiology. For now, however, these few examples illustrate how all the processes throughout the digestive system are precisely and automatically regulated without any conscious effort.

The System at Its Best This chapter describes the anatomy of the digestive tract on several levels: the sequence of digestive organs, the cells and structures of the villi, and the selective machinery of the cell membranes. The intricate architecture of the digestive system makes it sensitive and responsive to conditions in its environment. Several different kinds of GI tract cells confer specific immunity against intestinal diseases such as inflammatory bowel disease. In addition, secretions from the GI tract—saliva, mucus, gastric acid, and digestive enzymes—not only help with digestion, but also defend against foreign invaders. Together the GI's team of bacteria, cells, and secretions defend the body against numerous challenges.

One indispensable condition is good health of the digestive system itself. Like all the other organs of the body, the GI tract depends on a healthy supply of blood. The cells of the GI tract become weak and inflamed when blood flow is diminished, as may occur in heart disease when arteries become clogged or blood clots form. Just as a diminished blood flow to the heart or brain can cause a heart attack or stroke, respectively, too little blood to the intestines can also be



© Shutterstock.com/Monkey Business Images

Nourishing foods and pleasant conversations support a healthy digestive system.

damaging—or even fatal. A diminished blood flow to the intestines—called **intestinal ischemia**—is characterized by abdominal pain, forceful bowel movements, and blood in the stool.

The health of the digestive system is also affected by such lifestyle factors as sleep, physical activity, and state of mind. Adequate sleep allows for repair and maintenance of tissue and removal of wastes that might impair efficient functioning. Activity promotes healthy muscle tone. Stress influences the activity of regulatory nerves and hormones.[8] For healthy digestion, mealtimes should be relaxed and tranquil. Pleasant conversations and peaceful environments during meals ease the digestive process.

Another factor in GI health is the kind of foods eaten. Among the characteristics of meals that promote optimal absorption of nutrients are those mentioned in Chapter 2: balance, moderation, variety, and adequacy. Balance and moderation require having neither too much nor too little of anything. For example, too much fat can be harmful, but some fat is beneficial in slowing down intestinal motility and providing time for absorption of some of the nutrients that are slow to be absorbed.

Variety is important for many reasons, but one is that some food constituents interfere with nutrient absorption. For example, some compounds common in high-fiber foods such as whole-grain cereals, certain leafy green vegetables, and legumes bind with minerals. To some extent, then, the minerals in those foods may become unavailable for absorption. These high-fiber foods are still valuable, but they need to be balanced with a variety of other foods that can provide the minerals.

As for adequacy—in a sense, this entire book is about dietary adequacy. A diet must provide all the essential nutrients, fiber, and energy in amounts sufficient to maintain health. But here, at the end of this chapter, is a good place to emphasize the interdependence of the nutrients. It could almost be said that every nutrient depends on every other. All the nutrients work together, and all are present in the cells of a healthy digestive tract. To maintain health and promote the functions of the GI tract, make balance, moderation, variety, and adequacy features of every day's meals.

REVIEW IT Describe how bacteria, hormones, and nerves influence the health and activities of the GI tract.

A diverse and abundant bacteria population supports GI health. The regulation of GI processes depends on the coordinated efforts of the hormonal system and the nervous system. Together, digestion and absorption break down foods into nutrients for the body's use. To function optimally, a healthy GI tract needs a balanced diet, adequate rest, and regular physical activity.

Nutrition Portfolio

A digestive system that is well cared for most of the time can adjust to handle almost any diet or combination of foods with ease on occasion. Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Choose the day you thought you ate most poorly, and looking at it, record in your journal answers to the following:

- Describe the physical and emotional environment that typically surrounds your meals, including how it affects you and how it might be improved.
- Did you experience any GI discomfort on that day? Do you experience any GI discomfort regularly? If so, which of the foods that you ate might have contributed to your discomfort? What can you do to prevent or alleviate GI problems in the future? Use Table H3-1 (p. 93) as a guide.
- List any changes you can make in your eating habits to promote overall GI health.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

intestinal ischemia (is-KEY-me-ah): a diminished blood flow to the intestines that is characterized by abdominal pain, forceful bowel movements, and blood in the stool.

REFERENCES

1. 100th Anniversary Symposium of Umami Discovery, *American Journal of Clinical Nutrition* 90 (2009): entire supplement.
2. A. Stengel and Y. Taché, Neuroendocrine control of the gut during stress: Corticotropin-releasing factor signaling pathways in the spotlight, *Annual Review of Physiology* 71 (2009): 219–239; P. Holzer, Opioid receptors in the gastrointestinal tract, *Regulatory Peptides* 155 (2009): 11–17; J. López-Herce, Gastrointestinal complications in critically ill patients: What differs between adults and children? *Current Opinion in Clinical Nutrition and Metabolic Care* 12 (2009): 180–185.
3. E. M. Bik, Composition and function of the human-associated microbiota, *Nutrition Reviews* 67 (2009): S164–S171.
4. P. Hunter, The secret garden. The human digestive system is teeming with microbiotic life, but just how important are these interlopers for health and disease? *European Molecular Biology Organization Reports* 10 (2009): 1082–1086.
5. S. C. Bischoff and M. Zeitz, Scientific evidence for the medical use of probiotics, *Annals of Nutrition and Metabolism* 57 (2010): S1–S5; N. T. Williams, Probiotics, *American Journal of Health System Pharmacy* 15 (2010): 449–458; M. E. Sanders, How do we know when something called "probiotic" is really a probiotic? A guideline for consumers and health care professionals, *Functional Food Reviews* 1 (2009): 3–12.
6. K. Whelan and C. E. Myers, Safety of probiotics in patients receiving nutritional support: A systematic review of case reports, randomized controlled trials, and nonrandomized trials, *American Journal of Clinical Nutrition* 91 (2010): 687–703.
7. I. Trebichavsky and coauthors, Cross-talk of human gut with bifidobacteria, *Nutrition Reviews* 67 (2009): 77–82; N. G. Hord, Eukaryotic-microbiota crosstalk: Potential mechanisms for health benefits of prebiotics and probiotics, *Annual Review of Nutrition* 28 (2008): 215–231.
8. A. Stengel and Y. Taché, Neuroendocrine control of the gut during stress: Corticotropin-releasing factor signaling pathways in the spotlight, *Annual Review of Physiology* 71 (2009): 219–239.

LEARN IT Outline strategies to prevent or alleviate common GI problems.

Common Digestive Problems

The facts of anatomy and physiology presented in Chapter 3 permit easy understanding of some common problems that occasionally arise in the digestive tract. Food may slip into the airways instead of the esophagus, causing choking. Bowel movements may be loose and watery, as in diarrhea, or painful and hard, as in constipation. Some people complain about belching, while others are bothered by intestinal gas. Sometimes people develop medical problems such as ulcers. This highlight describes some of the symptoms of these common digestive problems and suggests strategies for preventing them (the accompanying glossary defines related terms).



© Corbis Super RF/Alamy

Choking

Sometimes a sip of a beverage or a tiny bit of food "slips down the wrong pipe." The body's first response is to cough, and quite often coughing clears the passage. When someone is truly choking, however, food has slipped into the **trachea** and completely blocked the air passageways (see Figure H3-1). Thus the person cannot cough—or even breathe. Without oxygen, the person may suffer permanent brain damage within 5 minutes—or die. For this reason, it is imperative that everyone learn to recognize the universal distress signal for choking (shown in Figure H3-2) and act promptly.

Because the **larynx** is in the trachea and makes sounds only when air is pushed across it, a person choking will be unable to speak. For this reason, to help a person who is choking, first ask "Can you speak?" If the person is coughing, breathing adequately, or able to speak, do not interfere. Whatever you do, do not hit him on the back as the particle may become lodged more firmly in his air passageway. If the person cannot speak or cough, shout for help and perform the **Heimlich maneuver** (described in Figure H3-2). Almost any food can cause choking, although some are cited more often than others: chunks of meat, hot dogs, nuts, whole grapes, raw carrots, marshmallows, hard or sticky candies, gum, popcorn, and peanut butter. These foods are particularly difficult for young children (especially those 4 years of

GLOSSARY

acid controllers: medications used to prevent or relieve indigestion by suppressing production of acid in the stomach; also called *H2 blockers.* Common brands include Pepcid AC, Tagamet HB, Zantac 75, and Axid AR.

antacids: medications used to relieve indigestion by neutralizing acid in the stomach. Common brands include Alka-Seltzer, Maalox, Rolaids, and Tums.

belching: the release of air or gas from the stomach through the mouth.

bloating: uncomfortable abdominal fullness or distention.

celiac disease: an intestinal disorder in which the inability to absorb the protein portion of gluten results in an immune response that damages intestinal cells, also called *celiac sprue* or *gluten-sensitive enteropathy.*

colitis (ko-LYE-tis): inflammation of the colon.

colonic irrigation: the popular, but potentially harmful practice of "washing" the large intestine with a powerful enema machine.

constipation: the condition of having infrequent or difficult bowel movements.

defecate (DEF-uh-cate): to move the bowels and eliminate waste.

- **defaecare** = to remove dregs

diarrhea: the frequent passage of watery bowel movements.

diverticula (dye-ver-TIC-you-la): sacs or pouches that develop in the weakened areas of the intestinal wall (like bulges in an inner tube where the tire wall is weak).

- **divertir** = to turn aside

diverticulitis (DYE-ver-tic-you-LYE-tis): infected or inflamed diverticula.

- **itis** = infection or inflammation

diverticulosis (DYE-ver-tic-you-LOH-sis): the condition of having diverticula. Diverticulosis affects more than 50 percent of adults in later life.

- **osis** = condition

enema: solution inserted into the rectum and colon to stimulate a bowel movement and empty the lower large intestine.

flatulence: passage of excessive amounts of intestinal gas.

gastroesophageal reflux: the backflow of stomach acid into the esophagus, causing damage to the cells of the esophagus and the sensation of heartburn; commonly known as *heartburn* or *acid indigestion. Gastroesophageal reflux disease (GERD)* is characterized by symptoms of reflux occurring two or more times a week.

Heimlich (HIME-lick) **maneuver (abdominal thrusts):** a technique for dislodging an object from the trachea of a choking person (see Figure H3-2); named for the physician who developed it.

hemorrhoids (HEM-oh-royds): painful swelling of the veins surrounding the rectum.

indigestion: incomplete or uncomfortable digestion, usually accompanied by pain, nausea, vomiting, heartburn, intestinal gas, or belching.

- **in** = not

irritable bowel syndrome: an intestinal disorder of unknown cause. Symptoms include abdominal discomfort and cramping, diarrhea, constipation, or alternating diarrhea and constipation.

larynx (LAIR-inks): the entryway to the trachea that contains the vocal cords; also called the *voice box* (see Figure H3-1).

laxatives: substances that loosen the bowels and thereby prevent or treat constipation.

mineral oil: a purified liquid derived from petroleum and used to treat constipation.

peptic ulcer: a lesion in the mucous membrane of either the stomach (a *gastric ulcer*) or the duodenum (a *duodenal ulcer*).

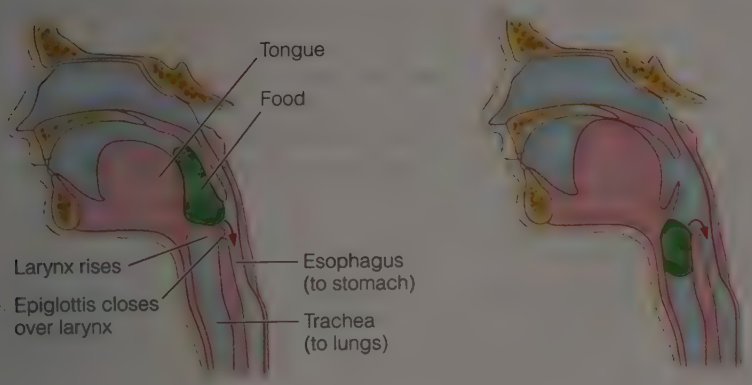
- **peptic** = concerning digestion

trachea (TRAKE-ee-uh): the air passageway from the larynx to the lungs; also called the *windpipe.*

ulcer: a lesion of the skin or mucous membranes characterized by inflammation and damaged tissues. See also *peptic ulcer.*

vomiting: expulsion of the contents of the stomach up through the esophagus to the mouth.

> **FIGURE H3-1** Normal Swallowing and Choking



Swallowing. The epiglottis closes over the larynx, blocking entrance to the lungs via the trachea. The red arrow shows that food is heading down the esophagus normally.

Choking. A choking person cannot speak or gasp because food lodged in the trachea blocks the passage of air. The red arrow points to where the food should have gone to prevent choking.

age and younger) to safely chew and swallow. Each year more than 10,000 children (14 years old or younger) in the United States choke; more than half choke on food. Every 5 days, a child in the United States chokes to death on food.[1] An adult should be present and alert to the dangers of choking whenever young children are eating. To prevent choking, cut food into small pieces, chew thoroughly before swallowing, don't talk or laugh with food in your mouth, and don't eat when breathing hard.

Vomiting

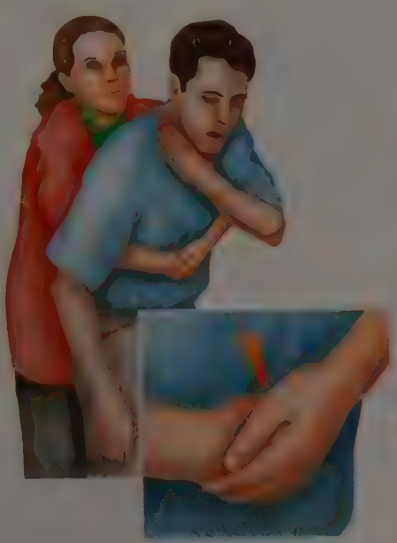
Vomiting can be a symptom of many different diseases or may arise in situations that upset the body's equilibrium, such as air or sea travel. For whatever reason, the contents of the stomach are propelled up through the esophagus to the mouth and expelled. Sometimes the muscular contractions will extend beyond the stomach and carry the contents of the duodenum, with its green bile, into the stomach and then up the esophagus. Although certainly unpleasant and wearying for the nauseated person,

> **FIGURE H3-2** First Aid for Choking

First aid for choking relies on abdominal thrusts, sometimes called the Heimlich maneuver. If abdominal thrusts are not successful and the person loses consciousness, lower him to the floor, call 911, remove the object blocking the airway if possible, and begin CPR. Because there is no time for hesitation when called upon to perform this death-defying act, you would do well to take a life-saving course to learn these techniques.



The universal signal for choking alerts others to the need for assistance.



Stand behind the person with your arms wrapped around him. Make a fist with one hand and place the thumb side snugly against the body, slightly above the navel and below the breastbone.

Grasp the fist with your other hand and make a quick upward and inward thrust. Repeat thrusts until the object is dislodged.



To perform abdominal thrusts on yourself, make a fist and place the thumb below your breastbone and above your navel. Grasp your fist with your other hand and press inward with a quick upward thrust. Alternatively, quickly thrust your upper body against a table edge, chair, or railing.

© Cengage Learning 2013

vomiting is often not a cause for alarm. Vomiting is one of the body's adaptive mechanisms to rid itself of something irritating. The best advice is to rest and drink small amounts of liquids as tolerated until the nausea subsides.

A physician's care may be needed, however, if vomiting causes such large losses of fluid as to threaten dehydration. As fluid is lost from the GI tract, the body's other fluids redistribute themselves, taking fluid from every cell of the body. Fluid leaving the cells is accompanied by salts that are absolutely essential to the life of the cells. Replacing salts and fluid is difficult if the vomiting continues, and intravenous feedings of saline and glucose may be necessary. Vomiting and dehydration are especially serious in an infant, and a physician should be contacted without delay.

Self-induced vomiting, such as occurs in bulimia nervosa, also has serious consequences. In addition to fluid and salt imbalances, repeated vomiting can cause irritation and infection of the pharynx, esophagus, and salivary glands; erosion of the teeth and gums; and dental caries. The esophagus may rupture or tear, as may the stomach. Sometimes the eyes become red from pressure during vomiting. Bulimic behavior reflects underlying psychological problems that require intervention. (Bulimia nervosa is discussed fully in Highlight 8.)

Diarrhea

Diarrhea is characterized by frequent, loose, watery stools. Such stools indicate that the intestinal contents have moved too quickly through the intestines for fluid absorption to take place or that water has been drawn from the cells lining the intestinal tract and added to the food residue. Like vomiting, diarrhea can lead to considerable fluid and salt losses, but the composition of the fluids is different. Stomach fluids lost in vomiting are highly acidic, whereas intestinal fluids lost in diarrhea are nearly neutral. When fluid losses require medical attention, correct replacement is crucial.

Diarrhea is a symptom of various medical conditions and treatments. It may occur abruptly in a healthy person as a result of infections (such as foodborne illness) or as a side effect of medications. When used in large quantities, food ingredients such as the sugar alternative sorbitol and the fat alternative olestra may also cause diarrhea in some people. If a food is responsible, then that food must be omitted from the diet, at least temporarily. If medication is responsible, a different medicine, when possible, or a different form (injectable versus oral, for example) may alleviate the problem. Diarrhea may also occur as a result of disorders of the GI tract, such as irritable bowel syndrome or colitis.

Irritable Bowel Syndrome

Irritable bowel syndrome is one of the most common GI disorders and is characterized by frequent or severe abdominal discomfort and a disturbance in the motility of the GI tract.[2] In most cases, GI contractions are stronger and last longer than normal, forcing intestinal contents through quickly and causing gas, **bloating**, and diarrhea. In some cases, however, GI contractions are weaker than normal, slowing the passage of intestinal contents and causing constipation. The exact cause of irritable bowel syndrome is not known, but researchers are actively investigating the role of the nervous system.[3] The condition seems to worsen for some people when they eat certain foods or during stressful events. These triggers seem to aggravate symptoms but not cause them. Dietary treatment hinges on identifying and avoiding individual foods that aggravate symptoms; small meals may also be beneficial.[4] Other treatments that may be effective include antispasmodic drugs and peppermint oil.[5]

Colitis

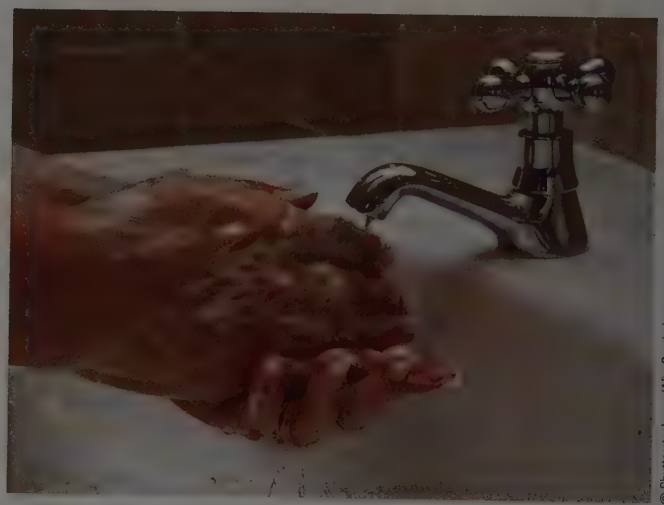
People with **colitis**, an inflammation of the large intestine, may also suffer from severe diarrhea. They often benefit from complete bowel rest and medication. If treatment fails, surgery to remove the colon and rectum may be necessary.

Celiac Disease

Celiac disease is an autoimmune disease characterized by inflammation of the small intestine that occurs in response to foods that contain gluten, a protein commonly found in wheat, barley, rye, and possibly oats. In people with celiac disease, gluten triggers an immune system reaction in the small intestine that causes inflammation, which damages the villi and decreases nutrient absorption. Common symptoms include abdominal pains, bloating and gas, and diarrhea—making it commonly misdiagnosed as irritable bowel syndrome. Treatment focuses on a gluten-free diet.[6]

Treatment

Treatment for diarrhea depends on cause and severity, but it always begins with rehydration. Mild diarrhea may subside with simple rest and extra liquids (such as clear juices and soups) to replace fluid losses.



© Shutterstock.com/Aka Oosthuizen

Personal hygiene (such as regular hand washing with soap and water) and safe food preparation (as described in Chapter 19) are easy and effective steps to take in preventing diarrheal diseases.

If diarrhea is bloody or if it worsens or persists—especially in an infant, young child, elderly person, or person with a compromised immune system—call a physician. Severe diarrhea can be life threatening.

Constipation

Like diarrhea, **constipation** describes a symptom, not a disease. Each person's GI tract has its own cycle of waste elimination, which depends on its owner's health, the type of food eaten, when it was eaten, and when the person takes time to **defecate.** What's normal for some people may not be normal for others. Some people have bowel movements three times a day; others may have them three times a week. The symptoms of constipation include straining during bowel movements, hard stools, and infrequent bowel movements (fewer than three per week). Abdominal discomfort, headaches, backaches, and the passing of gas sometimes accompany constipation.

Often a person's lifestyle may cause constipation. Being too busy to respond to the defecation signal is a common complaint. If a person receives the signal to defecate and ignores it, the signal may not return for several hours. In the meantime, fluids continue to be withdrawn from the fecal matter, so when the person does defecate, the stools are dry and hard. In such a case, a person's daily regimen may need to be revised to allow time to have a bowel movement when the body sends its signal.

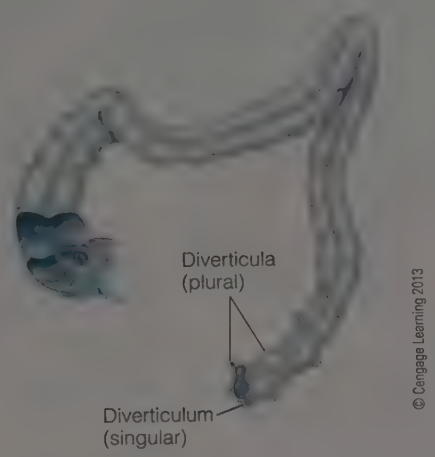
Although constipation usually reflects lifestyle habits, in some cases it may be a side effect of medication or a medical problem such as bowel obstruction. If discomfort is associated with passing fecal matter, seek medical advice to rule out disease. Once this has been done, simple treatments, such as increased fiber, fluids, and exercise, are recommended before the use of medications.

One dietary measure that may be appropriate is to increase dietary fiber to 20 to 25 grams per day gradually over the course of a week or two. Fibers found in fruits, vegetables, and whole grains help to prevent constipation by increasing fecal mass. In the GI tract, fiber attracts water, creating soft, bulky stools that stimulate bowel contractions to push the contents along. These contractions strengthen the intestinal muscles. The improved muscle tone, together with the water content of the stools, eases elimination, reducing the pressure in the rectal veins and helping to prevent **hemorrhoids**. Chapter 4 provides more information on fiber's role in maintaining a healthy colon and reducing the risks of colon cancer and diverticulosis. **Diverticulosis** is a condition in which the intestinal walls develop bulges in weakened areas, most commonly in the colon (see Figure H3-3). These bulging pockets, known as **diverticula**, can worsen constipation, entrap feces, and become painfully infected and inflamed **(diverticulitis)**. Treatment may require hospitalization, antibiotics, or surgery.

Drinking plenty of water in conjunction with eating high-fiber foods also helps to prevent constipation. The increased bulk physically stimulates the upper GI tract, promoting peristalsis throughout. Similarly, physical activity improves the muscle tone and motility of the digestive tract. As little as 30 minutes of physical activity a day can help prevent or alleviate constipation.

Eating prunes—or "dried plums" as some have renamed them—can also be helpful. Prunes are high in fiber and also contain a laxative substance.* If a morning defecation is desired, a person can drink prune juice at bedtime; if the evening is preferred, the person can drink prune juice with breakfast.

> **FIGURE H3-3 Diverticula in the Colon**
> Diverticula may develop anywhere along the GI tract, but they are most common in the colon.



If these suggested changes in lifestyle or diet do not correct constipation, then a physician might recommend the use of stool softeners, **laxatives,** or **mineral oil**. These products are best used for brief periods. If needed for extended times, they should be used under physician supervision. Frequent use of laxatives can lead to dependency and upset the body's fluid, salt, and mineral balances. Mineral oil interferes with the absorption of fat-soluble vitamins.

One potentially harmful but currently popular practice is **colonic irrigation**—the internal washing of the large intestine with a powerful **enema** machine. Such an extreme cleansing is not only unnecessary, but it can be hazardous, causing illness and death from equipment contamination, electrolyte depletion, and intestinal perforation. Less extreme practices can cause problems, too.

Belching and Gas

Many people complain of problems that they attribute to excessive gas. For some, belching is the complaint. Others blame intestinal gas for abdominal discomforts and embarrassment.

Belching

Belching results from swallowing air. Everyone swallows a little bit of air with each mouthful of food, but people who eat too fast may swallow too much air. Ill-fitting dentures, carbonated beverages, and chewing gum can also contribute to the swallowing of air with resultant belching. The best advice for belching seems to be to eat slowly, chew thoroughly, and relax while eating.

Intestinal Gas

Although **flatulence** can be an embarrassing experience, it is quite normal. (People who experience painful bloating from malabsorption diseases,

*This laxative substance is dihydroxyphenyl isatin.



© Polara Studios Inc.

People troubled by intestinal gas need to determine which foods bother them and then eat those foods in moderation.

however, require medical treatment.) Healthy people expel several hundred milliliters of intestinal gas several times a day. Almost all (99 percent) of the gases expelled—nitrogen, oxygen, hydrogen, methane, and carbon dioxide—are odorless. The remaining "volatile" gases are the infamous ones.

Foods that produce gas usually must be determined individually. The most common offenders are foods rich in the carbohydrates—sugars, starches, and fibers. When partially digested carbohydrates reach the large intestine, bacteria digest them, giving off gas as a by-product. People can test foods suspected of forming gas by omitting them individually for a trial period to see if there is any improvement.

Gastroesophageal Reflux

Almost everyone has experienced heartburn at one time or another, usually soon after eating a meal. Medically known as **gastroesophageal reflux**, heartburn is the painful sensation a person feels behind the breastbone when the lower esophageal sphincter allows the stomach contents to reflux into the esophagus (see Figure H3-4).[7] This may happen if a person eats or drinks too much (or both). Tight clothing and even changes of position (lying down, bending over) can cause it, too, as can some medications and smoking. Weight gain and overweight increase the frequency, severity, and duration of heartburn symptoms. A defect of the sphincter muscle itself is a possible, but less common, cause.

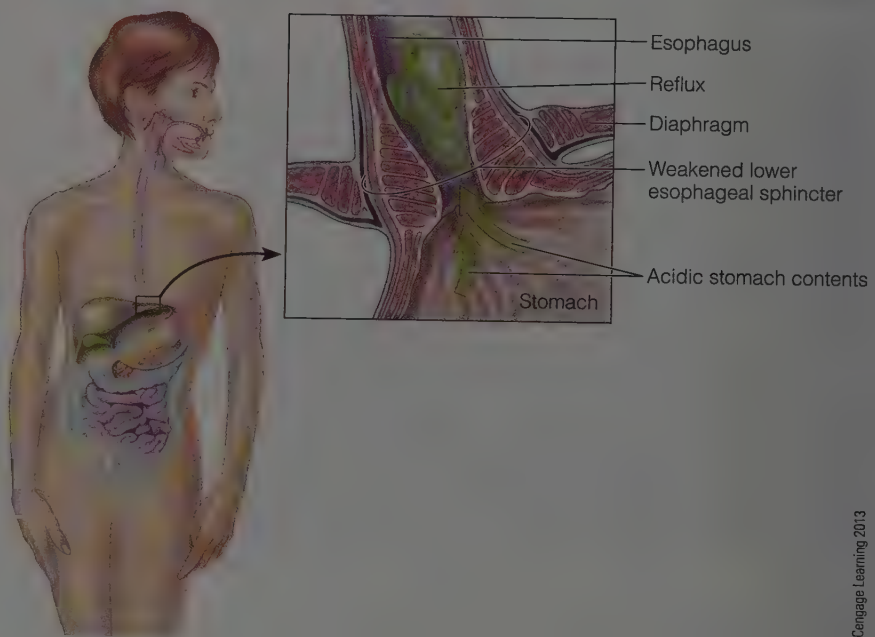
If heartburn is not caused by an anatomical defect, treatment is fairly simple. To avoid such misery in the future, the person needs to learn to eat less at a sitting, chew food more thoroughly, and eat more slowly. Additional strategies are presented in Table H3-1 at the end of this highlight.

People who overeat or eat too quickly are likely to suffer from **indigestion.** The muscular reaction of the stomach to unchewed lumps or to being overfilled may be so intense that it upsets normal peristalsis. When this happens, overeaters may taste the stomach acid and feel pain. Over-the-counter **antacids** and **acid controllers** may provide relief but should be used only infrequently for occasional heartburn; they may mask or cause problems if used regularly. If problems continue, people who suffer from frequent and regular bouts of heartburn and indigestion may need to see a physician, who can prescribe specific medication to control gastroesophageal reflux. Without treatment, the repeated splashes of acid can severely damage the cells of the esophagus, creating a condition known as Barrett's esophagus. At that stage, the risk of cancer in the throat or esophagus increases dramatically.[8] To repeat, if symptoms persist, see a doctor—don't self-medicate.

Ulcers

Ulcers are another common digestive problem, affecting an estimated 1 out of every 12 adults in the United States. An **ulcer** is a lesion (a sore), and a **peptic ulcer** is a lesion in the lining of the stomach (gastric ulcers) or the duodenum of the small intestine (duodenal ulcers). The compromised lining is left unprotected and exposed to gastric juices, which can be painful. In some cases, ulcers can cause internal bleeding. If GI bleeding is excessive, iron deficiency may develop. Ulcers that perforate the GI lining can pose life-threatening complications.

> FIGURE H3-4 Gastroesophageal Reflux



© Cengage Learning 2013

TABLE H3-1 Strategies to Prevent or Alleviate Common GI Problems

GI Problem	Strategies
Choking	• Take small bites of food. • Chew thoroughly before swallowing. • Don't talk or laugh with food in your mouth. • Don't eat when breathing hard.
Diarrhea	• Avoid strenuous activity. • Rest. • Drink fluids to replace losses. • Call for medical help if diarrhea persists.
Constipation	• Eat a high-fiber diet. • Drink plenty of fluids. • Exercise regularly. • Respond promptly to the urge to defecate.
Belching	• Eat slowly. • Chew thoroughly. • Relax while eating.
Intestinal gas	• Eat bothersome foods in moderation.
Heartburn	• Eat small meals. • Drink liquids between meals. • Sit up while eating; elevate your head when lying down. • Wait 3 hours after eating before lying down. • Wait 2 hours after eating before exercising. • Refrain from wearing tight-fitting clothing. • Avoid foods, beverages, and medications that aggravate your heartburn. • Refrain from smoking cigarettes or using tobacco products. • Lose weight if overweight.
Ulcer	• Take medicine as prescribed by your physician. • Avoid coffee and caffeine- and alcohol-containing beverages. • Avoid foods that aggravate your ulcer. • Minimize aspirin, ibuprofen, and naproxen use. • Refrain from smoking cigarettes.

© Cengage Learning 2013

Many people naively believe that an ulcer is caused by stress or spicy foods, but this is not the case. The stomach lining in a healthy person is well protected by its mucous coat. What, then, causes ulcers to form?

Three major causes of ulcers have been identified: bacterial infection with *Helicobacter pylori* (commonly abbreviated *H. pylori*); the use of certain anti-inflammatory drugs such as aspirin, ibuprofen, and naproxen; and disorders that cause excessive gastric acid secretion. Most commonly, ulcers develop in response to *H. pylori* infection. The cause of the ulcer dictates the type of medication used in treatment. For example, people with ulcers caused by infection receive antibiotics, whereas those with ulcers caused by medicines discontinue their use.[9] In addition, all treatment plans aim to relieve pain, heal the ulcer, and prevent recurrence.

The regimen for ulcer treatment is to treat for infection, eliminate any food that routinely causes indigestion or pain, and avoid coffee and caffeine- and alcohol-containing beverages. Both regular and decaffeinated coffee stimulate acid secretion and so aggravate *existing* ulcers.

Ulcers and their treatments highlight the importance of not self-medicating when symptoms persist. People with *H. pylori* infection often take over-the-counter acid controllers to relieve the pain of their ulcers when, instead, they need physician-prescribed antibiotics. Suppressing gastric acidity not only fails to heal the ulcer, but it also actually worsens inflammation during an *H. pylori* infection. Furthermore, *H. pylori* infection has been linked with stomach cancer, making prompt diagnosis and appropriate treatment essential.

Table H3-1 summarizes strategies to prevent or alleviate common GI problems. Many of these problems reflect hurried lifestyles. For this reason, many of their remedies require that people slow down and take the time to eat leisurely; chew food thoroughly to prevent choking, heartburn, and acid indigestion; rest until vomiting and diarrhea subside; and heed the urge to defecate. In addition, people must learn how to handle life's day-to-day problems and challenges without overreacting and becoming upset; learn how to relax, get enough sleep, and enjoy life. Remember, "what's eating you" may cause more GI distress than what you eat.

REFERENCES

1. American Academy of Pediatrics, Policy statement: Prevention of choking among children, *Pediatrics* 125 (2010): 601–607.
2. E. A. Mayer, Irritable bowel syndrome, *New England Journal of Medicine* 358 (2008): 1692–1699.
3. C. M. Surawicz, Mechanisms of diarrhea, *Current Gastroenterology Reports* 12 (2010): 236–241.
4. W. D. Heizer, S. Southern, and S. McGovern, The role of diet in symptoms of irritable bowel syndrome in adults: A narrative review, *Journal of the American Dietetic Association* 109 (2009): 1204–1214.
5. American College of Gastroenterology IBS Task Force, An evidence-based position statement on the management of irritable bowel syndrome, *American Journal of Gastroenterology* 104 (2009): S1–S35; A. C. Ford and coauthors, Effect of fibre, antispasmodics, and peppermint oil in the treatment of irritable bowel syndrome: Systematic review and meta-analysis, *British Journal of Medicine* 337 (2008): a2313.
6. P. Fric, D. Gabrovska, and J. Nevoral, Celiac disease, gluten-free diet, and oats, *Nutrition Reviews* 69 (2011): 107–115.
7. P. J. Kahrilas, Gastroesophageal reflux disease, *New England Journal of Medicine* 359 (2008): 1700–1707.
8. P. Sharma, Barrett's esophagus, *New England Journal of Medicine* 361 (2009): 2548–2556.
9. N. Vakil and D. Vaira, Sequential therapy for *Helicobacter pylori*: Time to consider making the switch? *Journal of the American Medical Association* 300 (2008): 1346–1347.



CENGAGE LEARNING'S GLOBAL NUTRITION — GLOBAL NUTRITION RESOURCE CENTER

Carbohydrates support the quiet work of the brain and the active movement of the muscles. Go to Nutrition Basics and Tools → Carbohydrates to learn how they provide energy to the body. What are the risks and benefits of a low-carbohydrate diet? What other diet choices are needed to support a balanced diet?

4

The Carbohydrates: Sugars, Starches, and Fibers

Nutrition in Your Life

Whether you are studying for an exam or daydreaming about your next vacation, your brain needs carbohydrate to power its activities. Your muscles need carbohydrate to fuel their work, too, whether you are racing up the stairs to class or moving on the dance floor to your favorite music. Where can you get carbohydrate? Are some foods healthier choices than others? As you will learn from this chapter, whole grains, vegetables, legumes, and fruits naturally deliver ample carbohydrate and fiber with valuable vitamins and minerals and little or no fat. Milk products typically lack fiber, but they also provide carbohydrate along with an assortment of vitamins and minerals. In the Nutrition Portfolio at the end of this chapter, you can examine whether your current carbohydrate choices are meeting dietary goals.

A student, quietly studying a textbook, is seldom aware that within his brain cells, billions of glucose molecules are splitting to provide the energy that permits him to learn. Yet glucose provides nearly all of the energy the human brain uses daily. Similarly, a marathon runner, bursting across the finish line in an explosion of sweat and triumph, seldom gives credit to the glycogen fuel her muscles have devoured to help her finish the race. Yet, together, these two **carbohydrates**—glucose and its storage form glycogen—provide about half of all the energy muscles and other body tissues use. The other half of the body's energy comes mostly from fat.

People don't eat glucose and glycogen directly. When they eat foods rich in carbohydrates, their bodies receive glucose for immediate energy and convert some glucose into glycogen for reserve energy. All plant foods—whole grains, vegetables, legumes, and fruits—provide ample carbohydrate. Milk also contains carbohydrate.

Many people mistakenly think of carbohydrates as "fattening" and avoid them when trying to lose weight. Such a strategy may be helpful if the

LEARNING GPS

4.1 The Chemist's View of Carbohydrates 96

LEARN IT Identify the monosaccharides, disaccharides, and polysaccharides common in nutrition by their chemical structures and major food sources.

- Monosaccharides 96
- Disaccharides 98
- Polysaccharides 99

4.2 Digestion and Absorption of Carbohydrates 101

LEARN IT Summarize carbohydrate digestion and absorption.

- Carbohydrate Digestion 101
- Carbohydrate Absorption 103
- Lactose Intolerance 103

4.3 Glucose in the Body 104

LEARN IT Explain how the body maintains its blood glucose concentration and what happens when blood glucose rises too high or falls too low.

- A Preview of Carbohydrate Metabolism 105
- The Constancy of Blood Glucose 106

4.4 Health Effects and Recommended Intakes of Sugars 109

LEARN IT Describe how added sugars can contribute to health problems.

- Health Effects of Sugars 109
- Recommended Intakes of Sugars 112
- Alternative Sweeteners 113

4.5 Health Effects and Recommended Intakes of Starch and Fibers 115

LEARN IT Identify the health benefits of, and recommendations for, starches and fibers.

- Health Effects of Starch and Fibers 115
- Recommended Intakes of Starch and Fibers 118
- From Guidelines to Groceries 118

Highlight 4 Carbs, kCalories, and Controversies 124

LEARN IT Summarize the key scientific evidence behind some of the current controversies surrounding carbohydrates and their kcalories.

carbohydrates: compounds composed of carbon, oxygen, and hydrogen arranged as monosaccharides or multiples of monosaccharides. Most, but not all, carbohydrates have a ratio of one carbon molecule to one water molecule: $(CH_2O)_n$.

- **carbo** = carbon (C)
- **hydrate** = with water (H_2O)

carbohydrates are the concentrated sugars of soft drinks, candies, and cookies, but it is counterproductive if the carbohydrates are from whole grains, vegetables, and legumes. As the next section explains, not all carbohydrates are created equal.

4.1 The Chemist's View of Carbohydrates

LEARN IT Identify the monosaccharides, disaccharides, and polysaccharides common in nutrition by their chemical structures and major food sources.

The dietary carbohydrate family includes:

- Monosaccharides: single sugars
- Disaccharides: sugars composed of pairs of monosaccharides
- Polysaccharides: large molecules composed of chains of monosaccharides

Monosaccharides and disaccharides (the sugars) are sometimes called *simple carbohydrates*, and polysaccharides (starches and fibers) are sometimes called *complex carbohydrates*.

To understand the structure of carbohydrates, look at the atoms within them. Each atom can form a certain number of chemical bonds with other atoms:

- Carbon atoms, four
- Nitrogen atoms, three
- Oxygen atoms, two
- Hydrogen atoms, only one

Chemists represent the bonds as lines between the chemical symbols (such as C, N, O, and H) that stand for the atoms (see Figure 4-1).

Atoms form molecules in ways that satisfy the bonding requirements of each atom. Figure 4-1 includes the structure of ethyl alcohol, the active ingredient of alcoholic beverages, as an example. The two carbons each have four bonds represented by lines; the oxygen has two; and each hydrogen has one bond connecting it to other atoms. Chemical structures always bond according to these rules.

The following list of the most important **sugars** in nutrition symbolizes them as hexagons and pentagons of different colors.* Three are monosaccharides:

- Glucose
- Fructose
- Galactose

Three are disaccharides:

- Maltose (glucose + glucose)
- Sucrose (glucose + fructose)
- Lactose (glucose + galactose)

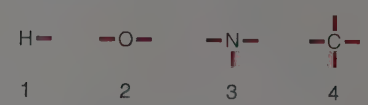
Monosaccharides The three **monosaccharides** most important in nutrition all have the same numbers and kinds of atoms—each contains 6 carbon atoms, 12 hydrogens, and 6 oxygens (written in shorthand as $C_6H_{12}O_6$). The monosaccharides differ in their arrangements of the atoms. These chemical differences account for the differing sweetness of the monosaccharides. A pinch of purified glucose on the tongue gives only a mild sweet flavor, and galactose hardly tastes sweet at all. Fructose, however, is as intensely sweet as honey and, in fact, is the sugar primarily responsible for honey's sweetness.

Glucose Chemically, **glucose** is a larger and more complicated molecule than the ethyl alcohol shown in Figure 4-1, but it obeys the same rules of chemistry: each

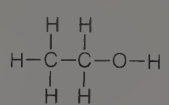
*Fructose is shown as a pentagon, but like the other monosaccharides, it has six carbons (as you will see in Figure 4-3). The disaccharides are illustrated with a simple bond, but actual linkages differ (as shown in Appendix C).

FIGURE 4-1 Atoms and Their Bonds

The four main types of atoms found in nutrients are hydrogen (H), oxygen (O), nitrogen (N), and carbon (C).



Each atom has a characteristic number of bonds it can form with other atoms.



Notice that in this simple molecule of ethyl alcohol, each H has one bond, O has two, and each C has four.

© Cengage Learning 2013

sugars: simple carbohydrates composed of monosaccharides or disaccharides.

monosaccharides (mon-oh-SACK-uh-rides): carbohydrates of the general formula $C_nH_{2n}O_n$ that typically form a single ring. The monosaccharides important in nutrition are *hexoses*, sugars with six atoms of carbon and the formula $C_6H_{12}O_6$. See Appendix C for the chemical structures of the monosaccharides.

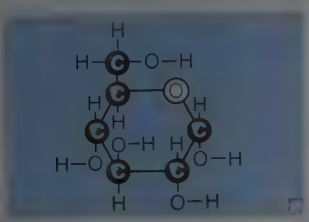
- **mono** = one
- **saccharide** = sugar
- **hex** = six

glucose (GLOO-kose): a monosaccharide; sometimes known as *blood sugar* in the body or *dextrose* in foods.

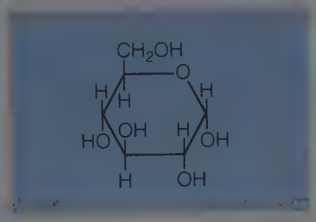
- **ose** = carbohydrate
- = glucose

> FIGURE 4-2 Chemical Structure of Glucose

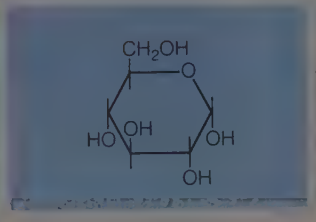
The diagram of a glucose molecule on the left shows all the bonds between the 6 carbon (C), 12 hydrogen (H), and 6 oxygen (O) atoms. It proves simple on examination, but chemists have adopted shortcuts to depict chemical structures. The middle and right diagrams also present the chemical structure of glucose, but as simplified versions with fewer symbols and bonds showing.



On paper, the structure of glucose has to be drawn flat, but in nature the five carbons and oxygen are roughly in a plane. The atoms attached to the ring carbons extend above and below the plane.



The lines representing some of the bonds and the carbons at the corners are not shown.



Now the single hydrogens are not shown, but lines still extend upward or downward from the ring to show where they belong.

© Cengage Learning 2013

carbon atom has four bonds; each oxygen, two bonds; and each hydrogen, one bond. Figure 4-2 illustrates the chemical structure of a glucose molecule.

Commonly known as blood sugar, glucose serves as an essential energy source for all the body's activities. Its significance to nutrition is tremendous. Later sections explain that glucose is one of the two sugars in every disaccharide and the unit from which the polysaccharides are made almost exclusively. One of these polysaccharides, starch, is the chief food source of energy for all the world's people; another, glycogen, is an important storage form of energy in the body. Glucose reappears frequently throughout this chapter and all those that follow.

Fructose **Fructose** is the sweetest of the sugars. Curiously, fructose has exactly the same chemical *formula* as glucose—$C_6H_{12}O_6$—but its *structure* differs (see Figure 4-3). The arrangement of the atoms in fructose stimulates the taste buds on the tongue to produce the sweet sensation. Fructose occurs naturally in fruits and honey; other sources include products such as soft drinks, ready-to-eat cereals, and desserts that have been sweetened with high-fructose corn syrup (defined on p. 109).

Galactose The monosaccharide **galactose** occurs naturally in foods as a single sugar only in very small amounts. Galactose has the same numbers and kinds of atoms as glucose and fructose in yet another arrangement. Figure 4-3 shows galactose beside a molecule of glucose for comparison.

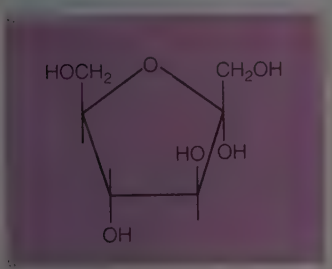


© iStockphoto.com/Kim Gunkel

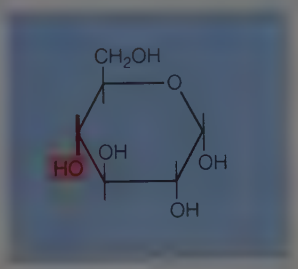
Fruits package their sugars with fibers, vitamins, and minerals, making them a sweet and healthy snack.

> FIGURE 4-3 The Monosaccharides

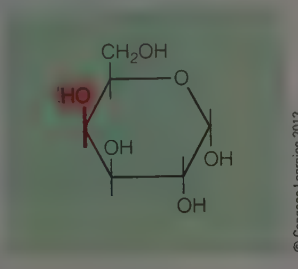
Notice the similarities—all three monosaccharides have 6 carbons (those shown plus one in each corner), 12 hydrogens (those shown plus one at the end of each single line), and 6 oxygens (all shown). Also notice the differences compared with glucose—in fructose, the ring is five-sided and in galactose, the position of one OH group differs slightly.



Fructose



Glucose



Galactose

© Cengage Learning 2013

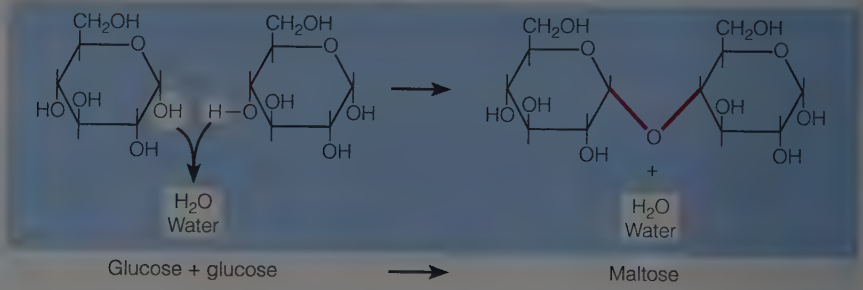
fructose (FRUK-tose or FROOK-tose) a monosaccharide; sometimes known as *fruit sugar* or *levulose*. Fructose is found abundantly in fruits, honey, and saps.

- **fruct** = fruit
- = fructose

galactose (ga-LAK-tose) a monosaccharide; part of the disaccharide lactose.

- = galactose

> **FIGURE 4-4** Condensation of Two Monosaccharides to Form a Disaccharide



© Cengage Learning 2013

Disaccharides The **disaccharides** are pairs of the three monosaccharides just described. Glucose occurs in all three; the second member of the pair is fructose, galactose, or another glucose. These carbohydrates—and all the other energy nutrients—are put together and taken apart by similar chemical reactions: condensation and hydrolysis.

Condensation To make a disaccharide, a chemical reaction known as **condensation** links two monosaccharides together (see Figure 4-4). A hydroxyl (OH) group from one monosaccharide and a hydrogen atom (H) from the other combine to create a molecule of water (H_2O). The two originally separate monosaccharides link together with a single oxygen (O).

Hydrolysis To break a disaccharide in two, a chemical reaction known as **hydrolysis** occurs (see Figure 4-5). A molecule of water (H_2O) splits to provide the H and OH needed to complete the resulting monosaccharides. Hydrolysis reactions commonly occur during digestion.

Maltose The disaccharide **maltose** consists of two glucose units. Maltose is produced whenever starch breaks down—as happens in human beings during carbohydrate digestion. It also occurs during the fermentation process that yields alcohol. Maltose is only a minor constituent of a few foods, most notably barley.

Sucrose Fructose and glucose together form the disaccharide **sucrose**. Sucrose is the sweetest of the disaccharides because it contains fructose, the sweetest of the monosaccharides. These sugars account for the natural sweetness of fruits, vegetables, and grains. To make table sugar, sucrose is refined from the juices of sugarcane and sugar beets, then granulated. Depending on the extent to which it

disaccharides (dye-SACK-uh-rides): pairs of monosaccharides linked together. See Appendix C for the chemical structures of the disaccharides.

- **di** = two

condensation: a chemical reaction in which water is released as two molecules combine to form one larger product.

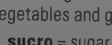
hydrolysis (high-DROL-ih-sis): a chemical reaction in which one molecule is split into two molecules, with hydrogen (H) added to one and a hydroxyl group (OH) to the other (from water, H_2O). (The noun is *hydrolysis;* the verb is *hydrolyze.*)

- **hydro** = water
- **lysis** = breaking

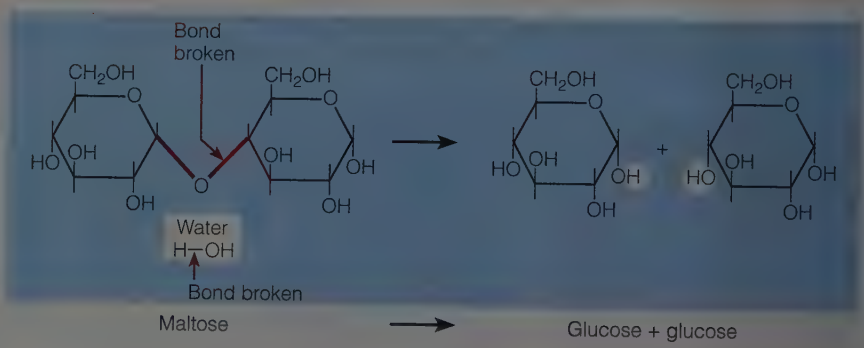
maltose (MAWL-tose): a disaccharide composed of two glucose units; sometimes known as malt sugar.

-  = maltose

sucrose (SUE-krose): a disaccharide composed of glucose and fructose; commonly known as *table sugar, beet sugar,* or *cane sugar.* Sucrose also occurs in many fruits and some vegetables and grains.

- **sucro** = sugar
-  = sucrose

> **FIGURE 4-5** Hydrolysis of a Disaccharide



© Cengage Learning 2013

The disaccharide maltose splits into two glucose molecules with H added to one and OH to the other (from the water molecule).

is refined, the product becomes the familiar brown, white, and powdered sugars available at grocery stores.

Lactose The combination of galactose and glucose makes the disaccharide **lactose**, the principal carbohydrate of milk. Known as milk sugar, lactose contributes half of the energy (kcalories) provided by fat-free milk.

Polysaccharides In contrast to the simple carbohydrates just mentioned—the monosaccharides glucose, fructose, and galactose and the disaccharides maltose, sucrose, and lactose—the **polysaccharides** are slightly more complex, containing many glucose units and, in some cases, a few other monosaccharides strung together. Three types of polysaccharides are important in nutrition: glycogen, starches, and fibers.

Glycogen is a storage form of energy in the body; starch is the storage form of energy in plants; and fibers provide structure in stems, trunks, roots, leaves, and skins of plants. Both glycogen and starch are built of glucose units; fibers are composed of a variety of monosaccharides and other carbohydrate derivatives.

Glycogen Glycogen is found to only a limited extent in meats and not at all in plants.* For this reason, food is not a significant source of glycogen. Glycogen performs an important role in the body, however: it stores glucose for future use. Glycogen is made of many glucose molecules linked together in highly branched chains (see the left side of Figure 4-6). When the hormonal message "release energy" arrives at a liver or muscle cell, enzymes respond by attacking the many branches of glycogen simultaneously, making a surge of glucose available.**

Starches The human body stores glucose as glycogen, but plant cells store glucose as **starches**—long, branched or unbranched chains of hundreds or thousands of glucose molecules linked together (see the middle and right side of Figure 4-6). These giant starch molecules are packed side by side in grains such as wheat or rice, in root crops and tubers such as yams and potatoes, and in legumes such as peas and beans. When you eat the plant, your body hydrolyzes the starch to glucose and uses the glucose for its own energy purposes.

All starchy foods come from plants. Grains are the richest food source of starch, providing much of the food energy for people all over the world—rice in Asia; wheat in Canada, the United States, and Europe; corn in much of Central and

*Glycogen in animal muscles rapidly hydrolyzes after slaughter.

**Normally, liver cells produce glucose from glycogen to be sent directly to the blood; muscle cells can also produce glucose from glycogen, but must use it themselves. Muscle cells can restore the blood glucose level indirectly, however, as Chapter 7 explains.



© Polara Studios, Inc

Major sources of starch include grains (such as rice, wheat, millet, rye, barley, and oats), legumes (such as kidney beans, black-eyed peas, pinto beans, navy beans, and garbanzo beans), tubers (such as potatoes), and root crops (such as yams and cassava).

lactose (LAK-tose): a disaccharide composed of glucose and galactose; commonly known as *milk sugar.*

- **lact** = milk
-  = lactose

polysaccharides: compounds composed of many monosaccharides linked together. An intermediate string of 3 to 10 monosaccharides is an *oligosaccharide.*

- **poly** = many
- **oligo** = few

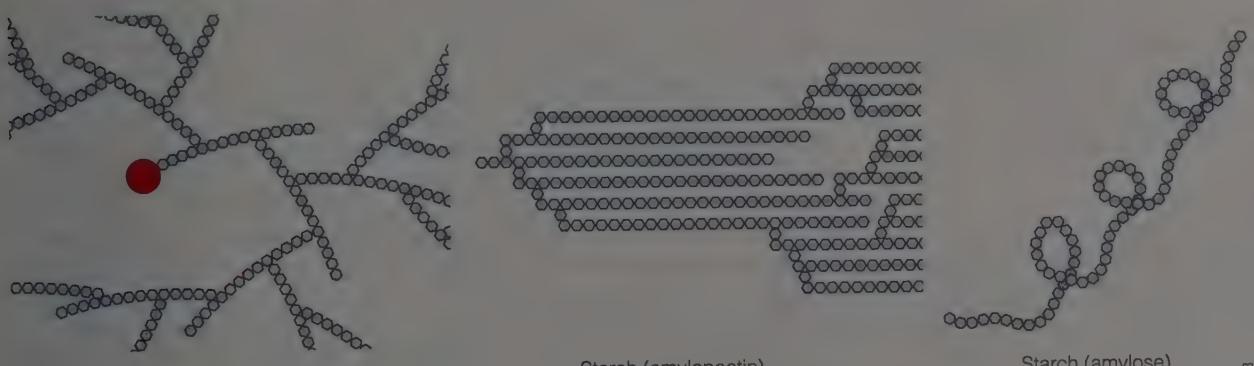
glycogen (GLY-ko-jen): an animal polysaccharide composed of glucose; a storage form of glucose manufactured and stored in the liver and muscles. Glycogen is not a significant food source of carbohydrate and is not counted as a dietary carbohydrate in foods.

- **glyco** = glucose
- **gen** = gives rise to

starches: plant polysaccharides composed of many glucose molecules.

> FIGURE 4-6 Glycogen and Starch Compared

For details of the chemical structures, see Appendix C.



Glycogen

A glycogen molecule contains hundreds of glucose units in highly branched chains. Each new glycogen molecule needs a special protein (shown here in red) for the attachment of the first glucose.

Starch (amylopectin)

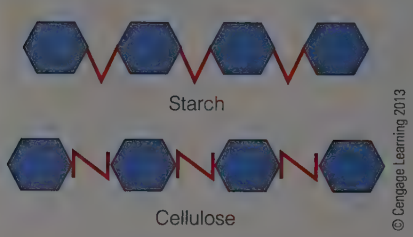
Starch (amylose)

A starch molecule contains hundreds of glucose molecules in either occasionally branched chains (amylopectin) or unbranched chains (amylose).

© Cengage Learning 2013

FIGURE 4-7 The Bonds of Starch and Cellulose Compared

Human enzymes can digest starch but they cannot digest cellulose because the bonds that link the glucose molecules together are different. See Appendix C for chemical structures and descriptions of linkages.



© Cengage Learning 2013

South America; and millet, rye, barley, and oats elsewhere. Legumes and tubers are also important sources of starch.

Fibers **Dietary fibers** are the structural parts of plants and thus are found in all plant-derived foods—vegetables, fruits, whole grains, and legumes. Most dietary fibers are polysaccharides. As mentioned earlier, starches are also polysaccharides, but dietary fibers differ from starches in that the bonds between their monosaccharides cannot be broken down by digestive enzymes in the body. For this reason, dietary fibers are often described as *nonstarch polysaccharides*.* Figure 4-7 illustrates the difference in the bonds that link glucose molecules together in starch with those found in the fiber cellulose. Because dietary fibers pass through the body undigested, they contribute no monosaccharides, and therefore little or no energy.

Even though most foods contain a variety of fibers, researchers often sort dietary fibers into two groups according to their solubility. Such distinctions help to explain their actions in the body.

Some dietary fibers dissolve in water **(soluble fibers)**, form gels **(viscous)**, and are easily digested by bacteria in the colon **(fermentable)**.** Commonly found in oats, barley, legumes, and citrus fruits, soluble fibers are most often associated with protecting against heart disease and diabetes by lowering blood cholesterol and glucose levels, respectively.[1]

Other fibers do not dissolve in water **(insoluble fibers)**, do not form gels (nonviscous), and are less readily fermented. Found mostly in whole grains (bran) and vegetables, insoluble fibers promote bowel movements, alleviate constipation, and prevent diverticular disease.[2]

As mentioned, *dietary fibers* occur naturally in plants. When these fibers have been extracted from plants or are manufactured and then added to foods or used in supplements, they are called *functional fibers*—if they have beneficial health effects. Cellulose in cereals, for example, is a dietary fiber, but when consumed as a supplement to alleviate constipation, cellulose is considered a functional fiber. *Total fiber* refers to the sum of dietary fibers and functional fibers.

A few starches are classified as dietary fibers. Known as **resistant starches**, these starches escape digestion and absorption in the small intestine. Starch may resist digestion for several reasons, including the body's efficiency in digesting starches and the food's physical properties. Resistant starch is common in whole or partially milled grains, legumes, and just-ripened bananas. Cooked potatoes, pasta, and rice that have been chilled also contain resistant starch. Similar to insoluble fibers, resistant starch may support a healthy colon.[3]

Phytic acid is not a dietary fiber, but it is often found in fiber-rich foods. Because of this close association, researchers have been unable to determine whether it is the dietary fiber, the phytic acid, or both, that binds with minerals, preventing their absorption. This binding presents a risk of mineral deficiencies, but the risk is minimal when total fiber intake is reasonable (less than 40 grams a day) and mineral intake is adequate. The nutrition consequences of mineral losses are described further in Chapters 12 and 13.

REVIEW IT Identify the monosaccharides, disaccharides, and polysaccharides common in nutrition by their chemical structures and major food sources.

The carbohydrates are made of carbon (C), oxygen (O), and hydrogen (H). Each of these atoms can form a specified number of chemical bonds: carbon forms four, oxygen forms two, and hydrogen forms one.

The three monosaccharides (glucose, fructose, and galactose) all have the same chemical formula ($C_6H_{12}O_6$), but their structures differ. The three disaccharides (maltose, sucrose, and lactose) are pairs of monosaccharides, each containing a glucose paired with one of the three monosaccharides. The sugars derive primarily from plants, except for lactose and its component galactose, which come from milk and milk products. Two monosaccharides can be linked together by a condensation reaction to form a disaccharide and water. A disaccharide, in turn, can be broken into its two monosaccharides by a hydrolysis reaction using water.

dietary fibers: in plant foods, the *nonstarch polysaccharides* that are not digested by human digestive enzymes, although some are digested by GI tract bacteria.

soluble fibers: nonstarch polysaccharides that dissolve in water to form a gel. An example is pectin from fruit, which is used to thicken jellies.

viscous: a gel-like consistency.

fermentable: the extent to which bacteria in the GI tract can break down fibers to fragments that the body can use.

insoluble fibers: nonstarch polysaccharides that do not dissolve in water. Examples include the tough, fibrous structures found in the strings of celery and the skins of corn kernels.

resistant starches: starches that escape digestion and absorption in the small intestine of healthy people.

phytic (FYE-tick) **acid:** a nonnutrient component of plant seeds; also called *phytate* (FYE-tate). Phytic acid occurs in the husks of grains, legumes, and seeds and is capable of binding minerals such as zinc, iron, calcium, magnesium, and copper in insoluble complexes in the intestine, which the body excretes unused.

*The nonstarch polysaccharide fibers include cellulose, hemicelluloses, pectins, gums, and mucilages. Fibers also include some *nonpolysaccharides* such as lignins, cutins, and tannins.

**Dietary fibers are fermented by bacteria in the colon to short-chain fatty acids, which are absorbed and metabolized by cells in the GI tract and liver (Chapter 5 describes fatty acids).

The polysaccharides are chains of monosaccharides and include glycogen, starches, and dietary fibers. Both glycogen and starch are storage forms of glucose—glycogen in the body, and starch in plants—and both yield energy for human use. The dietary fibers also contain glucose (and other monosaccharides), but their bonds cannot be broken by human digestive enzymes, so they yield little, if any, energy. Table 4-1 summarizes the carbohydrate family of compounds.

TABLE 4-1 The Carbohydrate Family

Monosaccharides
Glucose
Fructose
Galactose
Disaccharides
Maltose (glucose + glucose)
Sucrose (glucose + fructose)
Lactose (glucose + galactose)
Polysaccharides
Glycogen[a]
Starches (amylose and amylopectin)
Fibers (soluble and insoluble)

[a]Glycogen is a polysaccharide, but not a common dietary source of carbohydrate

© Cengage Learning 2013

4.2 Digestion and Absorption of Carbohydrates

LEARN IT Summarize carbohydrate digestion and absorption.

The ultimate goal of digestion and absorption of sugars and starches is to break them into small molecules—chiefly glucose—that the body can absorb and use. The large starch molecules require extensive breakdown; the disaccharides need only be broken once and the monosaccharides not at all. The details follow.

Carbohydrate Digestion Figure 4-8 (p. 102) traces the digestion of carbohydrates through the GI tract. When a person eats foods containing starch, enzymes hydrolyze the long chains to shorter chains, the short chains to disaccharides, and, finally, the disaccharides to monosaccharides.* This process begins in the mouth.

In the Mouth In the mouth, thoroughly chewing high-fiber foods slows eating and stimulates the flow of saliva. The salivary enzyme **amylase** starts to work, hydrolyzing starch to shorter polysaccharides and to the disaccharide maltose. In fact, you can taste the change if you chew a piece of starchy food like a cracker and hold it in your mouth for a few minutes without swallowing it—the cracker begins tasting sweeter as the enzyme acts on it. Because food is in the mouth for a relatively short time, very little carbohydrate digestion takes place there; it begins again in the small intestine.

In the Stomach Carbohydrate digestion ceases in the stomach. The activity of salivary amylase diminishes as the stomach's acid and protein-digesting enzymes inactivate the enzyme. The stomach's digestive juices contain no enzymes to break down carbohydrates. Fibers are not digested, but because they linger in the stomach, they delay gastric emptying, thereby providing a feeling of fullness and **satiety**.

In the Small Intestine The small intestine performs most of the work of carbohydrate digestion. A major carbohydrate-digesting enzyme, pancreatic amylase, enters the intestine via the pancreatic duct and continues breaking down the polysaccharides to shorter glucose chains and maltose. The final step takes place on the outer membranes of the intestinal cells. There specific enzymes break down specific disaccharides:

- **Maltase** breaks maltose into two glucose molecules.
- **Sucrase** breaks sucrose into one glucose and one fructose molecule.
- **Lactase** breaks lactose into one glucose and one galactose molecule.

At this point, all polysaccharides and disaccharides have been broken down to monosaccharides—mostly glucose molecules, with some fructose and galactose molecules as well.

In the Large Intestine Within 1 to 4 hours after a meal, all the sugars and most of the starches have been digested. Only the fibers remain in the digestive tract. Fibers in the large intestine attract water, which softens the stools for passage



When a person eats carbohydrate-rich foods, the body receives a valuable commodity—glucose.

amylase (AM-ih-lace) an enzyme that hydrolyzes amylose (a form of starch). Amylase is a *carbohydrase*, an enzyme that breaks down carbohydrates.

satiety (sah-TIE-eh-tee) the feeling of fullness and satisfaction that occurs after a meal and inhibits eating until the next meal. Satiety determines how much time passes between meals.

- **sate** = to fill

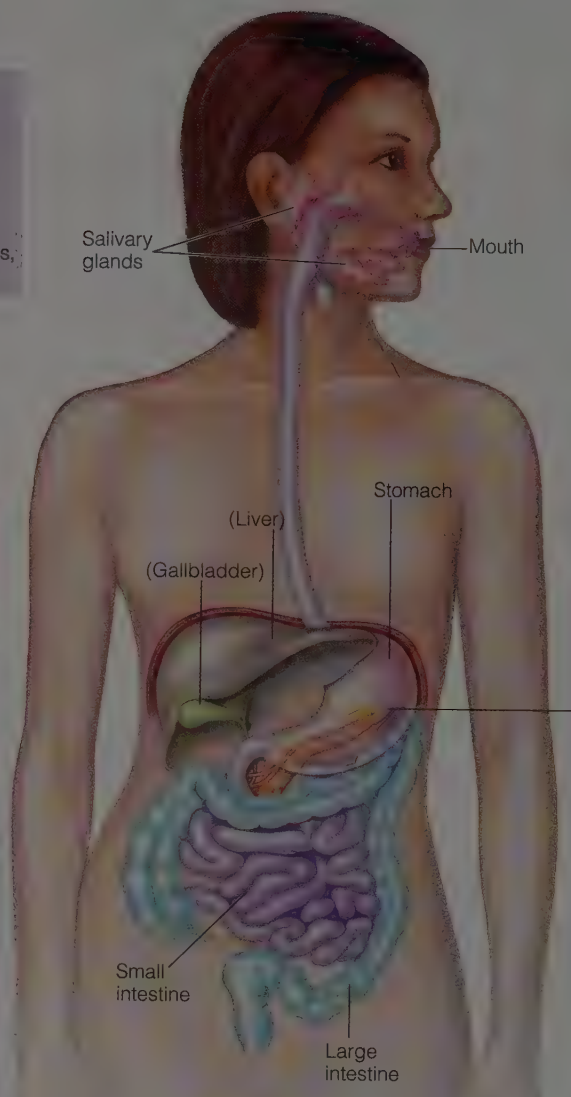
maltase: an enzyme that hydrolyzes maltose.

sucrase: an enzyme that hydrolyzes sucrose.

lactase: an enzyme that hydrolyzes lactose.

*The short chains of glucose units that result from the breakdown of starch are known as *dextrins*. The word sometimes appears on food labels because dextrins can be used as thickening agents in processed foods.

> **FIGURE 4-8** Carbohydrate Digestion in the GI Tract



© Cengage Learning 2013

without straining. Also, bacteria in the GI tract ferment some fibers. This process generates water, gas, and short-chain fatty acids (described in Chapter 5).* The cells of the colon use these small fat molecules for energy. Metabolism of short-chain fatty acids also occurs in the cells of the liver. Fibers, therefore, can contribute some energy (1.5 to 2.5 kcalories per gram), depending on the extent to which they are broken down by bacteria and the fatty acids are absorbed. How much energy fiber contributes to a person's daily intake remains unclear.[4]

*The short-chain fatty acids produced by GI bacteria are primarily acetic acid, propionic acid, and butyric acid.

Carbohydrate Absorption Glucose is unique in that it can be absorbed to some extent through the lining of the mouth, but for the most part, nutrient absorption takes place in the small intestine. Glucose and galactose enter the cells lining the small intestine by active transport; fructose is absorbed by facilitated diffusion.

As the blood from the small intestine circulates through the liver, cells there take up fructose and galactose and most often convert them to compounds within the same metabolic pathways as glucose. Figure 4-9 shows that fructose and galactose are mostly metabolized in the liver, whereas glucose is sent out to the body's cells for energy. In the end, all disaccharides provide at least one glucose molecule directly, and they can provide the equivalent of another one indirectly—through the metabolism of fructose and galactose in the liver.

Lactose Intolerance Normally, the intestinal cells produce enough of the enzyme lactase to ensure that the disaccharide lactose found in milk is both digested and absorbed efficiently. Lactase activity is highest immediately after birth, as befits an infant whose first and only food for a while will be breast milk or infant formula. In the great majority of the world's populations, lactase activity declines dramatically during childhood and adolescence to about 5 to 10 percent of the activity at birth. Only a relatively small percentage (about 30 percent) of the people in the world retain enough lactase to digest and absorb lactose efficiently throughout adult life.

Symptoms When more lactose is consumed than the available lactase can handle, lactose molecules remain in the intestine undigested, attracting water and causing bloating, abdominal discomfort, and diarrhea—the symptoms of **lactose intolerance**. The undigested lactose becomes food for intestinal bacteria, which multiply and produce irritating acid and gas, further contributing to the discomfort and diarrhea.

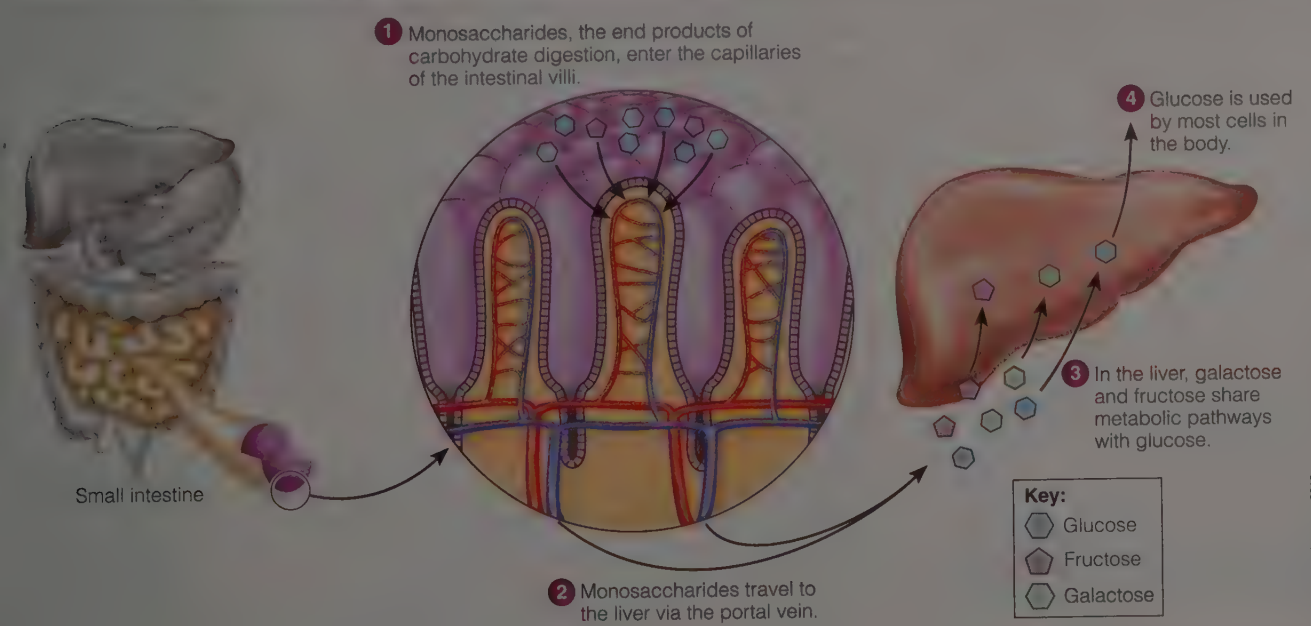
Causes As mentioned, lactase activity commonly declines with age. **Lactase deficiency** may also develop when the intestinal villi are damaged by disease, certain medicines, prolonged diarrhea, or malnutrition. Depending on the extent of the intestinal damage, lactose malabsorption may be temporary or permanent. In extremely rare cases, an infant is born with a lactase deficiency, making feeding a challenge.

Prevalence The prevalence of lactose intolerance varies widely among ethnic groups, indicating that the trait has a genetic component. The prevalence of

lactose intolerance: a condition that results from the inability to digest the milk sugar lactose; characterized by bloating, gas, abdominal discomfort, and diarrhea. Lactose intolerance differs from milk allergy, which is caused by an immune reaction to the protein in milk.

lactase deficiency: a lack of the enzyme required to digest the disaccharide lactose into its component monosaccharides (glucose and galactose).

> **FIGURE 4-9 Absorption of Monosaccharides**



© Cengage Learning 2013

lactose intolerance is lowest among Scandinavians and other northern Europeans and highest among native North Americans and Southeast Asians. An estimated 30 to 50 million people in the United States are lactose intolerant.

Dietary Changes Managing lactose intolerance requires some dietary changes, although total elimination of milk products usually is not necessary.[5] Excluding all milk products from the diet can lead to nutrient deficiencies because these foods are a major source of several nutrients, notably the mineral calcium, vitamin D, and the B vitamin riboflavin. Fortunately, many people with lactose intolerance can consume foods containing up to 6 grams of lactose (½ cup milk) without symptoms. The most successful strategies are to increase intake of milk products gradually, consume them with other foods in meals, and spread their intake throughout the day. In addition, yogurt containing live bacteria seems to improve lactose intolerance. A change in the type, number, and activity of GI bacteria—not the reappearance of the missing enzyme—accounts for the ability to adapt to milk products.[6] Importantly, most lactose-intolerant individuals need to *manage* their dairy consumption rather than *restrict* it.

In many cases, lactose-intolerant people can tolerate fermented milk products such as yogurt and **kefir**. The bacteria in these products digest lactose for their own use, thus reducing the lactose content. Even when the lactose content is equivalent to milk's, yogurt produces fewer symptoms. Hard cheeses, such as cheddar, and cottage cheese are often well tolerated because most of the lactose is removed with the whey during manufacturing. Lactose continues to diminish as cheese ages.

Many lactose-intolerant people use commercially prepared milk products (such as Lactaid) that have been treated with an enzyme that breaks down the lactose. Alternatively, they take enzyme tablets with meals or add enzyme drops to their milk. The enzyme hydrolyzes much of the lactose in milk to glucose and galactose, which lactose-intolerant people can absorb without ill effects.

Because people's tolerance to lactose varies widely, lactose-restricted diets must be highly individualized. A completely lactose-free diet can be difficult because lactose appears not only in milk and milk products but also as an ingredient in many nondairy foods such as breads, cereals, breakfast drinks, salad dressings, and cake mixes (see Table 4-2). People on strict lactose-free diets need to read labels and avoid foods that include milk, milk solids, whey (milk liquid), and casein (milk protein, which may contain traces of lactose). They also need to check all medications with the pharmacist because 20 percent of prescription drugs and 5 percent of over-the-counter drugs contain lactose as a filler.

People who consume few milk products must take care to meet riboflavin, vitamin D, and calcium needs. Later chapters on the vitamins and minerals offer help with finding good nonmilk sources of these nutrients.

TABLE 4-2 Lactose in Selected Foods

Foods	Lactose (g)
Whole-wheat bread, 1 slice	0.5
Dinner roll, 1	0.5
Cheese, 1 oz	
Cheddar or American	0.5
Parmesan or cream	0.8
Doughnut (cake type), 1	1.2
Chocolate candy, 1 oz	2.3
Sherbet, 1 c	4.0
Cottage cheese (low-fat), 1 c	7.5
Ice cream, 1 c	9.0
Milk, 1 c	12.0
Yogurt (low-fat), 1 c	15.0

NOTE: Yogurt is often enriched with nonfat milk solids, which increase its lactose content to a level higher than milk's.

© Cengage Learning 2013

REVIEW IT Summarize carbohydrate digestion and absorption.

In the digestion and absorption of carbohydrates, the body breaks down starches into the disaccharide maltose. Maltose and the other disaccharides (lactose and sucrose) from foods are broken down into monosaccharides, which are absorbed. The fibers help to regulate the passage of food through the GI system and slow the absorption of glucose, but they contribute little, if any, energy.

Lactose intolerance is a common condition that occurs when there is insufficient lactase to digest the disaccharide lactose found in milk and milk products. Symptoms are limited to GI distress. Because treatment requires limiting milk and milk products from the diet, other sources of riboflavin, vitamin D, and calcium must be included.

4.3 Glucose in the Body

LEARN IT Explain how the body maintains its blood glucose concentration and what happens when blood glucose rises too high or falls too low.

The primary role of the available carbohydrates in the body is to supply the cells with glucose for energy. Starch contributes most to the body's glucose supply, but any of the other monosaccharides can also provide glucose if needed.

kefir (keh-FUR): a fermented milk created by adding *Lactobacillus acidophilus* and other bacteria that break down lactose to glucose and galactose, producing a sweet, lactose-free product.

Scientists have long known that providing energy is glucose's primary role in the body, but they have recently uncovered additional roles that glucose and other sugars perform in the body.* When sugar molecules adhere to the body's protein and fat molecules, the consequences can be dramatic. Sugars attached to a protein change the protein's shape and function; when they bind to lipids in a cell's membranes, sugars alter the way cells recognize one another.**

A Preview of Carbohydrate Metabolism Glucose plays the central role in carbohydrate metabolism. This brief discussion provides just enough information about carbohydrate metabolism to illustrate that the body needs and uses glucose as a chief energy nutrient. Chapter 7 provides a full description of energy metabolism, and Chapter 10 shows how the B vitamins participate.

Storing Glucose as Glycogen After a meal, blood glucose rises, and liver cells link excess glucose molecules by condensation reactions into long, branching chains of glycogen (review Figure 4-6, p. 99). When blood glucose falls, the liver cells break down glycogen by hydrolysis reactions into single molecules of glucose and release them into the bloodstream. Thus glucose becomes available to supply energy to the brain and other tissues regardless of whether the person has eaten recently.

The liver stores about one-third of the body's total glycogen and releases glucose into the bloodstream as needed. Muscle cells can also store glucose as glycogen (the other two-thirds), but muscles hoard most of their supply, using it just for themselves during exercise. The brain maintains a small amount of glycogen, which is thought to provide an emergency energy reserve during times of severe glucose deprivation.

Glycogen holds water and, therefore, is rather bulky. The body can store only enough glycogen to provide energy for relatively short periods of time—less than a day during rest and a few hours at most during exercise. For its long-term energy reserves, for use over days or weeks of food deprivation, the body uses its abundant, water-free fuel, fat, as Chapter 5 describes.

Using Glucose for Energy Glucose fuels the work of most of the body's cells. Inside a cell, a series of reactions can break glucose into smaller compounds that yield energy when broken down completely to carbon dioxide and water (see Chapter 7).

Making Glucose from Protein As mentioned, the liver's glycogen stores last only for hours, not for days. Glucose is the preferred energy source for brain cells, other nerve cells, and developing red blood cells. To keep providing glucose to meet the body's energy needs, a person has to eat carbohydrate-rich foods frequently. Yet people who do not always attend faithfully to their bodies' carbohydrate needs still survive. How do they manage without glucose from dietary carbohydrate? Do they simply draw energy from the other two energy-yielding nutrients, fat and protein? They do draw energy from them, but not simply.

Fat cannot make glucose to any significant extent. The amino acids of protein can be used to make glucose to some extent, but amino acids and proteins have jobs of their own that no other nutrient can perform. Still, when a person does not replenish glucose by eating carbohydrate, body proteins are broken down to make glucose to fuel the brain and other special cells. These body proteins derive primarily from the liver and skeletal muscles.

The conversion of protein to glucose is called **gluconeogenesis**—literally, the making of new glucose. Only adequate dietary carbohydrate can prevent this use of protein for energy, and this role of carbohydrate is known as its **protein-sparing action**.

Making Ketone Bodies from Fat Fragments An inadequate supply of carbohydrate can shift the body's energy metabolism in a precarious direction. With less carbohydrate providing glucose to meet the brain's energy needs, fat takes an alternative



© Brian Leatart/Getty Images

The carbohydrates of grains, vegetables, fruits, and legumes supply most of the energy in a healthful diet.

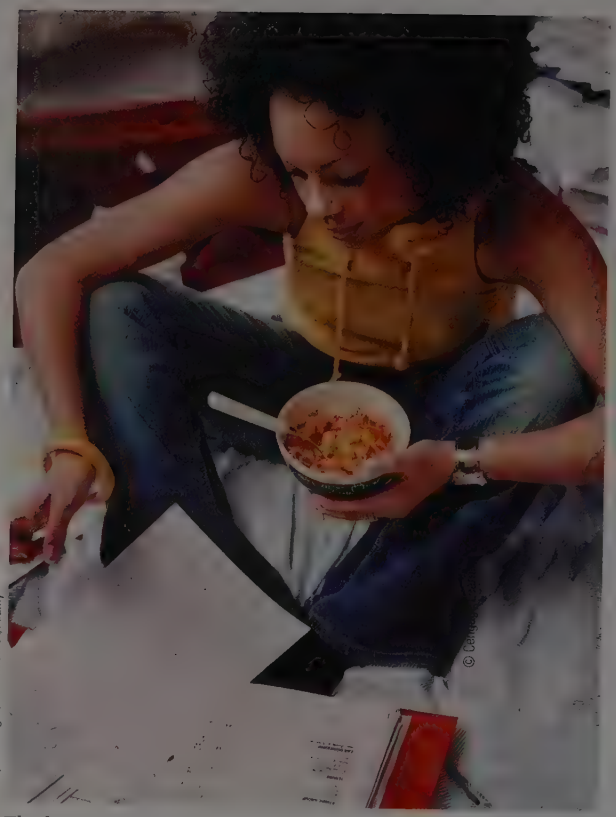
gluconeogenesis (gloo-ko-nee-oh-JEN-ih-sis) the making of glucose from a noncarbohydrate source (described in more detail in Chapter 7).

- **gluco** = glucose
- **neo** = new
- **genesis** = making

protein-sparing action: the action of carbohydrate (and fat) in providing energy that allows protein to be used for other purposes.

*The study of sugars and their derivatives is known as *glycobiology*.

**These combination molecules are known as *glycoproteins* and *glycolipids*, respectively.



© JupiterImages/BananaStock/Alamy

The brain uses glucose as its primary fuel for energy.

metabolic pathway; instead of entering the main energy pathway, fat fragments combine with one another, forming **ketone bodies**. Ketone bodies provide an alternate fuel source during starvation, but when their production exceeds their use, they accumulate in the blood, causing **ketosis**. Because most ketone bodies are acidic, ketosis disturbs the body's normal **acid-base balance**. (Chapter 7 explores ketosis and the metabolic consequences of low-carbohydrate diets further.)

To spare body protein and prevent ketosis, the body needs at least 50 to 100 grams of carbohydrate a day. Dietary recommendations urge people to select abundantly from carbohydrate-rich foods to provide for considerably more.

Using Glucose to Make Fat After meeting its immediate energy needs and filling its glycogen stores to capacity, the body must find a way to handle any extra glucose. When glucose is abundant, energy metabolism shifts to use more glucose instead of fat. If that isn't enough to restore glucose balance, the liver breaks glucose into smaller molecules and puts them together into the more permanent energy-storage compound—fat. Thus when carbohydrate is abundant, fat is either conserved (by using more carbohydrate in the fuel mix) or created (by using excess carbohydrate to make body fat). The fat then travels to the fatty tissues of the body for storage. Unlike the liver cells, which can store only enough glycogen to meet less than a day's energy needs, fat cells can store seemingly unlimited quantities of fat.

The Constancy of Blood Glucose

Every body cell depends on glucose for its fuel to some extent, and the cells of the brain and the rest of the nervous system depend almost exclusively on glucose for their energy. The activities of these cells never cease, and they have limited ability to store glucose. Day and night, they continually draw on the supply of glucose in the fluid surrounding them. To maintain the supply, a steady stream of blood moves past these cells bringing more glucose from either the small intestine (food) or the liver (via glycogen breakdown or gluconeogenesis).

Maintaining Glucose Homeostasis To function optimally, the body must maintain blood glucose within limits that permit the cells to nourish themselves. If blood glucose falls below normal, ♦ a person may become dizzy and weak; if it rises above normal, a person may become fatigued. Left untreated, fluctuations to the extremes—either high or low—can be fatal.

♦ Normal blood glucose (fasting): 70 to 100 mg/dL (published values vary slightly)

The Regulating Hormones Blood glucose homeostasis is regulated primarily by two hormones: *insulin*, which moves glucose from the blood into the cells, and *glucagon*, which brings glucose out of storage when necessary. Figure 4-10 depicts these hormonal regulators at work.

After a meal, as blood glucose rises, special cells of the pancreas respond by secreting **insulin** into the blood.* In general, the amount of insulin secreted corresponds with the rise in glucose. As the circulating insulin contacts the body's cells, receptors respond by ushering glucose from the blood into the cells. Most of the cells take only the glucose they can use for energy right away, but the liver and muscle cells can assemble the small glucose units into long, branching chains of glycogen for storage. The liver cells can also convert extra glucose to fat for export to other cells. Thus elevated blood glucose returns to normal levels as excess glucose is stored as glycogen and fat.

When blood glucose falls (as occurs between meals), other special cells of the pancreas respond by secreting **glucagon** into the blood.** Glucagon raises blood glucose by signaling the liver to break down its glycogen stores and release glucose into the blood for use by all the other body cells.

ketone (KEE-tone) **bodies:** compounds produced during the incomplete breakdown of fat when glucose is not available in the cells.

ketosis (kee-TOE-sis): an undesirably high concentration of ketone bodies in the blood and urine.

acid-base balance: the equilibrium in the body between acid and base concentrations (see Chapter 12).

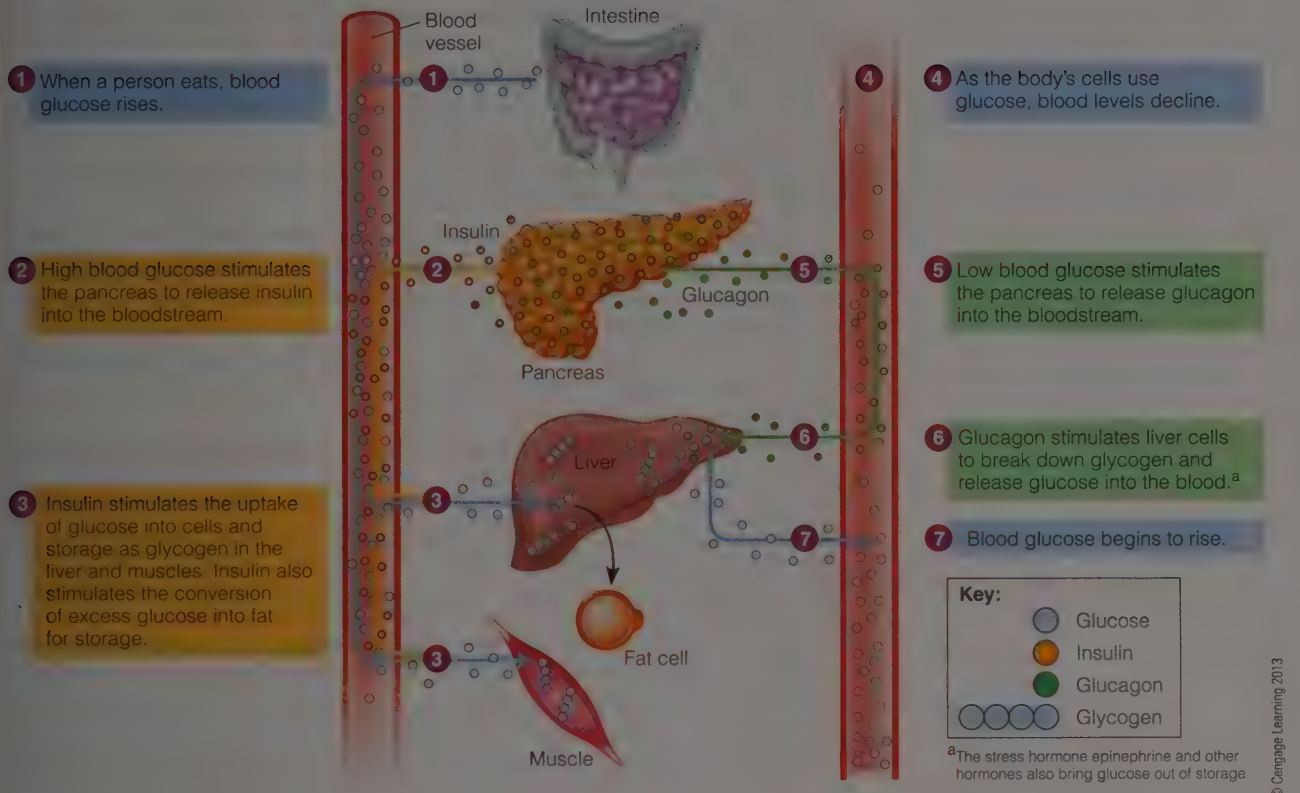
insulin (IN-suh-lin): a hormone secreted by special cells in the pancreas in response to (among other things) elevated blood glucose concentration. Insulin controls the transport of glucose from the bloodstream into the muscle and fat cells.

glucagon (GLOO-ka-gon): a hormone secreted by special cells in the pancreas in response to low blood glucose concentration. Glucagon elicits release of glucose from liver glycogen stores.

*The *beta* (BAY-tuh) *cells*, one of several types of cells in the pancreas, secrete insulin in response to elevated blood glucose concentration.

**The *alpha cells* of the pancreas secrete glucagon in response to low blood glucose concentration.

FIGURE 4-10 Maintaining Blood Glucose Homeostasis



Another hormone that signals the liver cells to release glucose is the "fight-or-flight" hormone, **epinephrine**. When a person experiences stress, epinephrine acts quickly to ensure that all the body cells have energy fuel in emergencies. Among its many roles in the body, epinephrine works to release glucose from liver glycogen to the blood.

Balancing within the Normal Range The maintenance of normal blood glucose depends on foods and hormones. When blood glucose falls below normal, food can replenish it, or in the absence of food, glucagon can signal the liver to break down glycogen stores. When blood glucose rises above normal, insulin can signal the cells to take in glucose for energy. Eating balanced meals that provide abundant carbohydrates, including fibers, and a little fat help to slow down the digestion and absorption of carbohydrate so that glucose enters the blood gradually. Eating at regular intervals also helps the body maintain a balance between the extremes.

Falling outside the Normal Range In some people, blood glucose regulation fails. When this happens, either of two conditions can result: diabetes or hypoglycemia. People with these conditions need to plan their diets and physical activities to help maintain their blood glucose within a normal range.

Diabetes In **diabetes**, blood glucose rises after a meal and remains above normal levels ♦ because insulin is either inadequate or ineffective. Notice that *blood* glucose is central to diabetes, but *dietary* carbohydrate does not cause diabetes.

There are two main types of diabetes. In **type 1 diabetes**, the less common type, the pancreas fails to produce insulin. Although the exact cause is unclear, some research suggests that in genetically susceptible people, certain viruses activate the immune system to attack and destroy cells in the pancreas as if they were foreign cells. In **type 2 diabetes**, the more common type of diabetes, the cells fail to respond to insulin. This condition tends to occur as a consequence of obesity. As the incidence of obesity in the United States has risen in recent decades, the incidence

♦ **Blood glucose (fasting):**
- Prediabetes: 100 to 125 mg/dL
- Diabetes: ≥126 mg/dL

epinephrine (EP-ih-NEFF-rin): a hormone of the adrenal gland that modulates the stress response; formerly called *adrenaline*. When administered by injection, epinephrine counteracts anaphylactic shock by opening the airways and maintaining heartbeat and blood pressure.

diabetes (DYE-uh-BEET-eez): a chronic disorder of carbohydrate metabolism, usually resulting from insufficient or ineffective insulin. When blood glucose levels are higher than normal, but below the diagnosis of diabetes, the condition is called *prediabetes*.

type 1 diabetes: the less common type of diabetes in which the pancreas produces little or no insulin.

type 2 diabetes: the more common type of diabetes in which the cells fail to respond to insulin.

of diabetes has followed. This trend is most notable among children and adolescents as obesity among the nation's youth reaches epidemic proportions. Because obesity can precipitate type 2 diabetes, the best preventive measure is to maintain a healthy body weight.

Concentrated sweets are not strictly excluded from the diabetic diet as they once were; they can be eaten in limited amounts with meals as part of a healthy diet. Chapter 15 describes the type of diabetes that develops in some women during pregnancy (gestational diabetes), and Chapter 18 gives full coverage to type 1 and type 2 diabetes and their associated problems.

Hypoglycemia In healthy people, blood glucose rises after eating and then gradually falls back into the normal range. The transition occurs without notice. Should blood glucose drop below normal, a person would experience the symptoms of **hypoglycemia:** weakness, rapid heartbeat, sweating, anxiety, hunger, and trembling. Most commonly, hypoglycemia is a consequence of poorly managed diabetes: too much insulin, strenuous physical activity, inadequate food intake, or illness that causes blood glucose levels to plummet.

Hypoglycemia in healthy people is rare. Most people who experience hypoglycemia need only adjust their diets by replacing refined carbohydrates with fiber-rich carbohydrates and ensuring an adequate protein intake at each meal. In addition, smaller meals eaten more frequently may help. Hypoglycemia caused by certain medications, pancreatic tumors, overuse of insulin, alcohol abuse, uncontrolled diabetes, or other illnesses requires medical intervention.

The Glycemic Response The **glycemic response** refers to how quickly glucose is absorbed after a person eats, how high blood glucose rises, and how quickly it returns to normal. Slow absorption, a modest rise in blood glucose, and a smooth return to normal are desirable (a low glycemic response). Fast absorption, a surge in blood glucose, and an overreaction that plunges glucose below normal are less desirable (a high glycemic response). The glycemic response may be particularly important to people with diabetes, who may benefit from limiting foods that produce too great a rise, or too sudden a fall, in blood glucose.[7]

♦ Glycemic index generalizations:
- Low: Legumes, milk and milk products
- Moderate: Whole grains, fruits
- High: Processed foods made from refined flour such as snack foods, breads, ready-to-eat cereals

Different foods elicit different glycemic responses; the **glycemic index** classifies foods accordingly. ♦ Some studies have shown that selecting foods with a low glycemic index is a practical way to improve glucose control.[8] Lowering the glycemic index of the diet may improve blood lipids and reduce the risk of heart disease as well.[9] A low glycemic diet may also help with weight management, although research findings are mixed.

Researchers debate whether selecting foods based on the glycemic index is practical or offers any real health benefits.[10] Those opposing the use of the glycemic index argue that it is not sufficiently supported by scientific research. The glycemic index has been determined for relatively few foods, and when the glycemic index has been established, it is based on an average of multiple tests with wide variations in their results. Values vary because of differences in the physical and chemical characteristics of foods, testing methods of laboratories, and digestive processes of individuals.[11]

Furthermore, the practical utility of the glycemic index is limited because this information is neither provided on food labels nor intuitively apparent. Indeed, a food's glycemic index is not always what one might expect. Ice cream, for example, is a high-sugar food but produces less of a glycemic response than baked potatoes, a high-starch food. Perhaps most relevant to real life, a food's glycemic effect differs depending on plant variety, food processing, cooking method, and whether it is eaten alone or with other foods. Most people eat a variety of foods, cooked and raw, that provide different amounts of carbohydrate, fat, and protein—all of which influence the glycemic index of a meal.

Paying attention to the glycemic index may be unnecessary because current guidelines already suggest many low and moderate glycemic index choices: whole grains, legumes, vegetables, fruits, and milk and milk products. In addition, eating frequent, small meals spreads glucose absorption across the day and thus

hypoglycemia (HIGH-po-gly-SEE-me-ah): an abnormally low blood glucose concentration.

glycemic (gly-SEEM-ic) **response:** the extent to which a food raises the blood glucose concentration and elicits an insulin response.

glycemic index: a method of classifying foods according to their potential for raising blood glucose.

offers similar metabolic advantages to eating foods with a low glycemic response. People wanting to follow a low glycemic diet should be careful not to adopt a low carbohydrate diet as well. Highlight 4 explores the controversies surrounding low-carbohydrate and high-glycemic diets.

REVIEW IT Explain how the body maintains its blood glucose concentration and what happens when blood glucose rises too high or falls too low.

Dietary carbohydrates provide glucose that can be used by the cells for energy, stored by the liver and muscles as glycogen, or converted into fat if intakes exceed needs. All of the body's cells depend on glucose; those of the central nervous system are especially dependent on it. Without glucose, the body is forced to break down its protein tissues to make glucose and to alter energy metabolism to make ketone bodies from fats. Blood glucose regulation depends primarily on two pancreatic hormones: insulin to move glucose from the blood into the cells when levels are high and glucagon to free glucose from glycogen stores and release it into the blood when levels are low.

4.4 Health Effects and Recommended Intakes of Sugars

LEARN IT Describe how added sugars can contribute to health problems.

Almost everyone finds pleasure in sweet foods—after all, the taste preference for sweets is inborn. To a child, the sweeter the food, the better. In adults, this preference is somewhat diminished, but most adults still enjoy an occasional sweet food or beverage.

In the United States, the natural sugars of milk, fruits, vegetables, and grains account for about half of the sugar intake; the other half consists of concentrated sugars that have been refined and added to foods for a variety of purposes. ♦ The use of added sugars has risen steadily over the past several decades, both in the United States and around the world, with soft drinks and sugared fruit drinks accounting for most of the increase. These added sugars assume various names on food labels: sucrose, invert sugar, corn sugar, corn syrups and solids, high-fructose corn syrup, and honey. A food is likely to be high in added sugars if its ingredient list starts with any of the sugars named in the accompanying glossary or if it includes several of them.

♦ As an additive, sugar:
- Enhances flavor
- Supplies texture and color to baked goods
- Provides fuel for fermentation, causing bread to rise or producing alcohol
- Acts as a bulking agent in ice cream and baked goods
- Acts as a preservative in jams
- Balances the acidity of tomato- and vinegar-based products

Health Effects of Sugars

In moderate amounts, sugars add pleasure to meals without harming health.[12] In excess, however, sugars can be detrimental, and the average American diet currently delivers excessive amounts. The *Dietary Guidelines* caution that added sugars may increase the risk of certain chronic diseases—even in the absence of overweight or obesity.[13]

GLOSSARY OF ADDED SUGARS

brown sugar: refined white sugar crystals to which manufacturers have added molasses syrup with natural flavor and color; 91 to 96 percent pure sucrose.

confectioners' sugar: finely powdered sucrose, 99.9 percent pure.

corn sweeteners: corn syrup and sugars derived from corn.

corn syrup: a syrup made from cornstarch that has been treated with acid, high temperatures, and enzymes to produce glucose, maltose, and dextrins. It may be dried and used as *corn syrup solids*. See also *high-fructose corn syrup (HFCS)*.

dextrose: the name food manufacturers use for the sugar that is chemically the same as glucose.

high-fructose corn syrup (HFCS): a syrup made from cornstarch that has been treated with an enzyme that converts some of the glucose to the sweeter fructose; made especially for use in processed foods and beverages, where it is the predominant sweetener. With a chemical structure similar to sucrose, HFCS has a fructose content of 42, 55, or 90 percent, with glucose making up the remainder.

honey: sugar (mostly sucrose) formed from nectar gathered by bees. Composition and flavor vary, but honey always contains a mixture of sucrose, fructose, and glucose.

invert sugar: a mixture of glucose and fructose formed by the hydrolysis of sucrose in a chemical process; sold only in liquid form and sweeter than sucrose. Invert sugar is used as a food additive to help preserve freshness and prevent shrinkage.

levulose: an older name for fructose.

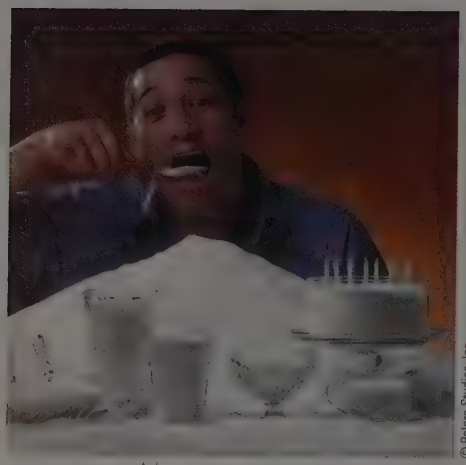
maple sugar: a sugar (mostly sucrose) purified from the concentrated sap of the sugar maple tree.

molasses: the thick brown syrup produced during sugar refining. Molasses retains residual sugar and other by-products and a few minerals; blackstrap molasses contains significant amounts of calcium and iron.

raw sugar: the first crop of crystals harvested during sugar processing. Raw sugar cannot be sold in the United States because it contains too much filth (dirt, insect fragments, and the like). Sugar sold as "raw sugar" domestically has actually gone through more than half of the refining steps.

turbinado (ter-bih-NOD-oh) **sugar:** sugar produced using the same refining process as white sugar, but without the bleaching and anticaking treatment. Traces of molasses give turbinado its sandy color.

white sugar: granulated sucrose or "table sugar," produced by dissolving, concentrating, and recrystallizing raw sugar.



© Polara Studios, Inc.

Almost half of the added sugars in our diet come from sugar-sweetened beverages, but baked goods, ice cream, candy, and breakfast cereals also make substantial contributions.

Obesity and Chronic Diseases Over the past several decades, as obesity rates increased sharply, consumption of added sugars reached an all-time high—much of it because high-fructose corn syrup use, especially in beverages, surged.[14] High-fructose corn syrup is composed of fructose and glucose in a ratio of roughly 50:50. Compared with sucrose, high-fructose corn syrup is less expensive, easier to use, and more soluble. Manufacturers prefer high-fructose corn syrup because it retains moisture, resists drying out, controls crystallization, prevents microbial growth and blends easily with other sweeteners, acids, and flavorings. In addition to being used in beverages, high-fructose corn syrup sweetens candies, baked goods, and hundreds of other foods.

In general, the energy intake of people who drink soft drinks, fruit punches, and other sugary beverages is greater than those who choose differently.[15] Adolescents, for example, who drink as much as 26 ounces or more (about two cans) of sugar-sweetened soft drinks daily, consume 400 more kcalories a day than teens who don't. Not too surprisingly, they also tend to weigh more.[16] Overweight children and adolescents consume more sweet desserts and soft drinks than their normal-weight peers. Research confirms that consuming sugary beverages correlates with increases in energy intake, body weight, and associated diseases.[17]

Some research suggests that added sugars in general, and fructose in particular, favor the fat-making pathways and impair the fat-clearing pathways in the body.[18] The resulting blood lipid profile increases the risk of heart disease.[19] As the liver busily makes lipids, its handling of glucose becomes unbalanced and insulin resistance develops—an indicator of prediabetes.[20] All in all, research is finding links between added sugars and the risk of diabetes, inflammation, hypertension, and heart disease.[21]

Nutrient Deficiencies Foods such as whole grains, vegetables, legumes, and fruits that contain some natural sugars and lots of starches and fibers provide protein, vitamins, and minerals. By comparison, foods and beverages that contain lots of added sugars such as cakes, candies, and sodas provide the body with glucose and energy, but few, if any, other essential nutrients or fiber. The more added sugars (and solid fats) in the diet, the more difficult it is to meet recommendations for dietary fiber, vitamins, and minerals and still stay within kcalorie limits.

A person spending 200 kcalories of a day's energy allowance on a 16-ounce soda gets little of value for those kcalories. In contrast, a person using 200 kcalories on three slices of whole-wheat bread gets 9 grams of protein, 6 grams of fiber, plus several of the B vitamins with those kcalories. For the person who wants something sweet, a reasonable compromise might be two slices of bread with a teaspoon of jam on each. The amount of sugar a person can afford to eat depends on how many discretionary kcalories are available beyond those needed to deliver indispensable vitamins and minerals.

By following the USDA Food Pattern and making careful food selections, a typical adult can obtain all the needed nutrients within an allowance of about 1500 kcalories. An inactive older woman who is limited to fewer than 1500 kcalories a day can afford to eat only the most nutrient-dense foods—with few, or no, discretionary kcalories available. In contrast, an active teenage boy may need as many as 3000 kcalories a day. If he chooses wisely, then he may use discretionary kcalories for nutrient-dense foods that contain added sugars—or even indulge in empty kcalorie choices such as cola beverages. Examples of nutrient-dense foods containing some added sugars include whole-grain breakfast cereals and vanilla yogurt.

Some people believe that because honey is a natural food, it is nutritious—or, at least, more nutritious than sugar.* A look at their chemical structures reveals the truth. Honey, like table sugar, contains glucose and fructose. The primary difference is that in table sugar the two monosaccharides are bonded together as the disaccharide sucrose, whereas in honey some of the monosaccharides are free. Whether a person eats monosaccharides individually, as in honey, or linked together, as in table sugar, they end up the same way in the body: as glucose and fructose.



© Matthew Farruggio

You receive about the same amount and kinds of sugars from an orange as from a tablespoon of honey, but the packaging makes a big nutrition difference.

*Honey should never be fed to infants because of the risk of botulism. Chapters 16 and 19 provide more details.

TABLE 4-3 Sample Nutrients in Sugar and Other Foods

The indicated portion of any of these foods provides approximately 100 kcalories. Notice that for a similar number of kcalories and grams of carbohydrate, foods such as milk, legumes, fruits, grains, and vegetables offer more of the other nutrients than do the sugars.

	Size of 100 kcal Portion	Carbohydrate (g)	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µg)	Vitamin C (mg)
Foods							
Milk, 1% low-fat	1 c	12	8	300	0.1	144	2
Kidney beans	½ c	20	7	30	1.6	0	2
Apricots	6	24	2	30	1.1	554	22
Bread, whole-wheat	1½ slices	20	4	30	1.9	0	0
Broccoli, cooked	2 c	20	12	188	2.2	696	148
Sugars							
Sugar, white	2 tbs	24	0	trace	trace	0	0
Molasses, blackstrap	2½ tbs	28	0	343	12.6	0	0.1
Cola beverage	1 c	26	0	6	trace	0	0
Honey	1½ tbs	26	trace	2	0.2	0	trace

© Cengage Learning 2013

Honey does contain a few vitamins and minerals, but not many. Honey is denser than crystalline sugar, too, so it provides more energy per spoonful. Table 4-3 shows that honey and white sugar are similar nutritionally—and both fall short of milk, legumes, fruits, grains, and vegetables.

Although the body cannot distinguish whether fructose and glucose derive from honey or table sugar, this is not to say that all sugar sources are alike. Some sugar sources are more nutritious than others. Consider a fruit, say, an orange. The fruit may give you the same amounts of fructose and glucose and the same number of kcalories as a spoonful of sugar or honey, but the packaging is more valuable nutritionally. The fruit's sugars arrive in the body diluted in a large volume of water, packaged in fiber, and mixed with essential vitamins, minerals, and phytochemicals.

As these comparisons illustrate, the significant difference between sugar sources is not between "natural" honey and "purified" sugar but between concentrated sugars and the dilute, naturally occurring sugars that sweeten foods. You can suspect an exaggerated nutrition claim when someone asserts that one product is more nutritious than another because it contains honey.

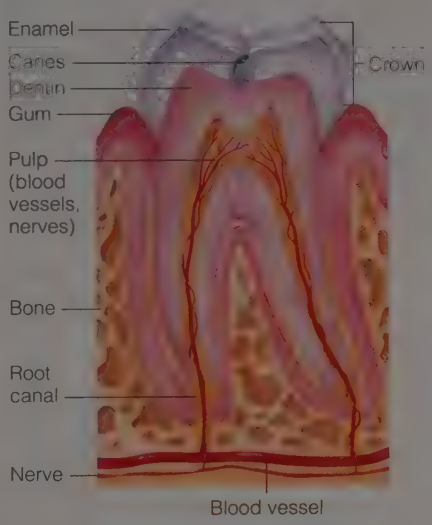
Added sugars contribute to nutrient deficiencies by displacing nutrients. For nutrition's sake, the appropriate attitude to take is not that sugar is "bad" and must be avoided, but that nutritious foods must come first. If nutritious foods crowd sugar out of the diet, that is fine—but not the other way around. As always, balance, variety, and moderation guide healthy food choices.

Dental Caries Both naturally occurring and added sugars from foods and from the breakdown of starches in the mouth can contribute to tooth decay. Bacteria in the mouth ferment the sugars and, in the process, produce an acid that erodes tooth enamel (see Figure 4-11), causing **dental caries**, or tooth decay. People can eat sugar without this happening, though. Much depends on how long foods stay in the mouth. Sticky foods stay on the teeth longer and continue to yield acid longer than foods that are readily cleared from the mouth. For that reason, sugar in a juice consumed quickly, for example, is less likely to cause dental caries than sugar in a pastry. By the same token, the sugar in sticky foods such as raisins can be more detrimental than the quantity alone would suggest.

Another concern is how often people eat sugar. Bacteria produce acid for 20 to 30 minutes after each exposure. If a person eats three pieces of candy at one time, the teeth will be exposed to approximately 30 minutes of acid destruction. But, if the person eats three pieces at half-hour intervals, the time of exposure increases to 90 minutes. Likewise, slowly sipping a sugary sports beverage may be more harmful

> FIGURE 4-11 Dental Caries

Dental caries begins when acid dissolves the enamel that covers the tooth. If not repaired, the decay may penetrate the dentin and spread into the pulp of the tooth, causing inflammation, abscess, and possible loss of the tooth.



dental caries: decay of teeth.
- **caries** = rottenness

than drinking quickly and clearing the mouth of sugar. Nonsugary foods can help remove sugar from tooth surfaces; hence, it is better to eat sugar with meals than between meals. Foods such as milk and cheese may be particularly helpful in protecting against dental caries by neutralizing acids, stimulating salivary flow, inhibiting bacterial activity, and promoting remineralization of damaged enamel.

Beverages such as soft drinks, orange juice, and sports drinks not only contain sugar but also have a low pH. These acidic drinks can erode tooth enamel and may explain why the prevalence of dental erosion is growing steadily.

The development of caries depends on several factors: the bacteria that reside in **dental plaque**, the saliva that cleanses the mouth, the minerals that form the teeth, and the foods that remain after swallowing. For most people, good oral hygiene will prevent ♦ dental caries. In fact, regular brushing (twice a day, with a fluoride toothpaste) and flossing may be more effective in preventing dental caries than restricting sugary foods. Still nutrition is a key component of dental health.[22] *The Dietary Guidelines for Americans* recommend a combined approach to prevent dental caries—practicing good oral hygiene, drinking fluoridated water, and consuming sugar- and starch-containing foods and beverages less frequently.

♦ To prevent dental caries:
- Limit between-meal juices and snacks containing sugars and starches.
- Brush with a fluoride toothpaste and floss teeth regularly.
- If brushing and flossing are not possible, at least rinse with water.
- Get a dental checkup regularly.
- Drink fluoridated water.

Recommended Intakes of Sugars

Estimates indicate that, on average, each person in the United States consumes about 30 teaspoons (about 120 grams) of sugars a day.[23] Most of the sugars in the average American diet are added to foods and beverages by manufacturers during processing; major sources of added sugars include sugar-sweetened beverages (sodas, energy drinks, sports drinks, fruit drinks), desserts, and candy. Some sugars are also added by consumers during food preparation and at the table. Because added sugars deliver kcalories, but few or no nutrients or fiber, the *Dietary Guidelines for Americans* urge consumers to "reduce the intake of kcalories from added sugars." These added sugar kcalories (and those from solid fats and alcohol) are considered discretionary kcalories—and most people need to limit their intake. By reducing the intake of foods and beverages with added sugars, consumers can lower the kcalorie content of the diet without compromising the nutrient content. The accompanying "How To" provides strategies for reducing the intake of added sugars.



> DIETARY GUIDELINES FOR AMERICANS 2010
Reduce the intake of kcalories from added sugars.

♦ 1 tsp white sugar =
- 1 tsp brown sugar
- 1 tsp candy
- 1 tsp corn syrup
- 1 tsp honey or agave nectar
- 1 tsp jam or jelly
- 1 tsp maple sugar or maple syrup
- 1 tsp molasses
- 1½ oz carbonated soda
- 1 tbs ketchup

Estimating the *added* sugars in a diet is not always easy for consumers. Food labels list the *total* grams of sugar a food provides, but this total reflects both added sugars and those occurring naturally in foods. To help estimate sugar and energy intakes accurately, the list in the margin ♦ shows the amounts of concentrated sweets that are equivalent to 1 teaspoon of white sugar. These sugars all provide *about* 5 grams of carbohydrate and *about* 20 kcalories per teaspoon. Some are lower (16 kcalories for table sugar) and others are higher (22 kcalories for honey), but a 20-kcalorie average is an acceptable approximation. For a person who uses ketchup liberally, it may help to remember that 1 tablespoon of ketchup supplies about 1 teaspoon of sugar.

The DRI committee did not publish a Tolerable Upper Intake Level (UL) for sugar, but as mentioned, excessive intakes can interfere with sound nutrition and good health. Few people can eat lots of sugary treats and still meet all of their nutrient needs without exceeding their kcalorie allowance. Specifically, the DRI suggests that added sugars should account for no more than 25 percent of the day's total energy intake.[24] One out of eight in the US population exceeds this maximum intake.[25] When added sugars occupy this much of a diet, intakes from the five food groups usually fall below recommendations. For a person consuming 2000 kcalories a day, 25 percent represents 500 kcalories ♦ (that is, 125 grams, or 31 teaspoons) from concentrated sugars—and that's a lot of sugar. Perhaps an athlete in training whose energy needs are high can afford the added

♦ For perspective, each of these concentrated sugars provides about 500 kcal:
- 40 oz cola
- ½ c honey
- 125 jelly beans
- 23 marshmallows
- 30 tsp sugar

How many kcalories from sugar does your favorite beverage or snack provide?

dental plaque: a gummy mass of bacteria that grows on teeth and can lead to dental caries and gum disease.

How To

Reduce the Intake of Added Sugars

- Use less table sugar when preparing meals and at the table.
- Use your sugar kcalories to sweeten nutrient-dense foods (such as oatmeal) instead of consuming empty kcalorie foods and beverages (such as candy and soda).
- Drink fewer regular sodas, sports drinks, energy drinks, and fruit drinks; choose water, fat-free milk, 100 percent fruit juice, or unsweetened tea or coffee instead. If you do drink sugar-sweetened beverages, have a small portion.
- Select fruit for dessert. Eat less cake, cookies, ice cream, other desserts, and candy. If you do eat these foods, have a small portion.
- Read the Nutrition Facts on a label to choose foods with less sugar. Compare the unsweetened version of a food (such as corn flakes) with the sweetened version (such as frosted corn flakes) to estimate the quantity of added sugars. The quantity of sugars listed in the Nutrition Facts for foods containing little or no milk or fruit are a good estimate of added sugars per serving.
- Read the ingredients list to identify foods with little or no added sugars. A food is likely to be high in added sugars if its ingredient list starts with any of the sugars named in the glossary on p. 109, or if it includes several of them.

TRY IT Compare the energy contents and ingredients lists of 1 cup of the following foods: fruit-flavored yogurt and plain yogurt, sugar-frosted corn flakes and plain corn flakes, orange soda and orange juice.

sugars from sports drinks without compromising nutrient intake, but most people do better by limiting their use of added sugars. Added sugars contribute an average of 16 percent of the total energy in the typical American diet.[26] The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) suggest restricting consumption of added sugars to less than 10 percent of total energy.

Alternative Sweeteners To control weight gain, blood glucose, and dental caries, many consumers turn to alternative sweeteners to help them limit kcalories and minimize sugar intake. In doing so, they encounter three sets of alternative sweeteners: artificial sweeteners, an herbal sweetener, and sugar alcohols.

Artificial Sweeteners Artificial sweeteners are sometimes called **nonnutritive sweeteners** because they provide virtually no energy. Table 4-4 (p. 114) provides general details about each of the sweeteners, including their **Acceptable Daily Intakes (ADI)**. Chapter 9 includes a discussion of their use in weight control and Chapter 19 focuses on some of the safety issues surrounding their use. Considering that all substances are toxic at some dose, it is little surprise that large doses of artificial sweeteners (or their components or metabolic by-products) may have adverse effects. The question to ask is whether their ingestion is safe for human beings in quantities people normally use (and potentially abuse).

Stevia—An Herbal Sweetener The herb stevia derives from a plant whose leaves have long been used by the people of South America to sweeten their beverages. The FDA has granted stevia the status of "generally recognized as safe," and it can be used as an additive in a variety of foods and beverages.

Sugar Alcohols Some "sugar-free" or reduced-kcalorie products contain **sugar alcohols.** ♦ The sugar alcohols (or polyols) occur naturally in fruits and vegetables; manufacturers also use sugar alcohols in many processed foods to add bulk and



© Matthew Farruggio

Consumers use artificial sweeteners to help them limit kcalories and minimize sugar intake.

♦ Examples of sugar alcohols:
- Erythritol
- Isomalt
- Lactitol
- Maltitol
- Mannitol
- Sorbitol
- Xylitol

artificial sweeteners: sugar substitutes that provide negligible, if any, energy; sometimes called *nonnutritive sweeteners.*

nonnutritive sweeteners: sweeteners that yield no energy (or insignificant energy in the case of aspartame).

Acceptable Daily Intake (ADI): the estimated amount of a sweetener that individuals can safely consume each day over the course of a lifetime without adverse effect.

sugar alcohols: sugarlike compounds that can be derived from fruits or commercially produced from dextrose; also called *polyols.* Sugar alcohols are absorbed more slowly than other sugars and metabolized differently in the human body; they are not readily utilized by ordinary mouth bacteria.

TABLE 4-4 Alternative Sweeteners

Sweetener	Chemical Composition	Body's Response	Relative Sweetness[a]	Energy (kcal/g)	Acceptable Daily Intake (ADI) and (Estimated Equivalent)[b]	Approval Status
Artificial Sweeteners						
Acesulfame potassium or Acesulfame K[c] (AY-sul-fame)	Potassium salt	Not digested or absorbed	200	0	15 mg/kg body weight[d] (30 cans diet soda)	Approved for use in the United States and Canada
Aspartame[e] (ah-SPAR-tame or ASS-par-tame)	Amino acids (phenyl-alanine and aspartic acid) and a methyl group	Digested and absorbed	200	4[f]	50 mg/kg body weight[g] (18 cans diet soda)	Approved for use in the United States and Canada; warning for PKU
Cyclamate (SIGH-kla-mate)	Sodium or calcium salt of cyclamic acid	Incompletely absorbed; absorbed cyclamate is excreted unchanged; unabsorbed cyclamate may be metabolized by bacteria in the GI tract	30	0	11 mg/kg body weight (8 cans of diet soda)	Approval pending in the United States; approved for use in Canada
Neotame (NEE-oh-tame)	Aspartame with an additional side group attached	Not digested or absorbed	8000	0	18 mg/day	Approved for use in the United States; no warning for PKU
Saccharin[h] (SAK-ah-ren)	Benzoic sulfimide	Rapidly absorbed and excreted	450	0	5 mg/kg body weight (10 packets of sweetener)	Approved for use in the United States; restricted use as a tabletop sweetener in Canada
Sucralose[i] (SUE-kra-lose)	Sucrose with Cl atoms instead of OH groups	Not digested or absorbed	600	0	5 mg/kg body weight (6 cans diet soda)	Approved for use in the United States and Canada
Tagatose[j] (TAG-ah-tose)	Monosaccharide similar in structure to fructose; naturally occurring or derived from lactose	Mostly not absorbed; some short-chain fatty acids absorbed	0.8	1.5	7.5 g/day	GRAS[k] approved; does not promote dental caries and may carry a health claim
Herbal Sweetener						
Stevia[l] (STEE-vee-ah)	Glycosides found in the leaves of the *Stevia rebaudiana* herb	Digested and absorbed	300	0	4 mg/kg body weight	GRAS[k] approved

[a]Relative sweetness is determined by comparing the approximate sweetness of a sugar substitute with the sweetness of pure sucrose, which has been defined as 1.0. Chemical structure, temperature, acidity, and other flavors of the foods in which the substance occurs all influence relative sweetness.
[b]The Acceptable Daily Intake (ADI) is the estimated amount of a sweetener that individuals can safely consume each day over the course of a lifetime without adverse effects. The Estimated Equivalent is based on a person weighing 70 kg (154 lb).
[c]Marketed under the trade names Sunett, Sweet One.
[d]Recommendations from the World Health Organization limit acesulfame-K intake to 9 mg per kilogram of body weight per day.
[e]Marketed under the trade names NutraSweet, Equal, NatraTaste, Canderel.
[f]Aspartame provides 4 kcal per gram, as does protein, but because so little is used, its energy contribution is negligible. In powdered form, it is sometimes mixed with lactose, however, so a 1 g packet may provide 4 kcal.
[g]Recommendations from the World Health Organization and in Europe and Canada limit aspartame intake to 40 mg per kilogram of body weight per day.
[h]Marketed under the trade names Sweet'N Low, Necta Sweet.
[i]Marketed under the trade names Splenda, SucraPlus.
[j]Marketed under the trade names Nutralose, Nutrilatose, Tagatesse.
[k]GRAS = food additives that are generally recognized as safe. The GRAS list is subject to revision as new facts become known.
[l]Marketed under the trade names Sweetleaf, Purevia, Truvia, Honey Leaf.

© Cengage Learning 2013

texture, to provide a cooling effect or sweet taste, to inhibit browning from heat, and to retain moisture. These products may claim to be "sugar-free" on their labels, but in this case, "sugar-free" does not mean free of kcalories. Sugar alcohols do provide kcalories (0.2 to 2.6 kcalories per gram), but fewer than the sugars. Because sugar alcohols yield energy, they are sometimes referred to as **nutritive sweeteners.**

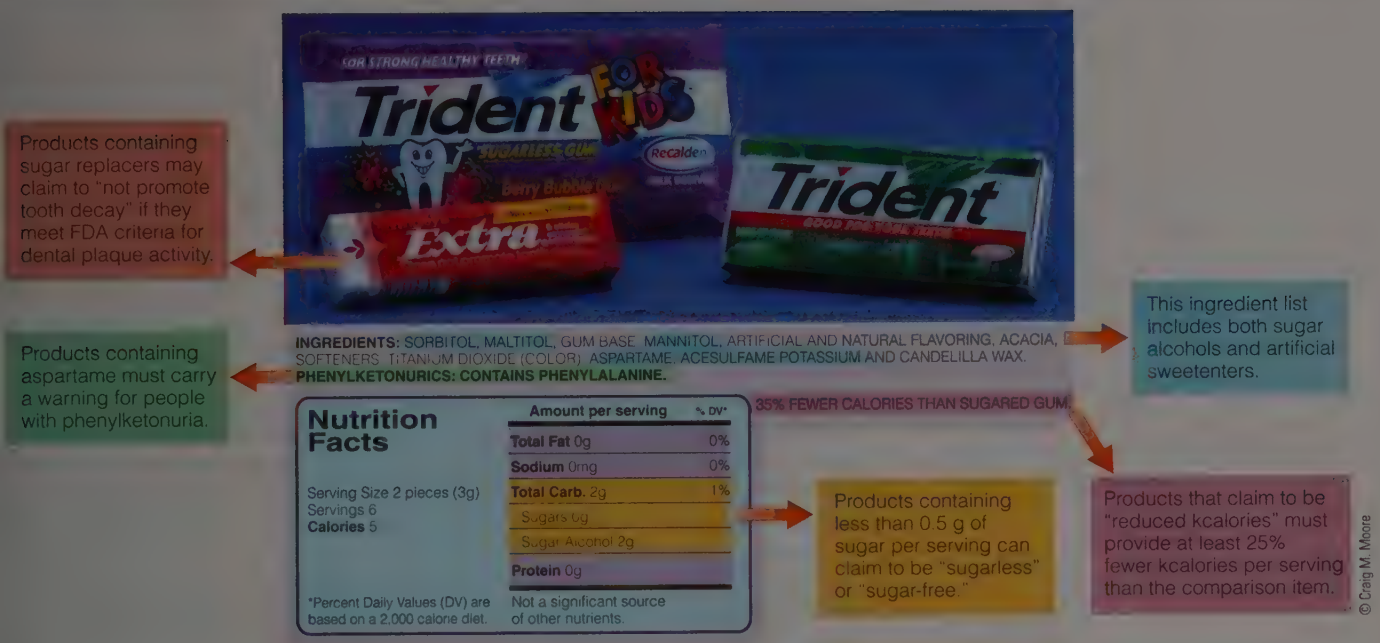
Sugar alcohols evoke a low glycemic response. The body partially absorbs some sugar alcohols and absorbs others slowly; consequently, they are slower to enter the bloodstream than other sugars. Unabsorbed sugar alcohols may be metabolized by bacteria in the GI tract, producing side effects such as intestinal gas, abdominal discomfort, and diarrhea. For this reason, regulations require food labels to state "Excess consumption may have a laxative effect" if reasonable consumption of that food could result in the daily ingestion of 50 grams of a sugar alcohol. ♦

The real benefit of using sugar alcohols is that they do not contribute to dental caries. Bacteria in the mouth cannot metabolize sugar alcohols as rapidly as sugar. Sugar alcohols are therefore valuable in chewing gums, breath mints, and other

♦ For perspective, a low-carbohydrate energy bar or shake may contain 10 to 15 grams of a sugar alcohol.

nutritive sweeteners: sweeteners that yield energy, including both sugars and sugar alcohols.

> **FIGURE 4-12** Sugar Alternatives on Food Labels



products that people keep in their mouths for a while. Figure 4-12 presents labeling information for products using sugar alternatives.

For consumers choosing to use alternative sweeteners, the Academy of Nutrition and Dietetics wisely advises that they be used in moderation and only as part of a well-balanced nutritious diet.[27] When used in moderation, these sweeteners will do no harm. In fact, they may even help, by providing an alternative to sugar for people with diabetes, by inhibiting caries-causing bacteria, and by limiting energy intake. People may find it appropriate to choose from among any of the sweeteners at times: artificial sweeteners, an herbal sweetener, sugar alcohols, and sugar itself.

REVIEW IT Describe how added sugars can contribute to health problems.
Sugars increase the risk of dental caries; excessive intakes displace needed nutrients and fiber and contribute to obesity when energy intake exceeds needs. A person deciding to limit daily sugar intake should recognize that not all sugars need to be restricted, just concentrated sweets, which are relatively empty of other nutrients and high in kcalories. Sugars that occur naturally in fruits, vegetables, and milk are acceptable. Alternative sweeteners may help to limit kcalories and sugar intake.

4.5 Health Effects and Recommended Intakes of Starch and Fibers

LEARN IT Indentify the health benefits of, and recommendations for, starches and fibers.

Carbohydrates and fats are the two major sources of energy in the diet. When one is high, the other is usually low—and vice versa. A diet that provides abundant carbohydrate (45 to 65 percent of energy intake) and some fat (20 to 35 percent of energy intake) within a reasonable energy allowance best supports good health. To increase carbohydrates in the diet, focus on whole grains, vegetables, legumes, and fruits—foods noted for their starch, fibers, and naturally occurring sugars.

Health Effects of Starch and Fibers In addition to starch, fibers, and natural sugars, remember that whole grains, vegetables, legumes, and fruits supply

valuable vitamins and minerals and little or no fat. The following paragraphs describe some of the health benefits of diets that include a variety of these foods daily.

Heart Disease Unlike high-carbohydrate diets rich in added sugars that can alter blood lipids to favor heart disease, those rich in whole grains, legumes, vegetables, and fruits may protect against heart attack and stroke by lowering blood pressure, improving blood lipids, and reducing inflammation.[28] Such diets are low in animal fat and cholesterol and high in dietary fibers, vegetable proteins, and phytochemicals—all factors associated with a lower risk of heart disease. (The role of animal fat and cholesterol in heart disease is discussed in Chapter 5. The role of vegetable proteins in heart disease is presented in Chapter 6. The benefits of phytochemicals in disease prevention are featured in Highlight 13.)

Oatmeal was the first food recognized for its ability to reduce cholesterol and the risk of heart disease.[29] Foods rich in soluble fibers (such as oat bran, barley, and legumes) lower blood cholesterol ♦ by binding with bile acids in the GI tract and thereby increasing their excretion. Consequently, the liver must use its cholesterol to make new bile acids. In addition, the bacterial by-products of fiber fermentation in the colon also inhibit cholesterol synthesis in the liver. The net result is that soluble fibers such as those found in oats lower blood cholesterol.[30]

♦ Consuming 5 to 10 g of soluble fiber daily reduces blood cholesterol by 3 to 5%. For perspective, ½ c dry oat bran provides 8 g of fiber, and 1 c cooked barley or ½ c cooked legumes provides about 6 g of fiber.

Several researchers have speculated that fiber may also exert its effect by displacing fats in the diet. Although this is certainly helpful, even when dietary fat is low, fibers exert a separate and significant cholesterol-lowering effect. In other words, a high-fiber diet helps to decrease the risk of heart disease independent of fat intake.

Diabetes High-fiber foods—especially whole grains—play a key role managing and preventing type 2 diabetes.[31] When soluble fibers trap nutrients and delay their transit through the GI tract, glucose absorption is slowed, which helps to prevent glucose surge and rebound.

GI Health Dietary fibers also enhance the health of the large intestine. The healthier the intestinal walls, the better they can block absorption of unwanted constituents. Taken with ample fluids, insoluble fibers such as cellulose (as in cereal brans, fruits, and vegetables) increase stool weight, ease passage, and reduce transit time.

Large, soft stools ease elimination for the rectal muscles and reduce pressure in the lower bowel, preventing constipation and making it less likely that rectal veins will swell (hemorrhoids). Fiber prevents compaction of the intestinal contents, which could obstruct the appendix and permit bacteria to invade and infect it (appendicitis). In addition, fiber stimulates the GI tract muscles so that they retain their strength and resist bulging out into pouches known as diverticula (illustrated in Figure H3-3 on p. 91).[32]



© Rita Maas/The Image Bank/Getty Images

Foods rich in starch and fiber offer many health benefits.

Cancer Research studies suggest that a high-fiber diet protects against colon cancer.[33] When a large study of diet and cancer examined the diets of more than a half million people in ten countries for several years, the researchers found an inverse association between dietary fiber and colon cancer.[34] People who ate the most dietary fiber (35 grams per day) reduced their risk of colon cancer by 40 percent compared with those who ate the least fiber (15 grams per day). Importantly, the study focused on dietary fiber, not fiber supplements or additives, which lack valuable nutrients and phytochemicals that also help protect against cancer. Plant foods—vegetables, fruits, and whole-grain products—reduce the risks of colon and rectal cancers.

Fibers may help prevent colon cancer by diluting, binding, and rapidly removing potential cancer-causing agents from the colon. In addition, soluble fibers stimulate bacterial fermentation of resistant starch and fiber in the colon, a process that produces short-chain fatty acids that lower the pH. These small fat molecules activate cancer-killing enzymes and inhibit inflammation in the colon.[35]

Weight Management High-fiber and whole-grain foods may help a person to maintain a healthy body weight.[36] Foods rich in fiber tend to be low in fat and added sugars and can therefore prevent weight gain and promote weight loss by delivering less energy per bite.[37] In addition, as fibers absorb water from the digestive juices, they swell, creating feelings of fullness, lowering food intake, and delaying hunger.[38]

Many weight-loss products on the market today contain bulk-inducing fibers such as methylcellulose, but buying pure fiber compounds like this is neither necessary nor advisable. Instead of fiber supplements, consumers should select whole grains, legumes, fruits, and vegetables. High-fiber foods not only add bulk to the diet but are economical and nutritious as well.

Dietary fiber provides numerous health benefits.[39] Table 4-5 summarizes fiber characteristics, food sources, actions in the body, and their health benefits.

Harmful Effects of Excessive Fiber Intake Despite fibers' benefits to health, a diet excessively high in fiber also has a few drawbacks. A person who has a small capacity and eats mostly high-fiber foods may not be able to eat enough food to meet energy or nutrient needs. The malnourished, the elderly, and young children adhering to all-plant (vegan) diets are especially vulnerable to this problem.

Switching from a low-fiber diet to a high-fiber diet suddenly can cause temporary bouts of abdominal discomfort, gas, and diarrhea and, more seriously, can obstruct the GI tract. To prevent such complications, a person adopting a high-fiber diet can take the following precautions:

- Increase fiber intake gradually over several weeks to give the GI tract time to adapt.
- Drink plenty of liquids to soften the fiber as it moves through the GI tract.
- Select fiber-rich foods from a variety of sources—fruits, vegetables, legumes, and whole-grain breads and cereals.

TABLE 4-5 Characteristics, Sources, and Health Effects of Fibers

	Major Food Sources	Types of Fibers	Actions in the Body	Probable Health Benefits
	Viscous, Soluble, More Fermentable			
 © Richard Lerner/Getty Images	• Barley, oats, oat bran, rye, fruits (apples, citrus), legumes (especially young green peas and black-eyed peas), seaweeds, seeds and husks, many vegetables, fibers used as food additives	• Gums • Pectins • Psyllium[a] • Some hemicellulose	• Lower blood cholesterol by binding bile • Slow glucose absorption • Slow transit of food through upper GI tract • Hold moisture in stools, softening them • Yield small fat molecules after fermentation that the colon can use for energy • Increase satiety	• Lower risk of heart disease • Lower risk of diabetes • Lower risk of colon and rectal cancer • Increased satiety, and may help with weight management
	Nonviscous, Insoluble, Less Fermentable			
 © Stockbyte/Getty Images	• Brown rice, fruits, legumes, seeds, vegetables (cabbage, carrots, brussels sprouts), wheat bran, whole grains, extracted fibers used as food additives	• Cellulose • Lignins • Resistant starch • Hemicellulose	• Increase fecal weight and speed fecal passage through colon • Provide bulk and feelings of fullness	• Alleviate constipation • Lower risk of diverticulosis, hemorrhoids, and appendicitis • Lower risk of colon and rectal cancer

[a]Psyllium, a soluble fiber derived from seeds, is used as a laxative and food additive.

Some fibers can limit the absorption of nutrients by speeding the transit of foods through the GI tract and by binding to minerals. When mineral intake is adequate, however, a *reasonable* intake of high-fiber foods (less than 40 grams a day) does not compromise mineral balance.

Clearly, fiber is like all nutrients in that "more" is "better" only up to a point. Again, the key dietary goals are balance, moderation, and variety.

♦ Acceptable Macronutrient Distribution Ranges (AMDR):
- Carbohydrate: 45 to 65%
- Fat: 20 to 35%
- Protein: 10 to 35%

Recommended Intakes of Starch and Fibers The DRI suggest that carbohydrates provide about half (45 to 65 percent) of the energy requirement. ♦ A person consuming 2000 kcalories a day should therefore have 900 to 1300 kcalories of carbohydrate, or about 225 to 325 grams. (Appendix K explains how to solve such problems.) This amount is more than adequate to meet the RDA for carbohydrate, which is set at 130 grams per day, based on the average minimum amount of glucose used by the brain.[40]

On food labels, the Food and Drug Administration (FDA) uses a 60 percent of kcalories guideline in setting the Daily Value for carbohydrate at 300 grams per day. To meet this goal, the *Dietary Guidelines* encourage people to choose a variety of whole grains, vegetables, fruits, and legumes daily.



> DIETARY GUIDELINES FOR AMERICANS 2010

Choose foods that provide more dietary fiber, a nutrient of concern in American diets. Dietary fiber is found in plants, notably legumes, vegetables, fruits, whole grains, and nuts.

♦ To increase your fiber intake:
- Eat raw vegetables.
- Eat fresh and dried fruit for snacks.
- Add legumes to soups, salads, and casseroles.
- Eat whole-grain breads that contain ≥3 g fiber per serving.
- Eat whole-grain cereals that contain ≥5 g fiber per serving.
- Eat fruits (such as pears) and vegetables (such as potatoes) with their skins.

Recommendations for fiber ♦ suggest the same foods just mentioned: whole grains, vegetables, fruits, and legumes, which also provide minerals and vitamins. The FDA sets the Daily Value for fiber at 25 grams, rounding up from the recommended 11.5 grams per 1000 kcalories for a 2000-kcalorie intake. The DRI recommendation is slightly higher, at 14 grams per 1000-kcalorie intake—roughly 25 to 35 grams of dietary fiber daily. These recommendations are about two times higher than the usual intake in the United States.[41] An effective way to add fiber while lowering fat is to substitute plant sources of proteins (legumes) for animal sources (meats). Table 4-6 presents a list of fiber sources.

Because high-fiber foods are so filling, they are not likely to be eaten in excess. Too much fiber can cause GI problems for some people, but it generally does not have adverse effects in most healthy people. For these reasons, the DRI committee did not set an Upper Level for fiber.



Some food labels use a "whole-grain stamp" to help consumers identify whole-grain foods.

© Courtesy Oldways and the Whole Grains Council, www.wholegrainscouncil.org

From Guidelines to Groceries A diet following the USDA Food Patterns, which include several servings of fruits, vegetables, and whole grains daily, can easily supply the recommended amount of carbohydrates and fiber. In selecting high-fiber foods, keep in mind the principle of variety. The fibers in oats lower cholesterol, whereas those in bran help promote GI tract health. (Review Table 4-5, p. 117, to see the diverse health effects of various fibers.)

Grains An ounce-equivalent of most foods in the grain group (for example, one slice of bread) provides about 15 grams of carbohydrate, mostly as starch. Be aware that some foods in this group, especially snack crackers and baked goods such as biscuits, croissants, and muffins, contain added sugars, solid fats, and sodium. When selecting from the grain group, limit refined grains and be sure to include at least half as whole-grain products (see Figure 4-13, p. 120). The "three are key" message may help consumers to remember to

TABLE 4-6 Fiber in Selected Foods

Grains

Whole-grain products provide about 1 to 2 g (or more) of fiber per serving:

- 1 slice whole-wheat, pumpernickel, rye bread
- 1 oz ready-to-eat cereal (100% bran cereals contain 10 g or more)
- ½ c cooked barley, bulgur, grits, oatmeal



© Polara Studios, Inc

Vegetables

Most vegetables contain about 2 to 3 g of fiber per serving:

- 1 c raw bean sprouts
- ½ c cooked broccoli, brussels sprouts, cabbage, carrots, cauliflower, collards, corn, eggplant, green beans, green peas, kale, mushrooms, okra, parsnips, potatoes, pumpkin, spinach, sweet potatoes, swiss chard, winter squash
- ½ c chopped raw carrots, peppers



© Polara Studios, Inc

Fruit

Fresh, frozen, and dried fruits have about 2 g of fiber per serving:

- 1 medium apple, banana, kiwi, nectarine, orange, pear
- ½ c applesauce, blackberries, blueberries, raspberries, strawberries
- Fruit juices contain very little fiber



© Polara Studios, Inc

Legumes

Many legumes provide about 6 to 8 g of fiber per serving:

- ½ c cooked baked beans, black beans, black-eyed peas, kidney beans, navy beans, pinto beans

Some legumes provide about 5 g of fiber per serving:

- ½ c cooked garbanzo beans, great northern beans, lentils, lima beans, split peas



© Polara Studios, Inc

NOTE: Appendix H provides fiber grams for more than 2000 foods.

choose a whole-grain cereal for breakfast, a whole-grain bread for lunch, and a whole-grain pasta or rice for dinner. Consumers who eat more whole grains tend to have healthier diets.[42]



> DIETARY GUIDELINES FOR AMERICANS 2010

Limit the consumption of foods that contain refined grains, especially refined-grain foods that contain solid fats, added sugars, and sodium. Replace refined grains with whole grains.

Vegetables The amount of carbohydrate a serving of vegetables provides depends primarily on its starch content. Starchy vegetables—corn, peas, or potatoes—provide about 15 grams of carbohydrate per half-cup serving. A serving of most other *nonstarchy* vegetables—such as a half-cup of broccoli, green beans, or tomatoes—provides about 5 grams.

Fruits A typical fruit serving—a small banana, apple, or orange or a half-cup of most canned or fresh fruit—contains an average of about 15 grams of carbohydrate, mostly as sugars, including the fruit sugar fructose. Fruits vary greatly in their water and fiber contents and, therefore, in their sugar concentrations.

Milks and Milk Products A serving (a cup) of milk or yogurt provides about 12 grams of carbohydrate. Cottage cheese provides about 6 grams of carbohydrate per cup, but most other cheeses contain little, if any, carbohydrate.

> FIGURE 4-13 Bread Labels Compared

Although breads may appear similar, their ingredients vary widely. Breads made mostly from whole-grain flours provide more benefits to the body than breads made of enriched, refined, wheat flours.

Some "high-fiber" breads may contain purified cellulose or more nutritious whole grains. "Low-carbohydrate" breads may be regular white bread, thinly sliced to reduce carbohydrates per serving, or may contain soy flour, barley flour, or flaxseed to reduce starch content.

A trick for estimating a bread's content of a nutritious ingredient, such as whole-grain flour, is to read the ingredients list (ingredients are listed in order of predominance). Bread recipes generally include one teaspoon of salt per loaf. Therefore, when a bulky nutritious ingredient, such as whole grain, is listed after the salt, you'll know that less than a teaspoonful of the nutritious ingredient was added to the loaf—not enough to significantly improve the nutrient value of one slice of bread.



Whole Grain
WHOLE WHEAT

Nutrition Facts
Serving size 1 slice (30g)
Servings Per Container 18

Amount per serving	
Calories 90	Calories from Fat 14
	% Daily Value*
Total Fat 1.5g	2%
***Trans* Fat** 0g	
Sodium 135mg	6%
Total Carbohydrate 15g	5%
Dietary fiber 2g	8%
Sugars 2g	
Protein 4g	

MADE FROM: UNBROMATED STONE GROUND 100% WHOLE WHEAT FLOUR, WATER, CRUSHED WHEAT, HIGH FRUCTOSE CORN SYRUP, PARTIALLY HYDROGENATED VEGETABLE SHORTENING (SOYBEAN AND COTTONSEED OILS), RAISIN JUICE CONCENTRATE, WHEAT GLUTEN, YEAST, WHOLE WHEAT FLAKES, UNSULPHURED MOLASSES, SALT, HONEY, VINEGAR, ENZYME MODIFIED SOY LECITHIN, CULTURED WHEY, UNBLEACHED WHEAT FLOUR AND SOY LECITHIN.

Natural
Wheat Bread

Nutrition Facts
Serving size 1 slice (30g)
Servings Per Container 15

Amount per serving	
Calories 90	Calories from Fat 14
	% Daily Value*
Total Fat 1.5g	2%
***Trans* Fat** 0g	
Sodium 220mg	9%
Total Carbohydrate 15g	5%
Dietary fiber less than 1g	2%
Sugars 2g	
Protein 4g	

INGREDIENTS: UNBLEACHED ENRICHED WHEAT FLOUR [MALTED BARLEY FLOUR, NIACIN, REDUCED IRON, THIAMIN MONONITRATE (VITAMIN B1), RIBOFLAVIN (VITAMIN B2), FOLIC ACID], WATER, HIGH FRUCTOSE CORN SYRUP, MOLASSES, PARTIALLY HYDROGENATED SOYBEAN OIL, YEAST, CORN FLOUR, SALT, GROUND CARAWAY, WHEAT GLUTEN, CALCIUM PROPIONATE (PRESERVATIVE), MONOGLYCERIDES, SOY LECITHIN.

Multi-fiber
Low carb

Nutrition Facts
Serving size 1 slice (30g)
Servings Per Container 21

Amount per serving	
Calories 60	Calories from Fat 15
	% Daily Value*
Total Fat 1.5g	2%
***Trans* Fat** 0g	
Sodium 135mg	6%
Total Carbohydrate 9g	3%
Dietary fiber 3g	12%
Sugars 0g	
Protein 5g	

INGREDIENTS: UNBLEACHED ENRICHED WHEAT FLOUR, WATER, WHEAT GLUTEN, CELLULOSE, YEAST, SOYBEAN OIL, CRACKED WHEAT, SALT, BARLEY, NATURAL FLAVOR PRESERVATIVES, MONOCALCIUM PHOSPHATE, MILLET, CORN, OATS, SOYBEANS, BROWN RICE, FLAXSEED, SUCRALOSE.

© Cengage Learning 2013

Protein Foods With two exceptions, protein foods deliver almost no carbohydrate to the diet. The exceptions are nuts, which provide a little starch and fiber along with their abundant fat, and legumes, which provide an abundance of both starch and fiber. Just a half-cup serving of legumes provides about 20 grams of carbohydrate, a third from fiber.

Read Food Labels Food labels list the amount, in grams, of *total* carbohydrate—including starch, fibers, and sugars—per serving (review Figure 4-13). Fiber grams are also listed separately, as are the grams of sugars. (With this information, you can calculate starch grams ♦ by subtracting the grams of fibers and sugars from the total carbohydrate.) Sugars reflect both added sugars and those that occur naturally in foods. Total carbohydrate and dietary fiber are also expressed as "% Daily Values" for a person consuming 2000 kcalories; there is no Daily Value for sugars.

♦ To calculate starch grams using the first label in Figure 4-13:
- 15 g total – 4 g (dietary fiber + sugars) = 11 g starch

REVIEW IT Identify the health benefits of, and recommendations for, starches and fibers.

Clearly, a diet rich in starches and fibers supports efforts to control body weight and prevent heart disease, some cancers, diabetes, and GI disorders. For these reasons, recommendations urge people to eat plenty of whole grains, vegetables, legumes, and fruits—enough to provide 45 to 65 percent of the daily energy intake from carbohydrate.

In today's world, there is one other reason why plant foods rich in complex carbohydrates and natural sugars are a better choice than animal foods or foods high in concentrated sugars: in general, less energy and fewer resources are required to grow and process plant foods than to produce sugar or foods derived from animals. Chapter 20 takes a closer look at the environmental impacts of food production and use.

Nutrition Portfolio

Foods that derive from plants—whole grains, vegetables, legumes, and fruits—naturally provide ample carbohydrates and fiber with little or no fat. Refined foods often contain added sugars and fat.

Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Intake Spreadsheet report. Scroll down until you see: carb (g).

- Which of your foods for this day were highest in carbohydrate? Which of these foods also contain added sugars and fats? List better alternatives.
- List the types and amounts of grain products you ate on that day, making note of which are whole-grain or refined foods and how your choices could include more whole-grain options.
- List the types and amounts of fruits and vegetables you ate on that day, making note of how many are dark green, red and orange, or deep yellow, how many are starchy or legumes, and how your choices could include more of these options.
- Describe choices you can make in selecting and preparing foods and beverages to lower your intake of added sugars.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. K. C. Maki and coauthors, Whole-grain ready-to-eat oat cereal, as part of a dietary program for weight loss, reduces low-density lipoprotein cholesterol in adults with overweight and obesity more than a dietary program including low-fiber control foods, *Journal of the American Dietetic Association* 110 (2010): 205–214; Z. Wei and coauthors, Time- and dose-dependent effect of psyllium on serum lipids in mild-to-moderate hypercholesterolemia: A meta-analysis of controlled clinical trials, *European Journal of Clinical Nutrition* 63 (2009): 821–827; L. Van Horn and coauthors, The evidence for dietary prevention and treatment of cardiovascular disease, *Journal of the American Dietetic Association* 108 (2008): 287–331; M. O. Weickert and A. F. Pfeiffer, Metabolic effects of dietary fiber consumption and prevention of diabetes, *Journal of Nutrition* 138 (2008): 439–442.
2. V. Vuksan and coauthors, Using cereal to increase dietary fiber intake to the recommended level and the effect of fiber on bowel function in healthy persons consuming North American diets, *American Journal of Clinical Nutrition* 88 (2008): 1256–1262.
3. S. S. Dronamraju and coauthors, Cell kinetics and gene expression in colorectal cancer patients given resistant starch: A randomized controlled trial, *Gut* 58 (2009): 413–420; K. C. Maki and coauthors, Beneficial effects of resistant starch on laxation in healthy adults, *International Journal of Food Sciences & Nutrition* 60 (2009): 296–305; S. J. D. O'Keefe and coauthors, Products of the colonic microbiota mediate the effects of diet on colon cancer risk, *Journal of Nutrition* 139 (2009): 2044–2048.
4. Committee on Dietary Reference Intakes, *Dietary Reference Intakes: Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005).
5. NIH Consensus Development Conference: Lactose intolerance and health, http://consensus.nih.gov/2010/lactosestatement.htm.
6. T. He and coauthors, Effects of yogurt and bifidobacteria supplementation on the colonic microbiotia in lactose-intolerant subjects, *Journal of Applied Microbiology* 104 (2008): 595–604.
7. G. Riccardi, A. A. Rivellese, and R. Giacco, Role of glycemic index and glycemic load in the healthy state, in prediabetes, and in diabetes, *American Journal of Clinical Nutrition* 87 (2008): 269S–274S.
8. G. Livesey and coauthors, Glycemic response and health—A systematic review and meta-analysis: Relations between dietary glycemic properties and health outcomes, *American Journal of Clinical Nutrition* 87 (2008): 258S–268S.
9. A. W. Barclay and coauthors, Glycemic index, glycemic load, and chronic disease risk: A meta-analysis of observational studies, *American Journal of Clinical Nutrition* 87 (2008): 627–637; J. Howlett and M. Ashwell, Glycemic response and health: Summary of a workshop, *American Journal of Clinical Nutrition* 87 (2008): 212S–216S.
10. H. Hare-Bruun and coauthors, Should glycemic index and glycemic load be considered in dietary recommendations? *Nutrition Reviews* 66 (2008): 569–590.

11. T. M. S. Wolever and coauthors, Measuring the glycemic index of foods: Interlaboratory study, *American Journal of Clinical Nutrition* 87 (2008): 247S–257S.
12. S. W. Rizkalla, Health implications of fructose consumption: A review of recent data, *Nutrition and Metabolism* 4 (2010): 82–98.
13. US Department of Agriculture and US Department of Health and Human Services, *Dietary Guidelines for Americans, 2010*, www.dietaryguidelines.gov; R. E. Kavey, How sweet it is: Sugar-sweetened beverage consumption, obesity, and cardiovascular risk in childhood, *Journal of the American Dietetic Association* 110 (2010): 1456–1460.
14. O. I. Bermudez and X. Gao, Greater consumption of sweetened beverages and added sugars is associated with obesity among US young adults, *Annals of Nutrition and Metabolism* 57 (2010): 211–218; S. N. Bleich and coauthors, Increasing consumption of sugar-sweetened beverages among US adults: 1988–1994 to 1999–2004, *American Journal of Clinical Nutrition* 89 (2009): 372–381.
15. Bermudez and Gao, 2010.
16. S. Harrington, The role of sugar-sweetened beverage consumption in adolescent obesity: A review of the literature, *Journal of School Nursing* 24 (2008): 3–12.
17. D. I. Jalal and coauthors, Increased fructose associates with elevated blood pressure, *Journal of the American Society of Nephrology* 21 (2010): 1543–1549; R. K. Johnson and B. A. Yon, Weighing in on added sugars and health, *Journal of the American Dietetic Association* 110 (2010): 1296–1299; V. S. Malik and coauthors, Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis, *Diabetes Care* 33 (2010): 2477–2483; L. Tappy and coauthors, Fructose and metabolic diseases: New findings, new questions, *Nutrition* 26 (2010): 1044–1049; T. T. Fung and coauthors, Sweetened beverage consumption and risk of coronary heart disease in women, *American Journal of Clinical Nutrition* 89 (2009): 1037–1042.
18. M. J. Dekker and coauthors, Fructose: A highly lipogenic nutrient implicated in insulin resistance, hepatic steatosis, and the metabolic syndrome, *American Journal of Physiology, Endocrinology and Metabolism* 299 (2010): E685–E694; M. E. Bocarsly and coauthors, High-fructose corn syrup causes characteristics of obesity in rats: Increased body weight, body fat and triglyceride levels, *Pharmacology Biochemistry and Behavior* 97 (2010): 101–106; K. L. Stanhope and coauthors, Consuming fructose-sweetened, not glucose-sweetened, beverages increases visceral adiposity and lipids and decreases insulin sensitivity in overweight/obese humans, *Journal of Clinical Investigation* 119 (2009): 1322–1334; K. A. Lê and coauthors, Fructose overconsumption causes dyslipidemia and ectopic lipid deposition in healthy subjects with and without a family history of type 2 diabetes, *American Journal of Clinical Nutrition* 89 (2009): 1760–1765; M. M. Swarbrick and coauthors, Consumption of fructose sweetened beverages for 10 weeks increases postprandial triacylglycerol and apolipoprotein-B concentrations in overweight and obese women, *British Journal of Nutrition* 100 (2008): 947–952; E. J. Parks and coauthors, Dietary sugars stimulate fatty acid synthesis in adults, *Journal of Nutrition* 138 (2008): 1039–1046.
19. J. A. Welsh and coauthors, Consumption of added sugars and indicators of cardiovascular disease risk among US adolescents, *Circulation* 123 (2011): 249–257; J. A. Welsh and coauthors, Caloric sweetener consumption and dyslipidemia among US adults, *Journal of the American Medical Association* 303 (2010): 1490–1497.
20. Lê and coauthors, 2009.
21. L. de Koning and coauthors, Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men, *American Journal of Clinical Nutrition* 93 (2011): 1321–1327; K. J. Duffey and coauthors, Drinking caloric beverages increases the risk of adverse cardiometabolic outcomes in the Coronary Artery Risk Development in Young Adults (CARDIA) Study, *American Journal of Clinical Nutrition* 92 (2010): 954–959; F. B. Hu and V. S. Malik, Sugar-sweetened beverages and risk of obesity and type 2 diabetes: Epidemiologic evidence, *Physiology and Behavior* 100 (2010): 47–54; R. K. Johnson and coauthors, Dietary sugars intake and cardiovascular health. A scientific statement from the American Heart Association, *Circulation* 120 (2009): 1011–1020; V. S. Malik and coauthors, 2010; A. Miller and K. Adeli, Dietary fructose and the metabolic syndrome, *Current Opinion in Gastroenterology* 24 (2008): 204–209.
22. Position of the American Dietetic Association: Oral health and nutrition, *Journal of the American Dietetic Association* 107 (2007): 1418–1428.
23. US Department of Agriculture, Agricultural Research Service, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville, MD) and US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics (Hyattsville, MD), *What We Eat in America*, NHANES 2007–2008, www.ars.usda.gov/ ba/bhnrc/fsrg, published 2010.
24. Committee on Dietary Reference Intakes, 2005.
25. B. P. Marriott and coauthors, Intake of added sugars and selected nutrients in the United States, National Health and Nutrition Examination Survey (NHANES) 2003–2006, *Critical Reviews in Food Science and Nutrition* 50 (2010): 228–258.
26. *Dietary Guidelines for Americans, 2010.*
27. Position of the American Dietetic Association: Use of nutritive and nonnutritive sweeteners, *Journal of the American Dietetic Association* 104 (2004): 255–275.
28. M. U. Jakobsen and coauthors, Intake of carbohydrates compared with intake of saturated fatty acids and risk of myocardial infarction: Importance of the glycemic index, *American Journal of Clinical Nutrition* 91 (2010): 1764–1768; M. T. Streppel and coauthors, Dietary fiber intake in relation to coronary heart disease and all-cause mortality over 40 y: The Zutphen Study, *American Journal of Clinical Nutrition* 88 (2008): 1119–1125.
29. M. B. Andon and J. W. Anderson, State of the art reviews: The oatmeal-cholesterol connection: 10 Years later, *American Journal of Lifestyle Medicine* 2 (2008): 51–57.
30. R. A. Othman, M. H. Moghadasian, and P. J. H. Jones, Cholesterol-lowering effects of oat β-glucan, *Nutrition Reviews* 69 (2011): 299–309.
31. H. Kim and coauthors, Glucose and insulin responses to whole grain breakfasts varying in soluble fiber, beta-glucan: A dose response study in obese women with increased risk for insulin resistance, *European Journal of Nutrition* 48 (2009): 170–175; V. Vuksan and coauthors, Fiber facts: Benefits and recommendations for individuals with type 2 diabetes, *Current Diabetes Reports* 9 (2009): 405–411.
32. S. Tarleton and J. K. Dibaise, Low-residue diet in diverticular disease: Putting an end to a myth, *Nutrition in Clinical Practice* 26 (2011): 137–142; A. Rocco and coauthors, Treatment options for uncomplicated diverticular disease of the colon, *Journal of Clinical Gastroenterology* 43 (2009): 803–808.
33. C. C. Dahm and coauthors, Dietary fiber and colorectal cancer risk: A nested case-control study using food diaries, *Journal of the National Cancer Institute* 102 (2010): 614–626; L. B. Sansbury and coauthors, The effect of strict adherence to a high-fiber, high-fruit and -vegetable, and low-fat eating pattern on adenoma recurrence, *American Journal of Epidemiology* 170 (2009): 576–584.
34. N. Slimani and B. Margetts, Nutrient intakes and patterns in the EPIC cohorts from ten European countries, *European J ournal of Clinical Nutrition* 63 (2009): S1–S274.
35. M. H. Pan and coauthors, Molecular mechanisms for chemoprevention of colorectal cancer by natural dietary compounds, *Molecular Nutrition and Food Research* 55 (2011): 32–45.
36. H. Du and coauthors, Dietary fiber and subsequent changes in body weight and waist circumference in European men and women, *American Journal of Clinical Nutrition* 91 (2010): 329–336; J. N. Davis and coauthors, Inverse relation between dietary fiber intake and visceral adiposity in overweight Latino youth, *American Journal of Clinical Nutrition* 90 (2009): 1160–1166.
37. L. A. Tucker and K. S. Thomas, Increasing total fiber intake reduces risk of weight and fat gains in women, *Journal of Nutrition* 139 (2009): 567–581.
38. P. Vitaglione and coauthors, β-Glucan-enriched bread reduces energy intake and modifies plasma ghrelin and peptide YY concentrations in the short term, *Appetite* 53 (2009): 338–344; A. Hamedani and coauthors, Reduced energy intake at breakfast is not compensated for at lunch if a high-insoluble-fiber cereal replaces a low-fiber cereal, *American Journal of Clinical Nutrition* 89 (2009): 1343–1349; N. Schroeder and coauthors, Influence of whole grain barely, whole grain wheat, and refined

rice-based foods on short-term satiety and energy intake, *Appetite* 53 (2009): 363–369.
39. J. W. Anderson and coauthors, Health benefits of dietary fiber, *Nutrition Reviews* 67 (2009): 188–205.
40. Committee on Dietary Reference Intakes, 2005.
41. *What We Eat in America*, 2010; Position of the American Dietetic Association: Health implications of dietary fiber, *Journal of the American Dietetic Association* 108 (2008): 1716–1731.
42. C. E. O'Neil and coauthors, Consumption of whole grains is associated with improved diet quality and nutrient intake in children and adolescents: The National Health and Nutrition Examination Survey 1999–2004, *Public Health Nutrition* 14 (2011): 347–355; C. E. O'Neil and coauthors, Whole-grain consumption is associated with diet quality and nutrient intake in adults: The National Health and Nutrition Examination Survey, 1999–2004, *Journal of the American Dietetic Association* 110 (2010): 1461–1468.

LEARN IT Summarize the key scientific evidence behind some of the current controversies surrounding carbohydrates and their kcalories.

Carbs, kCalories, and Controversies



© Susan Van Etten/Photo Edit

Carbohydrate-rich foods are easy to like. Mashed potatoes, warm muffins, blueberry pancakes, freshly baked bread, and tasty rice and pasta dishes tempt most people's palates. In recent years, such homey foods have been blamed for causing weight gain and harming health. Popular writers have persuaded consumers that carbohydrates are "bad."[1] In contrast, the *Dietary Guidelines* urge people to consume plenty of fruits, vegetables, legumes, and whole grains—all carbohydrate-rich foods.

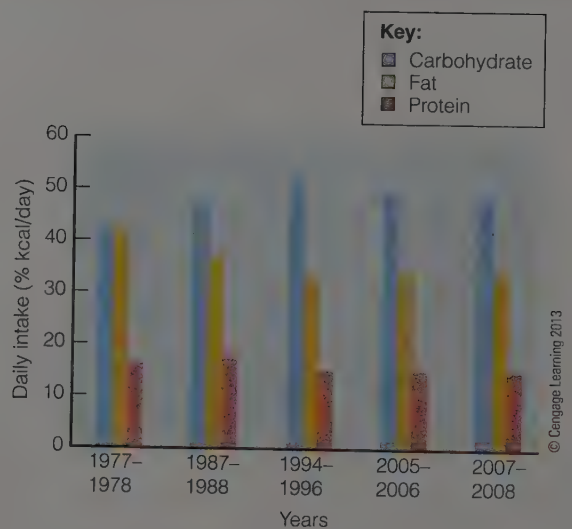
Do carbohydrate-rich foods cause obesity and related health problems?[2] Should people "cut carbs" to lose weight and protect their health? Many popular diet books espouse a carbohydrate-restricted or carbohydrate-modified diet. Some claim that all or some types of carbohydrates are bad. Some go so far as to equate carbohydrates with toxic poisons or addictive drugs. "Bad" carbohydrates—such as sugar, white flour, and potatoes—are considered evil because they are absorbed easily and raise blood glucose. The pancreas then responds by secreting insulin—and insulin is touted as the real villain responsible for our nation's obesity epidemic. Whether restricting overall carbohydrate intake or replacing certain "bad" carbohydrates with "good" carbohydrates, many of these popular diets tend to distort the facts. This highlight examines the scientific evidence behind some of the current controversies surrounding carbohydrates and their kcalories.

Carbohydrates' kCalorie Contributions

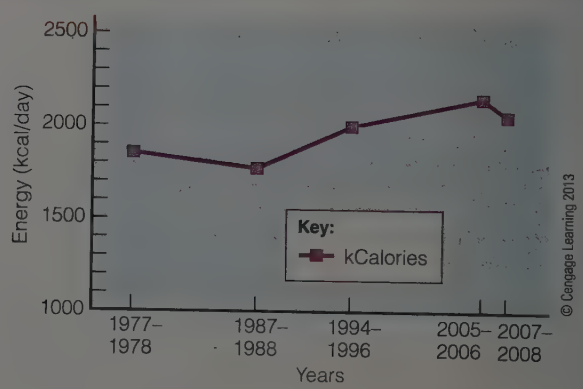
The incidence of obesity in the United States has risen dramatically over the past several decades.[3] Popular diet books often blame carbohydrates for this increase in obesity. One way researchers can explore whether the amount of carbohydrate in the diet contributes to increases in body weight over time is by reviewing national food intake survey records, such as NHANES (introduced in Chapter 1). Figure H4-1 presents a summary of energy nutrient data over the past three decades. Since the 1970s, kcalories from carbohydrates increased from 42 percent to 49 percent today.[4] At the same time, kcalories from fat dropped from 41 percent to 34 percent. The percentage of protein intake stayed about the same.

A closer look at the data reveals that, as the percentage of kcalories from the three energy nutrients shifted slightly, total daily energy intake increased significantly. In general, as food became more readily available in this nation, consumers began to eat more than they had in the past.[5] Since the 1970s, total energy intakes have increased by about 200 to 300 kcalories a day (see Figure H4-2).[6] All of the increase in kcalories came from an increase in carbohydrate kcalories. At the same time, most people were not active enough to use up those extra kcalories; in fact, activity levels declined.[7] Consequently, the average body weight for adults increased over these decades by about 20 pounds (see Figure H4-3).

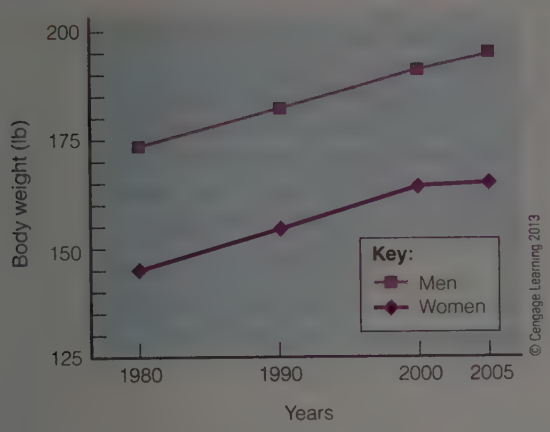
> **FIGURE H4-1** Energy Nutrients over Time



> **FIGURE H4-2** Daily Energy Intake over Time



> **FIGURE H4-3 Increases in Adult Body Weight over Time**



Might too many carbohydrates in the diet be to blame for weight gains? Interestingly, epidemiological studies find an *inverse* relationship between carbohydrate intake and body weight.[8] Those with the highest carbohydrate intake have the lowest body weight and vice versa. Dietary fiber, which favors a healthy body weight, explains some but not all of this relationship.

Might a low-carbohydrate diet support weight losses? For the most part, weight loss is similar for people following either a low-carbohydrate diet or a low-fat diet.[9] This is an important point. Weight losses reflect restricted kcalories—not the proportion of energy nutrients in the diet.[10] Any diet can produce weight loss, at least temporarily, if energy intake is restricted.

Sugars' Share in the Problem

As the chapter mentioned, the use of high-fructose corn syrup sweetener parallels unprecedented increases in the incidence of obesity, but does it mean that the increasing sugar intakes are responsible for the increase in body fat and its associated health problems?[11] Excess sugar in the diet is associated with more fat on the body. When eaten in excess of need, energy from added sugars contributes to body fat stores, just as excess energy from other sources does. Added sugars provide excess energy, raising the risk of weight gain. When total energy intake is controlled, however, *moderate* amounts of sugar do not *cause* obesity. In other words, foods containing added sugars are no more likely to contribute to weight gain than any other foods. Yet moderating sugar intake can be a challenge.

The liquid form of sugar in soft drinks makes it especially easy to overconsume kcalories. Swallowing liquid kcalories requires little effort. The sugar kcalories of sweet beverages also cost less than many other energy sources, and they are widely available. Also, beverages are energy-dense, providing more than 150 kcalories per 12-ounce can, and many people drink several cans a day. The convenience, economy, availability, and flavors of sugary foods and beverages make overconsumption especially likely.

Limiting selections of foods and beverages high in added sugars can be an effective weight-loss strategy, especially for people whose excess kcalories come primarily from added sugars. Replacing a can of cola with a glass of water every day, for example, can help a person lose a pound (or at least not gain a pound) in 1 month.[12] That may not sound like much, but it adds up to more than 10 pounds a year, for very little effort.

Cravings and Addictions

Some people blame their excessive sugar intakes on cravings and addictions. Foods in general, and carbohydrates and sugars more specifically, are not physically addictive in the ways that drugs are. Yet some people describe themselves as having "carbohydrate cravings" or being "sugar addicts." One frequently noted theory is that people seek carbohydrates as a way to increase their levels of the brain neurotransmitter serotonin, which elevates mood. Interestingly, when those with self-described carbohydrate cravings indulge, they tend to eat more of everything; the percentage of energy from carbohydrates remains unchanged.

One reasonable explanation for the carbohydrate cravings that some people experience involves the self-imposed labeling of a food as both "good" and "bad"—that is, one that is desirable but should be eaten with restraint. Restricting intake heightens the desire further (a "craving"). Then "addiction" is used to explain why resisting the food is so difficult and, sometimes, even impossible. But the "addiction" is not physiological or pharmacological.

Appetite Control

Recall from Chapter 4 that glucose stimulates the release of insulin from the pancreas. Insulin, in turn, sets off a sequence of hormonal actions that suppress the appetite.[13] (Appetite regulation is discussed fully in Chapter 8.) Fructose, in contrast, does not stimulate the release of insulin, and therefore does not suppress appetite. Theoretically, then, eating lots of fructose would never satisfy a person's appetite. In fact, fructose metabolism tends to promote hunger and thereby increase food intake.[14] Although, this idea sounds plausible, a major flaw exists: people don't typically eat pure fructose. They eat sucrose or high-fructose corn syrup, and both of these sugars contain sufficient glucose to stimulate the release of insulin and suppress appetite accordingly.

Whether the meal or snack is liquid or solid may also affect appetite.[15] Even when kcaloric intake is the same, a fresh apple suppresses appetite more than apple juice.[16] Consequently, beverages can influence weight gains both by providing energy and by not satisfying hunger.

Insulin's Response

Several popular diet books hold insulin responsible for the obesity problem and a low-glycemic diet as the weight-loss solution. Yet, among nutrition researchers, controversy continues to surround the questions of whether insulin promotes weight gain or a low-glycemic diet fosters weight loss.[17]

Recall that just after a meal, blood glucose rises and insulin responds. How high insulin levels surge may influence whether the body stores or uses its glucose and fat supplies. What does insulin do? Among its roles, insulin facilitates the transport of glucose into the cells, the storage of fatty acids as fat, and the synthesis of cholesterol. It is an anabolic hormone that builds and stores. True—but there's more to the story. Insulin is only one of many factors involved in the body's metabolism of nutrients and regulation of body weight.

Furthermore, as Chapter 4's discussion of the glycemic index pointed out, the glycemic effect of a particular food varies; diet books often mislead people by claiming that each food has a set glycemic effect. The glycemic effect of a food depends on how the food is ripened, processed, and cooked; the time of day the food is eaten; the other foods eaten with it; and the presence or absence of certain diseases such as type 2 diabetes in the person eating the food.[18]

Most importantly, insulin is critical to maintaining health, as any person with type 1 diabetes can attest. Insulin causes problems only when a person develops insulin resistance—that is, when the body's cells do not respond to the large quantities of insulin that the pancreas continues to pump out in an effort to get a response. Insulin resistance is a major health problem—but it is not caused by carbohydrate, or by protein, or by fat. It most often results from being obese. Importantly, when a person loses weight, insulin response usually improves.

The Glycemic Index and Body Weight

As Chapter 4 mentions, the glycemic index identifies foods that raise blood glucose and stimulate insulin secretion. What is the relationship between a diet's glycemic index and body weight? In general, studies find that diets with a high glycemic index are positively associated with body weight.[19]

Might a low-glycemic diet foster weight loss?[20] In general, research examining the use of low glycemic diets for weight loss finds inconsistent results.[21] Still, a low-glycemic diet may offer other advantages. A low-glycemic meal seems to curb appetite and limit energy intake of the next meal. Low-glycemic diets are also more likely to be rich in nutrients and fiber than high-glycemic diets.

Clearly, if kcalories are low, obese people on either a low-glycemic diet or a traditional low-fat diet can lose weight. Overweight people can lose as much or more weight by emphasizing low-glycemic foods as they can by following a typical low-fat, portion-controlled weight-loss diet.

The Individual's Response to Foods

The body's insulin response to carbohydrate depends not only on a food, but also on a person's metabolism.[22] Some people react to dietary carbohydrate with a low insulin response. Others have a high insulin response. One study reports that increases in body weight over 6 years were similar in people following either a high-carbohydrate diet or a low-carbohydrate diet. But those with a high insulin response gained more weight, especially when they were on a high-carbohydrate diet.[23] By the same token, for those with a higher insulin response, weight loss may be greater on a low-glycemic diet.

How energy is stored after a meal depends in part on how the body responds to insulin. After eating a high-carbohydrate meal, normal-weight people who are insulin resistant tend to synthesize about half as much glycogen in muscles and make about twice as much fat in the liver as people who are insulin sensitive. Some research suggests that restricting carbohydrate intake may improve glucose control, insulin response, and blood lipids.[24]

In Summary

As might be expected given the similarity in their chemical composition, high-fructose corn syrup and sucrose produce similar effects in appetite control and energy metabolism.[25] In fact, high-fructose corn syrup is more like sucrose than it is like pure fructose. As mentioned, people don't eat pure fructose; they eat foods and drink beverages that contain added sugars—either high-fructose corn syrup or sucrose. Limiting these sugars is a helpful strategy when trying to control body weight, but restricting all carbohydrates would be unwise.

The quality of the diet suffers when carbohydrates are restricted. Without fruits, vegetables, and whole grains, low-carbohydrate diets lack not only carbohydrate, but fiber, vitamins, minerals, and phytochemicals as well—all dietary factors protective against disease. The DRI recommends that carbohydrates contribute between 45 and 65 percent of daily energy intake. Intakes within this range can support healthy body weight and do not contribute to obesity—when added sugar intake is moderate and total energy intake is appropriate. Similarly, added sugars increase energy intake, but need not contribute to obesity—when added sugar intake is moderate and total energy intake is appropriate. When choosing carbohydrates, emphasize a variety of naturally occurring carbohydrates—such as whole grains, legumes, vegetables, and fruits—and limit foods and beverages with added sugars.

REFERENCES

1. G. A. Bray, *Viewpoint: Good kCalories, Bad kCalories* by Gary Taubes, *Obesity Reviews* 9 (2008): 251–263.
2. D. B. Allison and R. D. Mattes, Nutritively sweetened beverage consumption and obesity: The need for solid evidence on a fluid issue, *Journal of the American Medical Association* 301 (2009): 318–320.
3. K. M. Flegal and coauthors, Prevalence and trends in obesity among US adults, 1999–2008, *Journal of the American Medical Association* 303 (2010): 235–241.
4. US Department of Agriculture, Agricultural Research Service, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville, MD) and US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics (Hyattsville, MD), *What We Eat in America,* NHANES 2007–2008, www.ars.usda.gov/ba/bhnrc/fsrg, published 2010.
5. B. A. Swinburn and coauthors, Estimating the changes in energy flux that characterize the rise in obesity prevalence, *American Journal of Clinical Nutrition* 89 (2009): 1723–1728.
6. *What We Eat in America*, 2010.
7. US Department of Health and Human Services, *2008 Physical Activity Guidelines for Americans* Summary, www.health.gov/PAGuidelines/guidelines/summary.aspx.

8. A. T. Merchant and coauthors, Carbohydrate intake and overweight and obesity among healthy adults, *Journal of the American Dietetic Association* 109 (2009): 1165–1172.
9. G. D. Foster and coauthors, Weight and metabolic outcomes after 2 years on a low-carbohydrate versus low-fat diet: A randomized trial, *Annals of Internal Medicine* 153 (2010): 147–157; I. Shai and coauthors, Weight loss with a low-carbohydrate, Mediterranean, or low-fat diet, *New England Journal of Medicine* 359 (2008): 229–241; R. F. Kushner and B. Doerfler, Low-carbohydrate, high-protein diets revisited, *Current Opinion in Gastroenterology* 24 (2008): 198–203.
10. F. M. Sacks and coauthors, Comparison of weight-loss diets with different compositions of fat, protein, and carbohydrates, *New England Journal of Medicine* 360 (2009): 859–873; R. M. van Dam and J. C. Seidell, Carbohydrate intake and obesity, *European Journal of Clinical Nutrition* 61 (2007): S75–S99.
11. R. D. Mattes and coauthors, Nutritively sweetened beverage consumption and body weight: A systematic review and meta-analysis of randomized experiments, *Obesity Reviews* 12 (2011): 346–365; S. M. Moeller and coauthors, The effects of high fructose syrup, *Journal of the American College of Nutrition* 28 (2009): 619–626.
12. L. Chen and coauthors, Reduction in consumption of sugar-sweetened beverages is associated with weight loss: The PREMIER trial, *American Journal of Clinical Nutrition* 89 (2009): 1299–1306.
13. K. J. Melanson and coauthors, High-fructose corn syrup, energy intake, and appetite regulation, *American Journal of Clinical Nutrition* 88 (2008): 1738S–1744S.
14. M. D. Lane and S. H. Cha, Effect of glucose and fructose on food intake via malonyl-CoA signaling in the brain, *Biochemical and Biophysical Research Communications* 382 (2009): 1–5.
15. R. D. Mattes and W. W. Campbell, Effects of food form and timing of ingestion on appetite and energy intake in lean young adults and in young adults with obesity, *Journal of the American Dietetic Association* 109 (2009): 430–437.
16. Mattes and Campbell, 2009.
17. G. Radulian and coauthors, Metabolic effects of low glycaemic index diets, *Nutrition Journal* 8 (2009): 5; J. Brand-Miller and coauthors, Carbohydrates: The good, the bad and the whole grain, *Asia Pacific Journal of Clinical Nutrition* 17 (2008): 16–19; A. W. Barclay and coauthors, Glycemic index, glycemic load, and chronic disease risk: A meta-analysis of observational studies, *American Journal of Clinical Nutrition* 87 (2008): 627–637; D. J. A. Jenkins and coauthors, Effect of a low-glycemic index or a high-cereal fiber diet on type 2 diabetes, *Journal of the American Medical Association* 300 (2008): 2742–2753.
18. P. Small and J. Brand-Miller, From complex carbohydrate to glycemic index, *Nutrition Today* 44 (2009) 236–243; G. Riccardi, A. A. Rivellese, and R. Giacco, Role of glycemic index and glycemic load in the healthy state, in prediabetes, and in diabetes, *American Journal of Clinical Nutrition* 87 (2008): 269S–274S.
19. H. Hare-Bruun, A. Flint, and B. L. Heitmann, Glycemic index and glycemic load in relation to changes in body weight, body fat distribution, and body composition in adult Danes, *American Journal of Clinical Nutrition* 84 (2006): 871–879.
20. Brand-Miller and coauthors, 2008.
21. A. Esfahani and coauthors, The application of the glycemic index and glycemic load in weight loss: A review of the clinical evidence, *International Union of Biochemistry and Molecular Biology* 63 (2011): 7–13; S. Vega-López and S. N. Mayol-Kreiser, Use of the glycemic index for weight loss and glycemic control: A review of recent evidence, *Current Diabetes Reports* 9 (2009): 379–388.
22. W. J. Whelan and coauthors, The glycemic response is a personal attribute, *International Union of Biochemistry and Molecular Biology* 62 (2010): 637–641.
23. J. P. Chaput and coauthors, A novel interaction between dietary composition and insulin secretion: Effects on weight gain in the Quebec Family Study, *American Journal of Clinical Nutrition* 87 (2008): 303–309.
24. R. J. Wood and M. L. Fernandez, Carbohydrate-restricted versus low-glycemic-index diets for the treatment of insulin resistance and metabolic syndrome, *Nutrition Reviews* 67 (2009): 179–183.
25. K. L. Stanhope and P. J. Havel, Fructose consumption: Recent results and their potential implications, *Annals of the New York Academy of Sciences* 1190 (2010): 15–24; K. J. Melanson and coauthors, 2008.



CENGAGE LEARNING'S GLOBAL NUTRITION — GLOBAL NUTRITION RESOURCE CENTER

A recent study found a strong correlation between *trans* fatty acids and an increase in allergies in adolescents. Go to Nutrition Basics and Tools → Fats to learn about other adverse effects *trans* fatty acids may have on health. What food choices might be healthier alternatives to foods high in *trans* fats?

5

The Lipids: Triglycerides, Phospholipids, and Sterols

Nutrition in Your Life

Most likely, you know what you don't like about body fat, but do you appreciate how it insulates you against the cold or powers your hike around a lake? And what about food fat? You're right to credit fat for providing the delicious flavors and aromas of buttered popcorn and fried chicken—and to criticize it for contributing to the weight gain and heart disease so common today. The challenge is to strike a healthy balance of enjoying some fat, but not too much. Learning which kinds of fats are beneficial and which are most harmful will help you make wise decisions. In the Nutrition Portfolio at the end of this chapter, you can examine whether your current fat choices are meeting dietary goals.

Most people are surprised to learn that fat has some virtues and that a well-balanced diet needs at least a little fat. Getting enough fat is rarely a problem. In our society of abundance, people are more likely to consume too much fat, or too much of some kinds of fat—with consequent health problems.

Fat refers to the class of nutrients known as lipids. The lipid family includes triglycerides (fats and oils), phospholipids, and sterols. Triglycerides are most abundant, both in foods and in the body.

5.1 The Chemist's View of Fatty Acids and Triglycerides

LEARN IT Recognize the chemistry of fatty acids and triglycerides and differences between saturated and unsaturated fats.

Like carbohydrates, lipids are composed of carbon (C), hydrogen (H), and oxygen (O). Because lipids have many more carbons and hydrogens in proportion to their oxygens, they can supply more energy per gram than carbohydrates can (Chapter 7 provides details).

LEARNING GPS

5.1 The Chemist's View of Fatty Acids and Triglycerides 129
LEARN IT Recognize the chemistry of fatty acids and triglycerides and differences between saturated and unsaturated fats.
- Fatty Acids 130
- Triglycerides 133
- Characteristics of Solid Fats and Oils 133

5.2 The Chemist's View of Phospholipids and Sterols 136
LEARN IT Describe the chemistry, food sources, and roles of phospholipids and sterols.
- Phospholipids 136
- Sterols 137

5.3 Digestion, Absorption, and Transport of Lipids 137
LEARN IT Summarize fat digestion, absorption, and transport.
- Lipid Digestion 138
- Lipid Absorption 140
- Lipid Transport 141

5.4 Lipids in the Body 144
LEARN IT Outline the major roles of fats in the body, including a discussion of essential fatty acids and the omega fatty acids.
- Roles of Triglycerides 144
- Essential Fatty Acids 145
- A Preview of Lipid Metabolism 146

5.5 Health Effects and Recommended Intakes of Saturated Fats, *Trans* Fats, and Cholesterol 147
LEARN IT Explain the relationships among saturated fat, *trans* fat, and cholesterol and chronic diseases, noting recommendations.
- Health Effects of Saturated Fats, *Trans* Fats, and Cholesterol 147
- Recommended Intakes of Saturated Fat, *Trans* Fat, and Cholesterol 148

5.6 Health Effects and Recommended Intakes of Monounsaturated and Polyunsaturated Fats 149
LEARN IT Explain the relationships between monounsaturated and polyunsaturated fats and health, noting recommendations.
- Health Effects of Monounsaturated and Polyunsaturated Fats 149
- Recommended Intakes of Monounsaturated and Polyunsaturated Fats 150
- From Guidelines to Groceries 150

Highlight 5 High-Fat Foods—Friend or Foe? 159
LEARN IT Identify which fats support health and which impair it.

The many names and relationships in the lipid family can seem overwhelming—like meeting a friend's extended family for the first time. To ease the introductions, this chapter first presents each of the lipids from a chemist's point of view using both words and diagrams. Then the chapter follows the **lipids** through digestion and absorption and into the body to examine their roles in health and disease. For people who think more easily in words than in chemical symbols, this *preview* of the upcoming chemistry may be helpful:

1. Every triglyceride contains one molecule of glycerol and three fatty acids (basically, chains of carbon atoms).
2. Fatty acids may be 4 to 24 (even numbers of) carbons long, the 18-carbon ones being the most common in foods and especially noteworthy in nutrition.
3. Fatty acids may be saturated or unsaturated. Unsaturated fatty acids may have one or more points of unsaturation—that is, they may be *mono*unsaturated or *poly*unsaturated.
4. Of special importance in nutrition are the polyunsaturated fatty acids known as omega-3 fatty acids and omega-6 fatty acids.
5. The 18-carbon polyunsaturated fatty acids are linolenic acid (omega-3) and linoleic acid (omega-6). Both are essential fatty acids that the body cannot make. Each is the primary member of a family of longer-chain fatty acids that help to regulate blood pressure, blood clotting, and other body functions important to health.

The paragraphs, definitions, and diagrams that follow present this information again in much more detail.

Fatty Acids

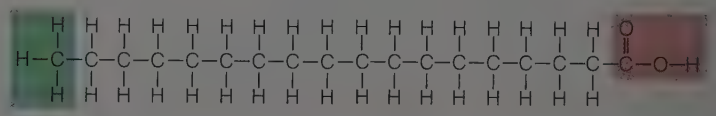
All **fatty acids** have the same basic structure—a chain of carbon and hydrogen atoms with an acid group (COOH) at one end and a methyl group (CH_3) at the other end. Fatty acids may differ from one another, however, in the length of their carbon chains and in the number and location of their double bonds, as the following paragraphs describe. (Fatty acids and related terms are defined in the accompanying glossary.)

The Length of the Carbon Chain

Most naturally occurring fatty acids contain even numbers of carbons in their chains—up to 24 carbons in length. This discussion begins with the 18-carbon fatty acids, which are abundant in our food supply. Stearic acid is the simplest of the 18-carbon fatty acids; the bonds between its carbons are all alike:

lipids: a family of compounds that includes triglycerides, phospholipids, and sterols. Lipids are characterized by their insolubility in water. (Lipids also include the fat-soluble vitamins, described in Chapter 11.)

Stearic acid, an 18-carbon saturated fatty acid



GLOSSARY OF FATTY ACID TERMS

fatty acids: organic compounds composed of a carbon chain with hydrogens attached and an acid group (COOH) at one end and a methyl group (CH_3) at the other end.

monounsaturated fatty acid (MUFA): a fatty acid that lacks two hydrogen atoms and has one double bond between carbons—for example, oleic acid. A *monounsaturated fat* is composed of triglycerides in which most of the fatty acids are monounsaturated.

- **mono** = one

point of unsaturation: the double bond of a fatty acid, where hydrogen atoms can easily be added to the structure.

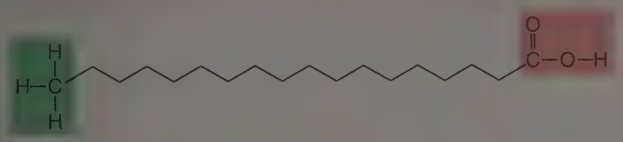
polyunsaturated fatty acid (PUFA): a fatty acid that lacks four or more hydrogen atoms and has two or more double bonds between carbons—for example, linoleic acid (two double bonds) and linolenic acid (three double bonds). A *polyunsaturated fat* is composed of triglycerides in which most of the fatty acids are polyunsaturated.

- **poly** = many

saturated fatty acid: a fatty acid carrying the maximum possible number of hydrogen atoms—for example, stearic acid. A *saturated fat* is composed of triglycerides in which most of the fatty acids are saturated.

unsaturated fatty acid: a fatty acid that lacks hydrogen atoms and has at least one double bond between carbons (includes monounsaturated and polyunsaturated fatty acids). An *unsaturated fat* is composed of triglycerides in which most of the fatty acids are unsaturated.

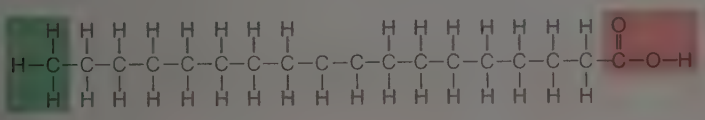
As you can see, stearic acid is 18 carbons long, and each atom meets the rules of chemical bonding described in Figure 4-1 on p. 96. The following structure also depicts stearic acid, but in a simpler way, with each "corner" on the zigzag line representing a carbon atom with two attached hydrogens:



Stearic acid (simplified structure)

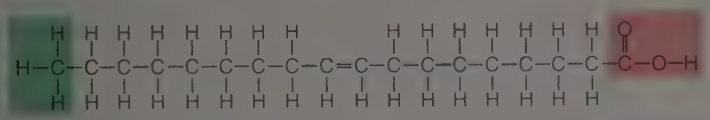
As mentioned, the carbon chains of fatty acids vary in length. The long-chain (12 to 24 carbons) fatty acids of meats, seafood, and vegetable oils are most common in the diet. Smaller amounts of medium-chain (6 to 10 carbons) and short-chain (fewer than 6 carbons) fatty acids also occur, primarily in dairy products. (Tables C-1 and C-2 in Appendix C provide the names, chain lengths, and sources of fatty acids commonly found in foods.)

The Number of Double Bonds Stearic acid (described and shown previously) is a **saturated fatty acid.** A saturated fatty acid is fully loaded with all its hydrogen atoms and contains only single bonds between its carbon atoms. If two hydrogens were missing from the middle of the carbon chain, the remaining structure might be:



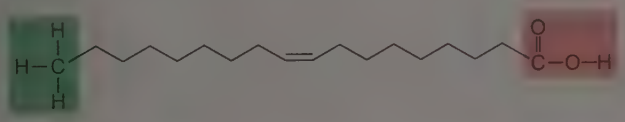
An impossible chemical structure

Notice that in this impossible chemical structure, two of the carbons have only three bonds each. Such a compound cannot exist because every carbon must have four bonds. To satisfy this rule, the two carbons form a double bond:



Oleic acid, an 18-carbon monounsaturated fatty acid

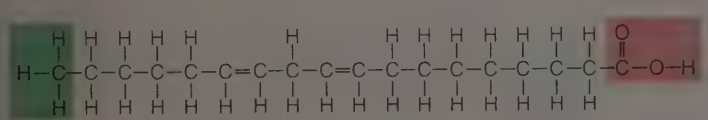
The same structure drawn more simply looks like this:*



Oleic acid (simplified structure)

Although drawn straight here, the actual shape bends at the double bond. The double bond is a **point of unsaturation.** A fatty acid like this—with two hydrogens missing and a double bond—is an **unsaturated fatty acid.** This one is the 18-carbon **monounsaturated fatty acid** oleic acid, which is abundant in olive oil and canola oil.

A **polyunsaturated fatty acid** has two or more carbon-to-carbon double bonds. **Linoleic acid,** the 18-carbon fatty acid common in vegetable oils, lacks four hydrogens and has two double bonds:



Linoleic acid, an 18-carbon polyunsaturated fatty acid

*Remember that each "corner" on the zigzag line represents a carbon atom with two attached hydrogens.

linoleic (lin-oh-LAY-ick) **acid:** an essential fatty acid with 18 carbons and two double bonds.

TABLE 5-1 18-Carbon Fatty Acids

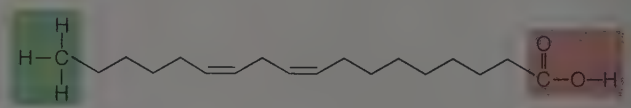
Name	Number of Carbon Atoms	Number of Double Bonds	Saturation	Common Food Sources
Stearic acid	18	0	Saturated	Most animal fats
Oleic acid	18	1	Monounsaturated	Olive and canola oils
Linoleic acid	18	2	Polyunsaturated	Sunflower, safflower, corn, and soybean oils
Linolenic acid	18	3	Polyunsaturated	Soybean and canola oils, flaxseed, walnuts

NOTE: Chemists use a shorthand notation to describe fatty acids. The first number indicates the number of carbon atoms; the second, the number of the double bonds. For example, the notation for stearic acid is 18:0

© Cengage Learning 2013

Drawn more simply, linoleic acid looks like this (though the actual shape would bend at the double bonds):

Linoleic acid (simplified structure)



A fourth 18-carbon fatty acid is **linolenic acid,** which has three double bonds. Table 5-1 presents the 18-carbon fatty acids.

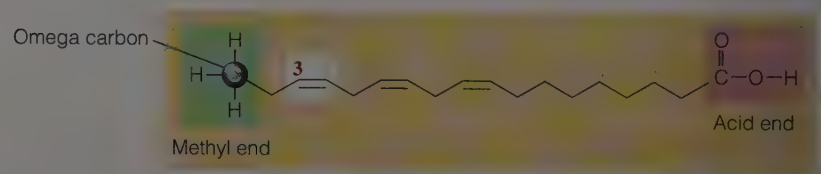
The Location of Double Bonds Fatty acids differ not only in the length of their chains and their degree of saturation, but also in the locations of their double bonds. Chemists identify polyunsaturated fatty acids by the position of the double bond closest to the methyl (CH_3) end of the carbon chain, which is described by an **omega** number. A polyunsaturated fatty acid with its closest double bond three carbons away from the methyl end is an **omega-3 fatty acid.** Similarly, an **omega-6 fatty acid** is a polyunsaturated fatty acid with its closest double bond six carbons away from the methyl end. Figure 5-1 compares two 18-carbon fatty acids—linolenic acid (an omega-3 fatty acid) and linoleic acid (an omega-6 fatty acid).

Monounsaturated fatty acids tend to belong to the omega-9 group, with their closest (and only) double bond nine carbons away from the methyl end. Oleic acid—the 18 carbon monounsaturated fatty acid common in olive oil mentioned earlier—is an omega-9 fatty acid. It is also the most predominant monounsaturated fatty acid in the diet.

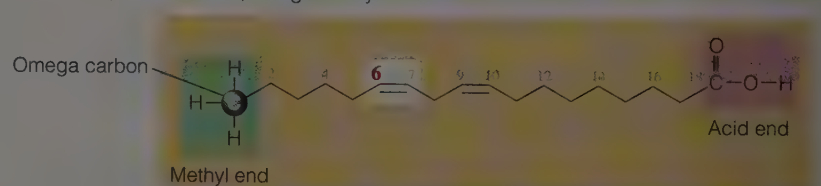
> FIGURE 5-1 Omega-3 and Omega-6 Fatty Acids Compared

The omega number indicates the position of the double bond closest to the methyl (CH_3) end. The fatty acids of an omega family may have different lengths and different numbers of double bonds, but the location of the double bond closest to the methyl end is the same in all of them. These structures are drawn linearly here to ease counting carbons and locating double bonds, but their shapes actually bend at the double bonds.

Linolenic acid, an 18-carbon, omega-3 fatty acid



Linoleic acid, an 18-carbon, omega-6 fatty acid



© Cengage Learning 2013

linolenic (lin-oh-LEN-ick) **acid:** an essential fatty acid with 18 carbons and three double bonds.

omega: the last letter of the Greek alphabet (ω), used by chemists to refer to the position of the closest double bond to the methyl (CH_3) end of a fatty acid.

omega-3 fatty acid: a polyunsaturated fatty acid in which the closest double bond to the methyl (CH_3) end of the carbon chain is three carbons away.

omega-6 fatty acid: a polyunsaturated fatty acid in which the closest double bond to the methyl (CH_3) end of the carbon chain is six carbons away.

Triglycerides Few fatty acids occur free in foods or in the body. Most often, they are incorporated into **triglycerides**—lipids composed of three fatty acids attached to a **glycerol.*** Figure 5-2 presents a glycerol molecule.

To make a triglyceride, a series of **condensation** reactions combine a hydrogen atom (H) from the glycerol and a hydroxyl (OH) group from a fatty acid, forming a molecule of water (H_2O) and leaving a bond between the two molecules (see Figure 5-3). Most triglycerides contain a mixture of more than one type of fatty acid (as shown on the right side of Figure 5-3).

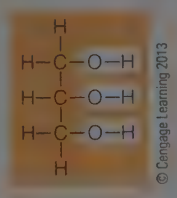
Characteristics of Solid Fats and Oils The chemistry of a fatty acid—whether it is short or long, saturated or unsaturated, with its closest double bond at carbon 3 or carbon 6—influences the characteristics of foods and the health of the body. A section later in this chapter explains how these features affect health; this section describes how the chemistry influences the fats and oils in foods.

Firmness The degree of unsaturation influences the firmness of fats at room temperature (see Figure 5-4). Generally speaking, most polyunsaturated vegetable oils are liquid at room temperature, and the more saturated animal fats are solid. Some oils—notably, cocoa butter, palm oil, palm kernel oil, and coconut oil—are

*Research scientists commonly use the term *triacylglycerols;* this book continues to use the more familiar term *triglycerides,* as do many other health and nutrition books and journals.

> FIGURE 5-2 Glycerol

When glycerol is free, an OH group is attached to each carbon. When glycerol is part of a triglyceride, each carbon is attached to a fatty acid (as shown in the next figure).



triglycerides (try-GLISS-er-rides) the chief form of fat in the diet and the major storage form of fat in the body; composed of a molecule of glycerol with three fatty acids attached; also called *triacylglycerols* (try-ay-seel-GLISS-er-ols).

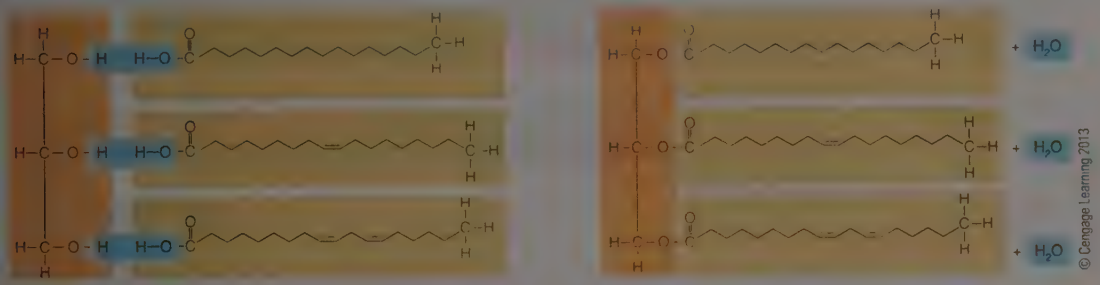
- **tri** = three
- **glyceride** = of glycerol

glycerol (GLISS-er-ol): an alcohol composed of a three-carbon chain, which can serve as the backbone for a triglyceride.

condensation: a chemical reaction in which water is released as two molecules combine to form one larger product

> FIGURE 5-3 Condensation of Glycerol and Fatty Acids to Form a Triglyceride

To make a triglyceride, three fatty acids attach to glycerol in condensation reactions.

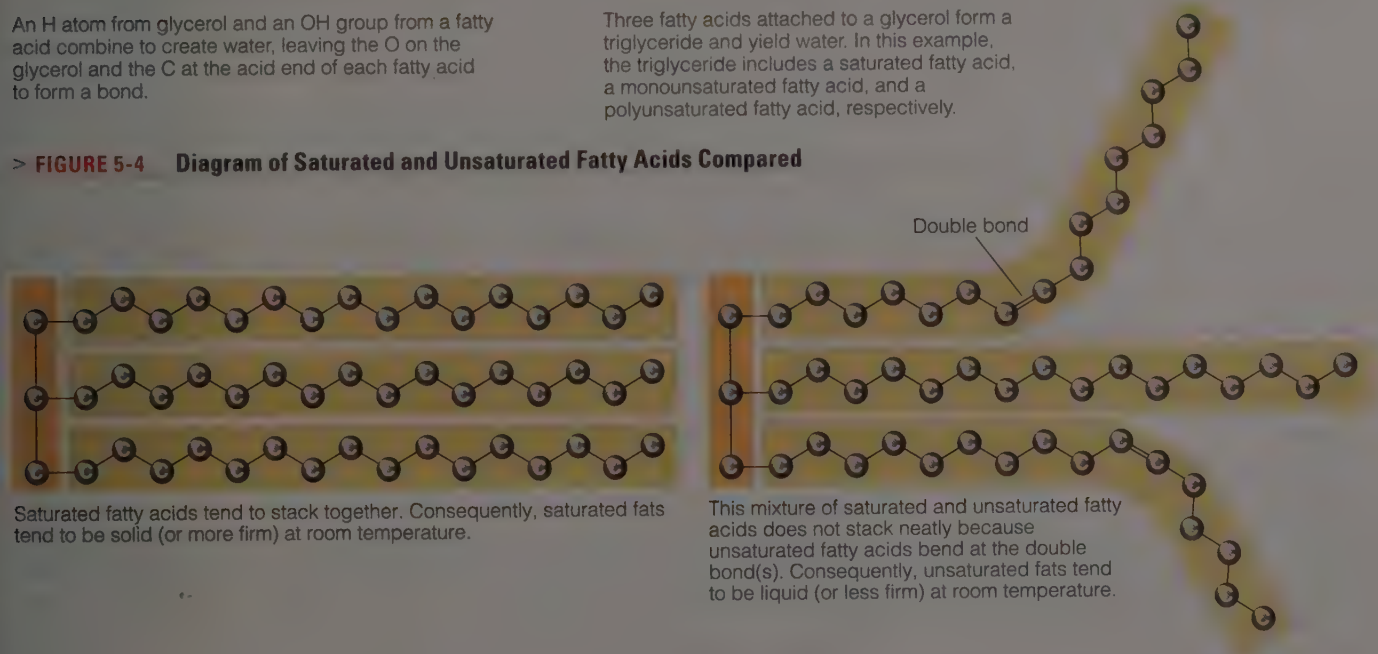


Glycerol + three fatty acids ⟶ Triglyceride + three water molecules

An H atom from glycerol and an OH group from a fatty acid combine to create water, leaving the O on the glycerol and the C at the acid end of each fatty acid to form a bond.

Three fatty acids attached to a glycerol form a triglyceride and yield water. In this example, the triglyceride includes a saturated fatty acid, a monounsaturated fatty acid, and a polyunsaturated fatty acid, respectively.

> FIGURE 5-4 Diagram of Saturated and Unsaturated Fatty Acids Compared



Saturated fatty acids tend to stack together. Consequently, saturated fats tend to be solid (or more firm) at room temperature.

This mixture of saturated and unsaturated fatty acids does not stack neatly because unsaturated fatty acids bend at the double bond(s). Consequently, unsaturated fats tend to be liquid (or less firm) at room temperature.

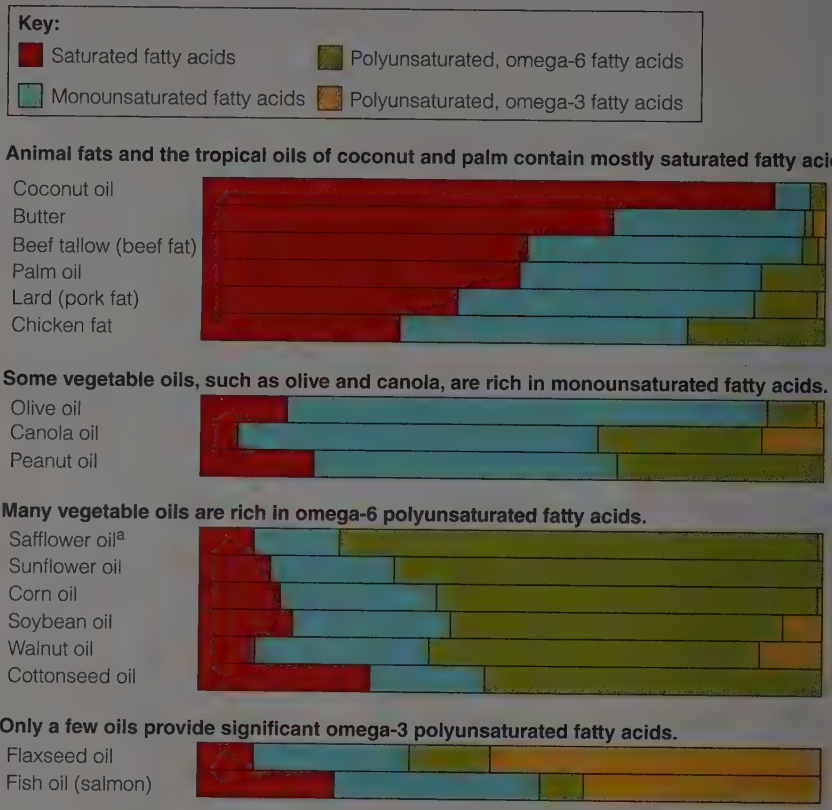


© Polara Studios, Inc

At room temperature, saturated fats (such as those commonly found in butter and other animal fats) are solid, whereas unsaturated fats (such as those found in vegetable oils) are usually liquid.

> FIGURE 5-5 Fatty Acid Composition of Common Food Fats

Most fats are a mixture of saturated, monounsaturated, and polyunsaturated fatty acids.



[a]*Salad or cooking type over 70% linoleic acid.*

© Cengage Learning 2013

saturated; they are firmer than most vegetable oils because of their saturation, but softer than most animal fats because of their shorter carbon chains (8 to 14 carbons long). Generally, the shorter the carbon chain, the softer the fat is at room temperature. Fatty acid compositions of selected **fats** and **oils** are shown in Figure 5-5, and Appendix H provides the fat and fatty acid contents of many other foods.

Stability The degree of unsaturation also influences stability. All fats become spoiled when exposed to oxygen. The **oxidation** of fats produces a variety of compounds that smell and taste rancid. (Other types of spoilage can occur due to microbial growth.) Polyunsaturated fats spoil most readily because their double bonds are unstable; monounsaturated fats are slightly less susceptible. Saturated fats are most resistant to oxidation and thus least likely to become rancid.

Manufacturers can protect fat-containing products against rancidity in three ways—none of which are perfect. First, products may be sealed in air-tight, nonmetallic containers, protected from light, and refrigerated—an expensive and inconvenient storage system. Second, manufacturers may add **antioxidants** to compete for the oxygen and thus protect the oil (examples are the additives BHA and BHT and vitamin E).* The advantages and disadvantages of antioxidant additives in food processing are presented in Chapter 19. Third, products may undergo a process known as hydrogenation.

Hydrogenation During **hydrogenation**, some or all of the points of unsaturation are saturated by adding hydrogen molecules. Hydrogenation offers two advantages. First, it protects against oxidation (thereby prolonging shelf life) by making polyunsaturated fats more saturated. Second, it alters the texture of foods

fats: lipids that are solid at room temperature (77°F or 25°C).

oils: lipids that are liquid at room temperature (77°F or 25°C).

oxidation (OKS-ee-day-shun): the process of a substance combining with oxygen; oxidation reactions involve the loss of electrons.

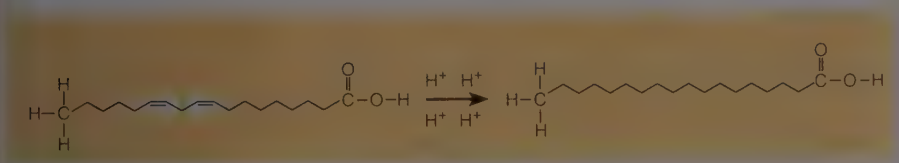
antioxidants: as a food additive, preservatives that delay or prevent rancidity of fats in foods and other damage to food caused by oxygen.

hydrogenation (HIGH-dro-jen-AY-shun or high-DROJ-eh-NAY-shun): a chemical process by which hydrogens are added to monounsaturated or polyunsaturated fatty acids to reduce the number of double bonds, making the fats more saturated (solid) and more resistant to oxidation (protecting against rancidity). Hydrogenation produces *trans*-fatty acids.

*BHA is butylated hydroxyanisole; BHT is butylated hydroxytoluene.

> FIGURE 5-6 Hydrogenation

Double bonds carry a slightly negative charge and readily accept positively charged hydrogen atoms, creating a saturated fatty acid. Most often, fat is *partially* hydrogenated, creating a *trans*-fatty acid (shown in Figure 5-7).



Polyunsaturated fatty acid → Hydrogenated (saturated) fatty acid

© Cengage Learning 2013

by making liquid vegetable oils more solid (as in margarine and shortening). Hydrogenated fats improve the texture of foods, making margarines spreadable, pie crusts flaky, and puddings creamy.

Figure 5-6 illustrates the *total* hydrogenation of a polyunsaturated fatty acid to a saturated fatty acid. Total hydrogenation rarely occurs during food processing. Most often, a fat is *partially* hydrogenated, and some of the double bonds that remain after processing change their configuration from ***cis*** to ***trans***.

***Trans*-Fatty Acids** In nature, most double bonds are *cis*—meaning that the hydrogens next to the double bonds are on the same side of the carbon chain. Only a few fatty acids (notably a small percentage of those found in milk and meat products) naturally occur as ***trans*-fatty acids**—meaning that the hydrogens next to the double bonds are on opposite sides of the carbon chain (see Figure 5-7). In the body, *trans*-fatty acids behave more like saturated fats, increasing blood cholesterol and the risk of heart disease (as a later section describes).[1]

Some research suggests that both naturally occurring and commercially created *trans* fats change blood lipids similarly; other research suggests that the negative effects are specific to only the commercial *trans* fats.[2] In any case, the important distinction is that a relatively small amount of *trans* fat in the diet comes from natural sources.* At current levels of consumption, natural *trans* fats have little, if any, effect on blood lipids. Some naturally occurring *trans* fatty acids, known as **conjugated linoleic acids**, may even have health benefits.[3] Conjugated linoleic acids are not counted as *trans* fats on food labels.

cis: on the near side of; refers to a chemical configuration in which the hydrogen atoms are located on the same side of a double bond.

trans: on the other side of; refers to a chemical configuration in which the hydrogen atoms are located on opposite sides of a double bond.

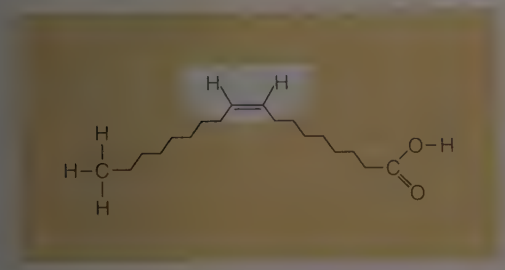
***trans*-fatty acids**: fatty acids with hydrogens on opposite sides of the double bond.

conjugated linoleic acids: several fatty acids that have the same chemical formula as linoleic acid (18 carbons, two double bonds) but with different configurations (the double bonds occur on adjacent carbons).

*For example, most dairy products contain less than 0.5 gram naturally occurring *trans* fat per serving.

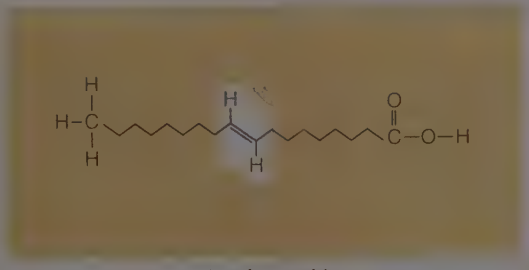
> FIGURE 5-7 *Cis*- and *Trans*-Fatty Acids Compared

This example compares the *cis* configuration for an 18-carbon monounsaturated fatty acid (oleic acid) with its corresponding *trans* configuration (elaidic acid).



cis-fatty acid

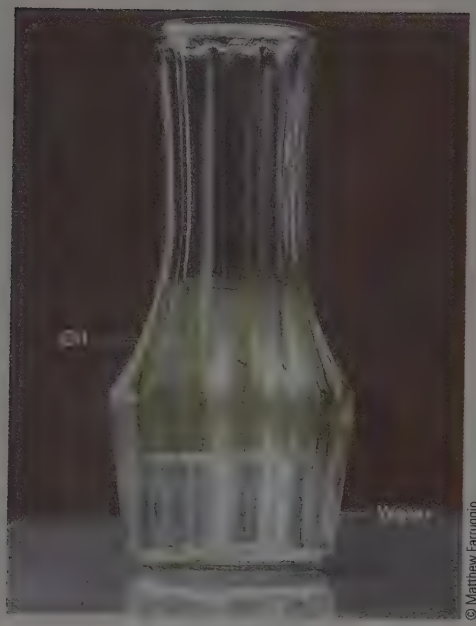
A *cis*-fatty acid has its hydrogens on the same side of the double bond; *cis* molecules bend into a U-like formation. Most naturally occuring unsaturated fatty acids in foods are *cis*.



trans-fatty acid

A *trans*-fatty acid has its hydrogens on the opposite sides of the double bond; *trans* molecules are more linear. The *trans* form typically occurs in partially hydrogenated foods when hydrogen atoms shift around some double bonds and change the configuration from *cis* to *trans*.

© Cengage Learning 2013

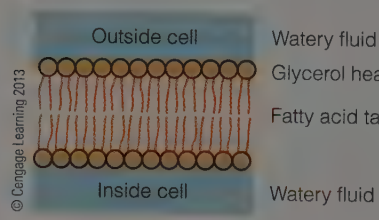


© Matthew Farruggio

Without help from emulsifiers, fats and water don't mix.

> FIGURE 5-9 Phospholipids of a Cell Membrane

A cell membrane is made of phospholipids assembled into an orderly formation called a bilayer. The fatty acid "tails" orient themselves away from the watery fluid inside and outside of the cell. The glycerol and phosphate "heads" are attracted to the watery fluid.



© Cengage Learning 2013

phospholipid (FOS-foe-LIP-id): a compound similar to a triglyceride but having a phosphate group (a phosphorus-containing salt) and choline (or another nitrogen-containing compound) in place of one of the fatty acids.

lecithin (LESS-uh-thin): one of the phospholipids. Both nature and the food industry use lecithin as an emulsifier to combine water-soluble and fat-soluble ingredients that do not ordinarily mix, such as water and oil.

choline (KOH-leen): a nitrogen-containing compound found in foods and made in the body from the amino acid methionine. Choline is part of the phospholipid lecithin and the neurotransmitter acetylcholine.

hydrophobic (high-dro-FOE-bick): a term referring to water-fearing, or non-water-soluble, substances; also known as *lipophilic* (fat loving).

- **hydro** = water
- **phobia** = fear
- **lipo** = lipid
- **phile** = love

hydrophilic (high-dro-FIL-ick): a term referring to water-loving, or water-soluble, substances.

emulsifiers: substances with both water-soluble and fat-soluble portions that promote the mixing of oils and fats in watery solutions.

REVIEW IT Recognize the chemistry of fatty acids and triglycerides and differences between saturated and unsaturated fats.

The predominant lipids both in foods and in the body are triglycerides: a molecule of glycerol with three fatty acids attached. Fatty acids vary in the length of their carbon chains, their degrees of unsaturation (number of double bonds), and the location of their double bond(s). Those that are fully loaded with hydrogens are saturated; those that are missing hydrogens and therefore have double bonds are unsaturated (monounsaturated or polyunsaturated). The vast majority of triglycerides contain more than one type of fatty acid. Fatty acid saturation affects fats' physical characteristics and storage properties. Hydrogenation, which converts polyunsaturated fats to saturated fats, protects fats from oxidation and alters the texture by making liquid vegetable oils more solid. In the process, hydrogenation creates *trans*-fatty acids that damage health in ways similar to those of saturated fatty acids.

5.2 The Chemist's View of Phospholipids and Sterols

LEARN IT Describe the chemistry, food sources, and roles of phospholipids and sterols.

The preceding pages have been devoted to one of the classes of lipids, the triglycerides, and their component parts, glycerol and the fatty acids. The other lipids, the phospholipids and sterols, make up only 5 percent of the lipids in the diet.

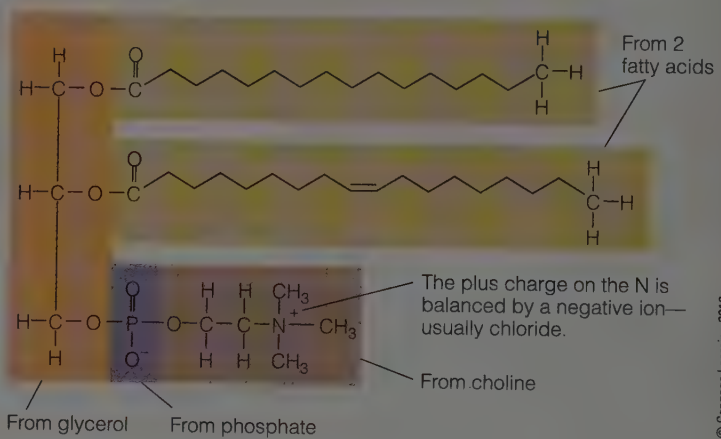
Phospholipids The best-known **phospholipid** is **lecithin** (see Figure 5-8). Notice that lecithin has one glycerol with two of its three attachment sites occupied by fatty acids like those in triglycerides. The third site is occupied by a phosphate group and a molecule of **choline**. The **hydrophobic** fatty acids make phospholipids soluble in fat; the **hydrophilic** phosphate group allows them to dissolve in water. Such versatility enables the food industry to use phospholipids as **emulsifiers** to mix fats with water in such products as mayonnaise, salad dressings, and candy bars.

Phospholipids in Foods In addition to the phospholipids used by the food industry as emulsifiers, phospholipids are also found naturally in foods. The richest food sources of lecithin are eggs, liver, soybeans, wheat germ, and peanuts.

Roles of Phospholipids Lecithin and other phospholipids are constituents of cell membranes (see Figure 5-9). Because phospholipids are soluble in both water and fat, they can help fat-soluble substances, including vitamins and hormones, to pass

> FIGURE 5-8 Lecithin

Lecithin is one of the phospholipids. Notice that a molecule of lecithin is similar to a triglyceride but contains only two fatty acids. The third position is occupied by a phosphate group and a molecule of choline. Other phospholipids have different fatty acids at the upper two positions and different groups attached to phosphate.



© Cengage Learning 2013

easily in and out of cells. Phospholipids also act as emulsifiers in the body, helping to keep fats suspended in the blood and body fluids.

Sterols In addition to triglycerides and phospholipids, the lipids include the **sterols,** compounds with a multiple-ring structure.* The most famous sterol is **cholesterol;** Figure 5-10 shows its chemical structure.

Sterols in Foods Foods derived from both plants and animals contain sterols, but only those from animals contain significant amounts of cholesterol—meats, eggs, seafood, poultry, and dairy products. Some people, confused about the distinction between dietary cholesterol and blood cholesterol, have asked which foods contain the "good" cholesterol. "Good" cholesterol is not a type of cholesterol found in foods, but it refers to the way the body transports cholesterol in the blood, as explained in a later section of this chapter.

Sterols other than cholesterol are naturally found in plants. Being structurally similar to cholesterol, plant sterols interfere with cholesterol absorption. By inhibiting cholesterol absorption, a diet rich in plant sterols lowers blood cholesterol levels.[4] Food manufacturers have fortified foods such as margarine with plant sterols, creating a functional food that helps to reduce blood cholesterol.

Roles of Sterols Many vitally important body compounds are sterols. Among them are bile acids, the sex hormones (such as testosterone), the adrenal hormones (such as cortisol), and vitamin D, as well as cholesterol itself. Cholesterol in the body can serve as the starting material for the synthesis of these compounds ♦ or as a structural component of cell membranes; more than 90 percent of all the body's cholesterol is found in the cells. Despite popular impressions, cholesterol is not a villain lurking in some evil foods—it is a compound the body makes and uses. The chemical structure is the same, but cholesterol that is made in the body is called **endogenous,** whereas cholesterol from outside the body (from foods) is called **exogenous.** Right now, as you read, your liver is manufacturing cholesterol from fragments of carbohydrate, protein, and fat. In fact, the liver makes about 800 to 1500 milligrams of cholesterol per day, thus contributing much more to the body's total than does the diet. For perspective, the Daily Value on food labels for cholesterol is 300 milligrams per day.

Cholesterol's harmful effects in the body occur when it accumulates in the artery walls and contributes to the formation of **plaque.** These plaque deposits lead to **atherosclerosis,** a disease that causes heart attacks and strokes. Chapter 18 provides many more details.

REVIEW IT Describe the chemistry, food sources, and roles of phospholipids and sterols.

Phospholipids, including lecithin, have a unique chemical structure that allows them to be soluble in both water and fat. The food industry uses phospholipids as emulsifiers, and in the body, phospholipids are part of cell membranes. Sterols have a multiple-ring structure that differs from the structure of other lipids. In the body, sterols include cholesterol, bile, vitamin D, and some hormones. Animal-derived foods are rich sources of cholesterol. Table 5-2 (p. 138) summarizes the lipid family of compounds.

5.3 Digestion, Absorption, and Transport of Lipids

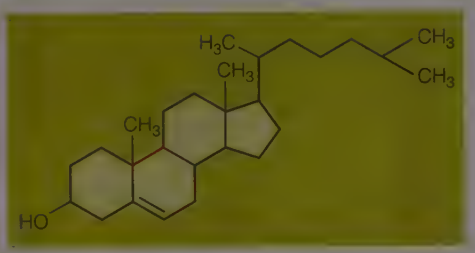
LEARN IT Summarize fat digestion, absorption, and transport.

Each day, the GI tract receives, on average from the food we eat, 50 to 100 grams of triglycerides, 4 to 8 grams of phospholipids, and 200 to 350 milligrams of cholesterol. These lipids are hydrophobic, whereas the digestive enzymes are hydrophilic. As you read, notice how the body elegantly meets the challenges of keeping

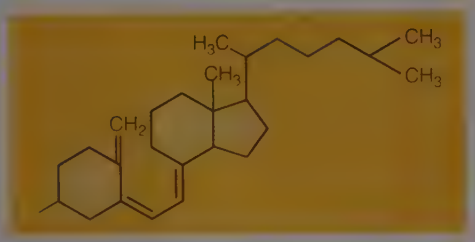
*The four-ring core structure identifies a steroid; sterols are alcohol derivatives with a steroid ring structure.

> FIGURE 5-10 Cholesterol

Notice how different cholesterol is from the triglycerides and phospholipids. The fat-soluble vitamin D is synthesized from cholesterol; notice the many structural similarities. The only difference is that cholesterol has a closed ring (highlighted in red), whereas vitamin D's is open, accounting for its vitamin activity.



Cholesterol



Vitamin D_3

© Cengage Learning 2013

♦ Compounds made from cholesterol:
- Bile acids
- Steroid hormones (testosterone, androgens, estrogens, progesterones, cortisol, cortisone, and aldosterone)
- Vitamin D

sterols (STARE-ols or STEER-ols): compounds containing a four-ring carbon structure with any of a variety of side chains attached.

cholesterol (koh-LESS-ter-ol): one of the sterols containing a four-ring carbon structure with a carbon side chain.

endogenous (en-DODGE-eh-nus): from within the body.
- **endo** = within
- **gen** = arising

exogenous (eks-ODGE-eh-nus): from outside the body.
- **exo** = outside

plaque (PLACK): an accumulation of fatty deposits, smooth muscle cells, and fibrous connective tissue that develops in the artery walls in atherosclerosis. Plaque associated with atherosclerosis is known as *atheromatous* (ATH-er-OH-ma-tus) *plaque.*

atherosclerosis (ATH-er-oh-scler-OH-sis): a type of artery disease characterized by plaques (accumulations of lipid-containing material) on the inner walls of the arteries (see Chapter 18).

TABLE 5-2 The Lipid Family

Triglycerides

- 1 Glycerol (per triglyceride) and
- 3 Fatty acids (per triglyceride); depending on the number of double bonds, fatty acids may be:
  - *Saturated* (no double bonds)
  - *Monounsaturated* (one double bond)
  - *Polyunsaturated* (more than one double bond); depending on the location of the double bonds, polyunsaturated fatty acids may be:
    - *Omega-3* (double bond closest to methyl end is 3 carbons away)
    - *Omega-6* (double bond closest to methyl end is 6 carbons away)

Phospholipids (such as lecithin)

Sterols (such as cholesterol)

© Cengage Learning 2013

the lipids mixed in the watery fluids of the GI tract and facilitating the work of the lipases.

Lipid Digestion Figure 5-11 traces the digestion of fat through the GI tract. The goal of fat digestion is to dismantle triglycerides into small molecules that the body can absorb and use—namely, **monoglycerides,** fatty acids, and glycerol. The following paragraphs provide the details.

In the Mouth Fat digestion starts off slowly in the mouth, with some hard fats beginning to melt when they reach body temperature. A salivary gland at the base of the tongue releases an enzyme (lingual lipase) that plays an active role in fat digestion in infants, but a relatively minor role in adults. In infants, this enzyme efficiently digests the short- and medium-chain fatty acids found in milk.

In the Stomach In a quiet stomach, fat would float as a layer above the watery components of swallowed food. But whenever food is present, the stomach becomes active. The strong muscle contractions of the stomach propel its contents toward the pyloric sphincter. Some chyme passes through the pyloric sphincter periodically, but the remaining partially digested food is propelled back into the body of the stomach. This churning grinds the solid pieces to finer particles, mixes the chyme, and disperses the fat into small droplets. These actions help to expose the fat for attack by the gastric lipase enzyme—an enzyme that performs best in the acidic environment of the stomach. Still, little fat digestion takes place in the stomach; most of the action occurs in the small intestine.

In the Small Intestine When fat enters the small intestine, it triggers the release of the hormone cholecystokinin (CCK), which signals the gallbladder to release its stores of bile. (Remember that the liver makes bile, and the gallbladder stores it until it is needed.) Among bile's many ingredients are bile acids, which are made in the liver from cholesterol and have a similar structure. In addition, bile acids often pair up with an amino acid (a building block of protein). The amino acid end is hydrophilic, and the sterol end is hydrophobic. This structure enables bile to act as an emulsifier, drawing fat molecules into the surrounding watery fluids. There, the fats are fully digested as they encounter lipase enzymes from the pancreas and small intestine. The process of emulsification is diagrammed in Figure 5-12 (p. 140).

Most of the hydrolysis of triglycerides occurs in the small intestine. The major fat-digesting enzymes are pancreatic lipases; some intestinal lipases are also active. These enzymes remove each of a triglyceride's outer fatty acids one at a

lipases: enzymes that hydrolyze lipids. *Lingual lipase* refers to the fat-digesting enzyme secreted from the salivary gland at the base of the tongue.

monoglycerides: molecules of glycerol with one fatty acid attached. A molecule of glycerol with two fatty acids attached is a *diglyceride.*

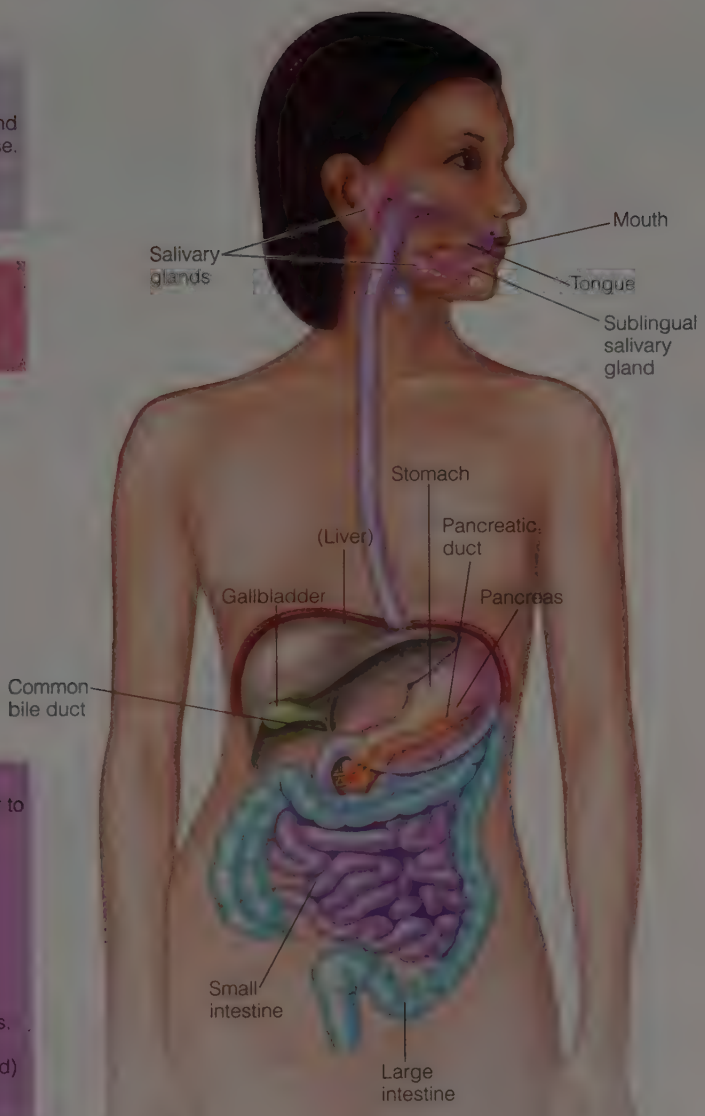
- **mono** = one
- **di** = two

FIGURE 5-11 Fat Digestion in the GI Tract

FAT

Mouth and salivary glands
Some hard fats begin to melt as they reach body temperature. The sublingual salivary gland in the base of the tongue secretes lingual lipase. The degree of hydrolysis by lingual lipase is slight for most fats but may be appreciable for milk fats.

Stomach
The stomach's churning action mixes fat with water and acid. A gastric lipase accesses and hydrolyzes (only a very small amount of) fat.



Small intestine
Cholecystokinin (CCK) signals the gallbladder to release bile (via the common bile duct):

Fat —(Bile)→ Emulsified fat

Pancreatic lipase flows in from the pancreas (via the pancreatic duct):

Emulsified fat (triglycerides) —(Pancreatic (and intestinal) lipase)→ Monoglycerides, glycerol, fatty acids (absorbed)

Large intestine
Some fat and cholesterol, trapped in fiber, exit in feces.

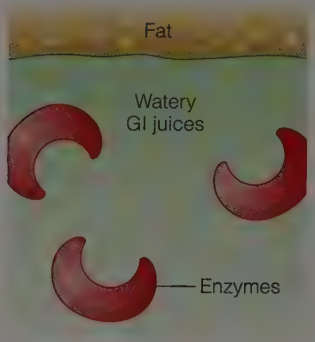
© Cengage Learning 2013

time, leaving a monoglyceride. Occasionally, enzymes remove all three fatty acids, leaving a free molecule of glycerol. Hydrolysis of a triglyceride is shown in Figure 5-13 (p. 140).

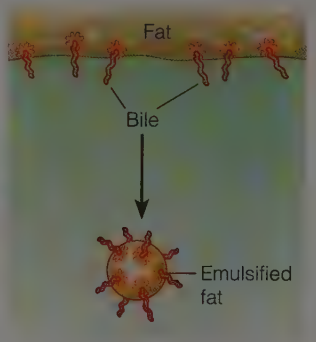
Phospholipids are digested similarly—that is, their fatty acids are removed by hydrolysis. The two fatty acids and the remaining glycerol and phosphate fragments are then absorbed. Most sterols can be absorbed as is; if any fatty acids are attached, they are first hydrolyzed off.

> **FIGURE 5-12 Emulsification of Fat by Bile**

Like bile, detergents are emulsifiers and work the same way, which is why they are effective in removing grease spots from clothes. Molecule by molecule, the grease is dissolved out of the spot and suspended in the water, where it can be rinsed away.



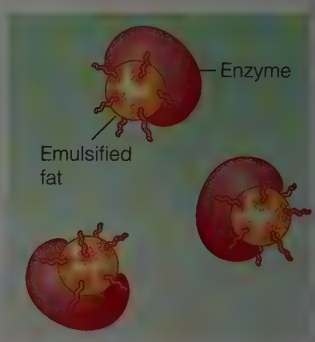
In the stomach, the fat and watery GI juices tend to separate. The enzymes in the GI juices can't get at the fat.



When fat enters the small intestine, the gallbladder secretes bile. Bile has an affinity for both fat and water, so it can bring the fat into the water.



Bile's emulsifying action converts large fat globules into small droplets that repel one another.



After emulsification, more fat is exposed to the enzymes, making fat digestion more efficient.

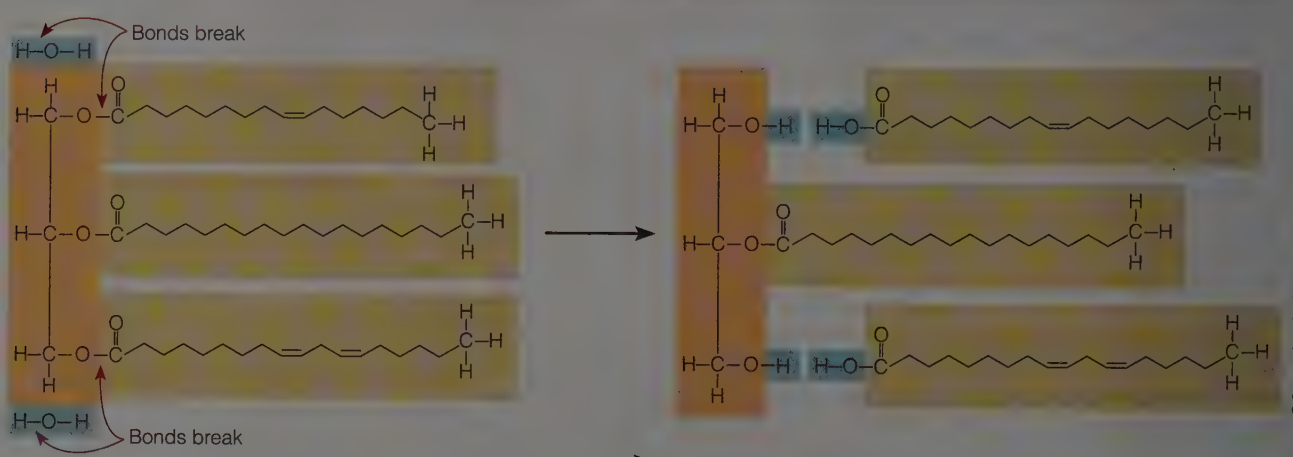
© Cengage Learning 2013

Bile's Routes After bile enters the small intestine and emulsifies fat, it has two possible destinations, illustrated in Figure 5-14. Most of the bile is reabsorbed from the small intestine and recycled. The other possibility is that some of the bile can be trapped by dietary fibers in the large intestine and excreted. Because cholesterol is needed to make bile, the excretion of bile effectively reduces blood cholesterol. As Chapter 4 explains, the dietary fibers most effective at lowering blood cholesterol this way are the soluble fibers commonly found in fruits, whole grains, and legumes.

Lipid Absorption Figure 5-15 illustrates the absorption of lipids. Small molecules (glycerol and short- and medium-chain fatty acids) can diffuse easily into the intestinal cells; they are absorbed directly into the bloodstream. Larger molecules (monoglycerides and long-chain fatty acids) are emulsified by bile, forming spherical complexes known as **micelles.** The micelles diffuse into the intestinal cells where the monoglycerides and long-chain fatty acids are reassembled into new triglycerides.

micelles (MY-cells): tiny spherical complexes of emulsified fat that arise during digestion; most contain bile salts and the products of lipid digestion, including fatty acids, monoglycerides, and cholesterol.

> **FIGURE 5-13 Digestion (Hydrolysis) of a Triglyceride**



Triglyceride

The triglyceride and two molecules of water are split. The H and OH from water complete the structures of two fatty acids and leave a monoglyceride.

Monoglyceride + two fatty acids

These products may pass into the intestinal cells, but sometimes the monoglyceride is split with another molecule of water to give a third fatty acid and glycerol. Fatty acids, monoglycerides, and glycerol are absorbed into intestinal cells.

© Cengage Learning 2013

Within the intestinal cells, the newly made triglycerides and other lipids (cholesterol and phospholipids) are packed with protein into transport vehicles known as chylomicrons. The intestinal cells then release the chylomicrons into the lymphatic system. The chylomicrons glide through the lymph until they reach a point of entry into the bloodstream at the thoracic duct near the heart. (Recall from Chapter 3 that nutrients from the GI tract that enter the lymph system initially bypass the liver.) The blood carries these lipids to the rest of the body for immediate use or storage. A look at these lipids in the body reveals the kinds of fat the diet has been delivering. The blood, fat stores, and muscle cells of people who eat a diet rich in unsaturated fats, for example, contain more unsaturated fats than those of people who select a diet high in saturated fats.

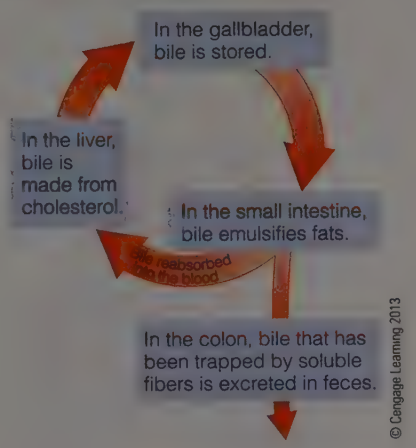
Lipid Transport The chylomicrons are only one of several clusters of lipids and proteins that are used as transport vehicles for fats. As a group, these vehicles are known as **lipoproteins**, and they solve the body's challenge of transporting fat through the watery bloodstream. The body makes four main types of lipoproteins, distinguished by their size and density.* Each type contains different kinds and amounts of lipids and proteins. The more lipids, the less dense; the more proteins, the more dense. Figure 5-16 (p. 142) shows the relative compositions and sizes of the lipoproteins.

Chylomicrons The **chylomicrons** are the largest and least dense of the lipoproteins. They transport *diet*-derived lipids (mostly triglycerides) from the

*Chemists can identify the various lipoproteins by their density. They place a blood sample below a thick fluid in a test tube and spin the tube in a centrifuge. The most buoyant particles (highest in lipids) rise to the top and have the lowest density; the densest particles (highest in proteins) remain at the bottom and have the highest density. Others distribute themselves in between.

> FIGURE 5-14 Enterohepatic Circulation

Most of the bile released into the small intestine is reabsorbed and sent back to the liver to be reused. This cycle is called the *enterohepatic circulation* of bile. Some bile is excreted.

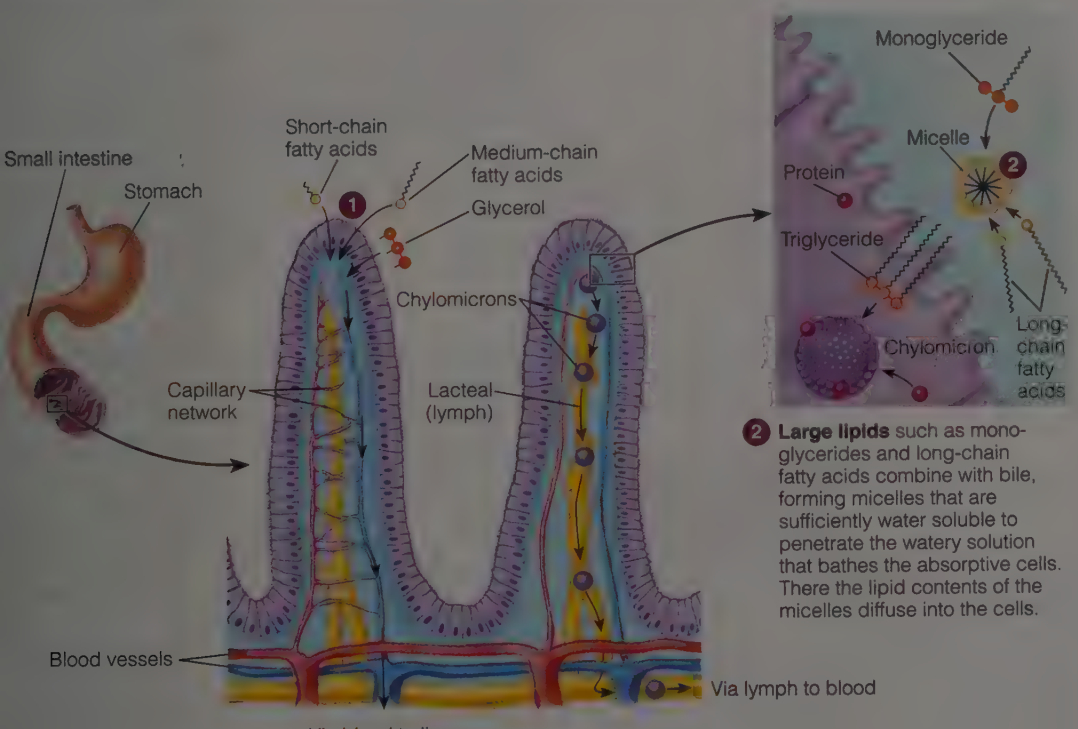


lipoproteins clusters of lipids associated with proteins that serve as transport vehicles for lipids in the lymph and blood

chylomicrons the class of lipoproteins that transport lipids from the intestinal cells to the rest of the body.

> FIGURE 5-15 *Animated* Absorption of Fat

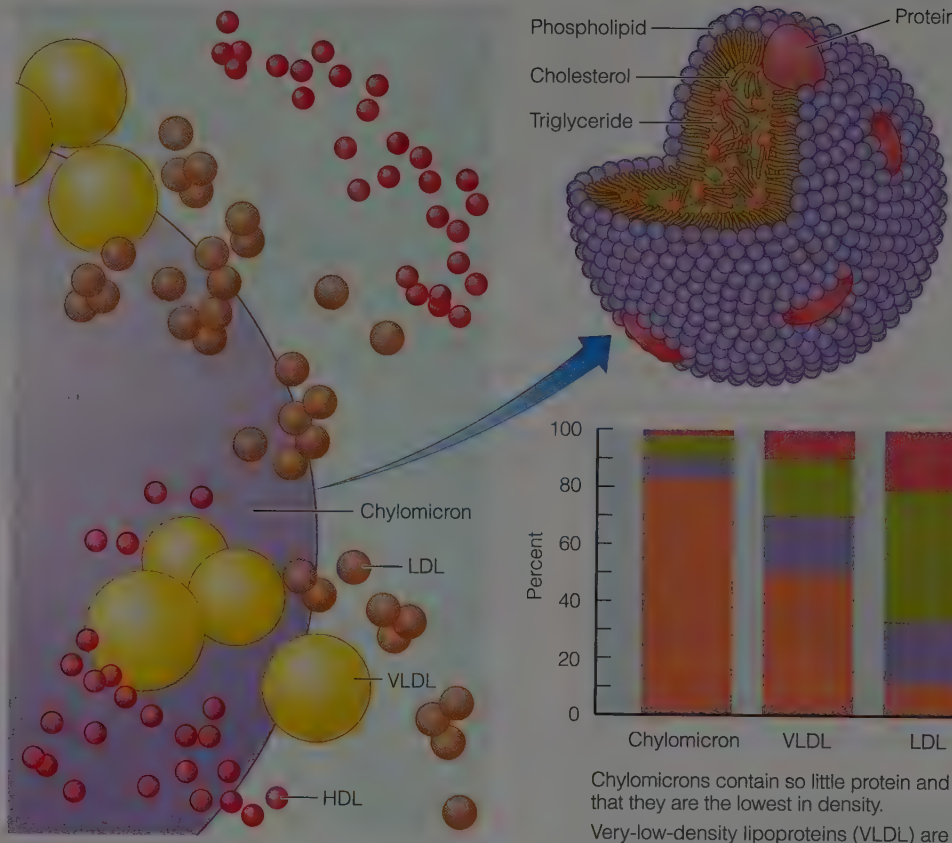
The end products of fat digestion are mostly monoglycerides, some fatty acids, and very little glycerol. Their absorption differs depending on their size. (In reality, molecules of fatty acid are too small to see without a powerful microscope, whereas villi are visible to the naked eye.)



1 Glycerol and small lipids such as short- and medium-chain fatty acids can move directly into the bloodstream.

2 Large lipids such as monoglycerides and long-chain fatty acids combine with bile, forming micelles that are sufficiently water soluble to penetrate the watery solution that bathes the absorptive cells. There the lipid contents of the micelles diffuse into the cells.

> FIGURE 5-16 Sizes and Compositions of the Lipoproteins



A typical lipoprotein contains an interior of triglycerides and cholesterol surrounded by phospholipids. The phospholipids' fatty acid "tails" point toward the interior, where the lipids are. Proteins near the outer ends of the phospholipids cover the structure. This arrangement of hydrophobic molecules on the inside and hydrophilic molecules on the outside allows lipids to travel through the watery fluids of the blood.

Notice how large the fat-filled chylomicron is compared with the others and how the others get progressively smaller as their proportion of fat declines and protein increases.

Chylomicrons contain so little protein and so much triglyceride that they are the lowest in density.

Very-low-density lipoproteins (VLDL) are half triglycerides, accounting for their very low density.

Low-density lipoproteins (LDL) are half cholesterol, accounting for their implication in heart disease.

High-density lipoproteins (HDL) are half protein, accounting for their high density.

© Cengage Learning 2013

small intestine (via the lymph system) to the rest of the body. Cells all over the body remove triglycerides from the chylomicrons as they pass by, so the chylomicrons get smaller and smaller. Within 14 hours after absorption, most of the triglycerides have been depleted, and only a few remnants of protein, cholesterol, and phospholipid remain. Special protein receptors on the membranes of the liver cells recognize and remove these chylomicron remnants from the blood.

VLDL (Very-Low-Density Lipoproteins) Meanwhile, in the liver—the most active site of lipid synthesis—cells are making cholesterol, fatty acids, and other lipid compounds. Ultimately, the lipids made in the liver and those collected from chylomicron remnants are packaged with proteins as **VLDL (very-low-density lipoproteins)** and shipped to other parts of the body.

As the VLDL travel through the body, cells remove triglycerides. As they lose triglycerides, the VLDL shrink and the proportion of lipids shifts. Cholesterol becomes the predominant lipid, and the lipoprotein becomes smaller and more dense. As this occurs, the VLDL becomes an **LDL (low-density lipoprotein)**, loaded with cholesterol, but containing relatively few triglycerides.*

VLDL (very-low-density lipoprotein): the type of lipoprotein made primarily by liver cells to transport lipids to various tissues in the body; composed primarily of triglycerides.

LDL (low-density lipoprotein): the type of lipoprotein derived from very-low-density lipoproteins (VLDL) as triglycerides are removed and broken down; composed primarily of cholesterol.

*Before becoming LDL, the VLDL are first transformed into intermediate-density lipoproteins (IDL), sometimes called VLDL remnants. Some IDL may be picked up by the liver and rapidly broken down; those IDL that remain in circulation continue to deliver triglycerides to the cells and eventually become LDL. Researchers debate whether IDL are simply transitional particles or a separate class of lipoproteins; normally, IDL do not accumulate in the blood. Measures of blood lipids include IDL with LDL.

LDL (Low-Density Lipoproteins) The LDL circulate throughout the body, making their contents available to the cells of all tissues—muscles (including the heart muscle), fat stores, the mammary glands, and others. The cells take triglycerides, cholesterol, and phospholipids to use for energy, make hormones or other compounds, or build new membranes. Special LDL receptors on the liver cells play a crucial role in the control of blood cholesterol concentrations by removing LDL from circulation.

HDL (High-Density Lipoproteins) The liver makes **HDL (high-density lipoprotein)** to remove cholesterol from the cells and carry it back to the liver for recycling or disposal. By efficiently clearing cholesterol, HDL lowers the risk of heart disease.[5] In addition, HDL have anti-inflammatory properties that seem to keep artery-clogging plaque from breaking apart and causing heart attacks. Figure 5-17 summarizes lipid transport via the lipoproteins.

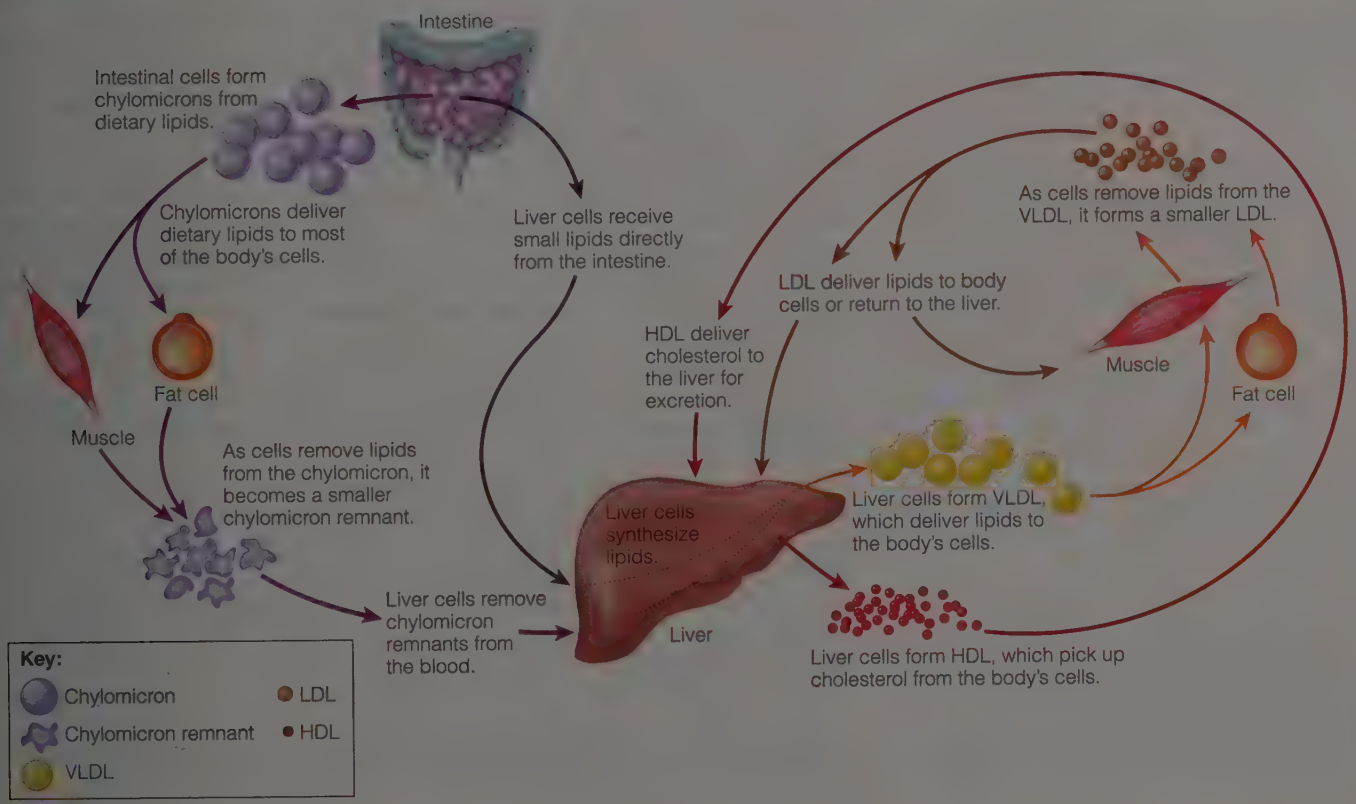
Health Implications The distinction between LDL and HDL has implications for the health of the heart and blood vessels. The blood lipid linked most directly to heart disease is LDL cholesterol. As mentioned, HDL also carry cholesterol, but elevated HDL represent cholesterol returning from the rest of the body to the liver for breakdown and excretion. The transport of cholesterol from the tissues back to the liver is sometimes called *reverse cholesterol transport* or the *scavenger pathway.*

High LDL cholesterol is associated with a high risk of heart attack, whereas high HDL cholesterol seems to have a protective effect. ♦ This explains why some people refer to LDL as "bad," and HDL as "good," cholesterol. Keep in mind that the cholesterol itself is the same and that the differences between LDL and HDL

♦ Think of **H**DL as **H**ealthy and **L**DL as **L**ess healthy.

HDL (high-density lipoprotein): the type of lipoprotein that transports cholesterol back to the liver from the cells; composed primarily of protein.

> **FIGURE 5-17 Lipid Transport via Lipoproteins**



© Cengage Learning 2013

♦ Factors that lower LDL and/or raise HDL:
- Weight control
- Monounsaturated or polyunsaturated, instead of saturated, fat in the diet
- Soluble dietary fibers (see Chapter 4)
- Phytochemicals (see Highlight 13)
- *Moderate* alcohol consumption
- Physical activity

reflect the *proportions* and *types* of lipids and proteins within them—not the type of cholesterol. The margin ♦ lists factors that influence LDL and HDL, and Chapter 18 provides many more details.

Not too surprisingly, numerous genes influence how the body handles the synthesis, transport, and degradation of lipids and lipoproteins. Much current research is focused on how nutrient-gene interactions may direct the progression of heart disease.

REVIEW IT Summarize fat digestion, absorption, and transport.

The body makes special arrangements to digest and absorb lipids. It provides the emulsifier bile to make them accessible to the fat-digesting lipases that dismantle triglycerides, mostly to monoglycerides and fatty acids, for absorption by the intestinal cells. The intestinal cells assemble absorbed lipids into chylomicrons, lipid packages with protein escorts, for transport so that cells all over the body may select needed lipids from them. Lipoproteins transport lipids around the body. All four types of lipoproteins carry all classes of lipids (triglycerides, phospholipids, and cholesterol), but the chylomicrons are the largest and contain mostly triglycerides from the diet; VLDL are smaller and are about half triglycerides; LDL are smaller still and contain mostly cholesterol; and HDL are the densest and are rich in protein. High LDL cholesterol indicates increased risk of heart disease, whereas high HDL cholesterol has a protective effect.

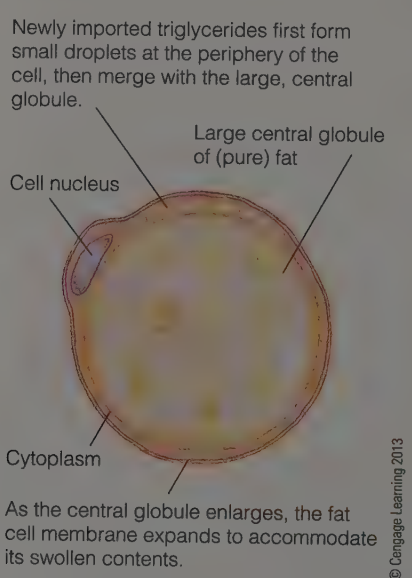
5.4 Lipids in the Body

LEARN IT Outline the major roles of fats in the body, including a discussion of essential fatty acids and the omega fatty acids.

In the body, lipids provide energy, insulate against temperature extremes, protect against shock, and maintain cell membranes. This section provides an overview of the roles of triglycerides and fatty acids and then of the metabolic pathways they can follow within the body's cells.

FIGURE 5-18 An Adipose Cell

Newly imported triglycerides first form small droplets at the periphery of the cell, then merge with the large, central globule.



Roles of Triglycerides

First and foremost, triglycerides—either from food or from the body's fat stores—provide the cells with energy. When a person dances all night, her dinner's triglycerides provide some of the fuel that keeps her moving. When a person loses his appetite, his stored triglycerides fuel much of his body's work until he can eat again.

Fat provides more than twice the energy of carbohydrate and protein, ♦ making it an extremely efficient storage form of energy. Unlike the liver's glycogen stores, the body's fat stores have virtually unlimited capacity, thanks to the special cells of the **adipose tissue**. The fat cells of the adipose tissue readily take up and store triglycerides. An adipose cell is depicted in Figure 5-18. Other body cells store only small amounts of fat for their immediate use; fat accumulation in nonadipose cells is toxic and impairs health.[6] This scenario occurs when the diet delivers excesses and the liver increases its fat production. Fatty liver linked to obesity causes chronic inflammation, which can advance to fibrosis, cirrhosis, and cancer.[7]

Adipose tissue is more than just a storage depot for fat. Adipose tissue actively secretes several hormones known as **adipokines**—proteins that help regulate energy balance and influence several body functions.[8] When body fat is markedly reduced or excessive, the type and quantity of adipokine secretions change, with consequences for the body's health. Researchers are currently exploring how adipokines influence the links between obesity and chronic diseases such as type 2 diabetes, hypertension, and heart disease.[9] Obesity, for example, increases the release of the adipokine resistin that promotes inflammation and insulin resistance—factors that predict heart disease and diabetes.[10] Similarly, obesity decreases the release of the adipokine adiponectin that protects against inflammation, diabetes, and heart disease.

♦ Gram for gram, fat provides more than twice as much energy (9 kcal) as carbohydrate or protein (4 kcal).

adipose (ADD-ih-poce) **tissue:** the body's fat tissue; consists of masses of triglyceride-storing cells.

adipokines (ADD-ih-poe-kines): proteins synthesized and secreted by adipose cells.

Fat serves other roles in the body as well. Because fat is a poor conductor of heat, the layer of fat beneath the skin insulates the body from temperature extremes. Fat pads also serve as natural shock absorbers, providing a cushion for the bones and vital organs. Fat provides the structural material for cell membranes and participates in cell signaling pathways.

Essential Fatty Acids The human body needs fatty acids, and it can make all but two of them—linoleic acid (the 18-carbon omega-6 fatty acid) and linolenic acid (the 18-carbon omega-3 fatty acid). These two fatty acids must be supplied by the diet and are therefore **essential fatty acids.** The cells do not possess the enzymes to make any of the omega-6 or omega-3 fatty acids from scratch, nor can they convert an omega-6 fatty acid to an omega-3 fatty acid or vice versa. Cells *can,* however, use the 18-carbon member of an omega family from the diet to make the longer fatty acids of that family by forming double bonds (desaturation) and lengthening the chain two carbons at a time (elongation), as shown in Figure 5-19. This is a slow process because the omega-3 and omega-6 families compete for the same enzymes. Too much of a fatty acid from one family can create a deficiency of the other family's longer fatty acids, which becomes critical only when the diet fails to deliver adequate supplies. Therefore, the most effective way to maintain body supplies of all the omega-6 and omega-3 fatty acids is to obtain them directly from foods—most notably, from vegetable oils, seeds, nuts, fish, and other seafoods.

Linoleic Acid and the Omega-6 Family Linoleic acid is the primary member of the omega-6 fatty acid family. When the body receives linoleic acid from the diet, it can make other members of the omega-6 family—such as the 20-carbon polyunsaturated fatty acid, **arachidonic acid** (as shown in Figure 5-19). Should a linoleic acid deficiency develop, arachidonic acid, and all other omega-6 fatty acids that derive from linoleic acid, would also become essential and have to be obtained from the diet. A nonessential nutrient (such as arachidonic acid) that must be supplied by the diet in special circumstances (as in a linoleic acid deficiency) is considered a **conditionally essential nutrient.** Normally, vegetable oils and meats supply enough omega-6 fatty acids to meet the body's needs.

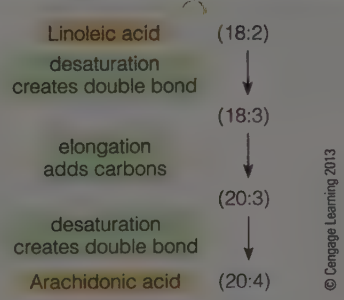
Linolenic Acid and the Omega-3 Family Linolenic acid is the primary member of the omega-3 fatty acid family.* Like linoleic acid, linolenic acid cannot be made in the body and must be supplied by foods. Given the 18-carbon linolenic acid, the body can make small amounts of the 20- and 22-carbon members of the omega-3 family, **eicosapentaenoic acid (EPA)** and **docosahexaenoic acid (DHA),** respectively. These omega-3 fatty acids are found in the eyes and brain and are essential for normal growth, visual acuity, and cognitive development.[11] They may also play an important role in the prevention and treatment of heart disease, as later sections explain.[12]

Eicosanoids The body uses the longer omega-3 and omega-6 fatty acids to make substances known as **eicosanoids.** Eicosanoids are a diverse group of compounds that are sometimes described as "hormonelike," but they differ from hormones in important ways. For one, hormones are secreted in one location and travel to affect cells all over the body, whereas eicosanoids appear to affect only the cells in which they are made or nearby cells in the same localized environment. For another, hormones elicit the same response from all their target cells, whereas eicosanoids often have different effects on different cells.

The actions of various eicosanoids sometimes oppose one another. For example, one causes muscles to relax and blood vessels to dilate, whereas another causes muscles to contract and blood vessels to constrict. Certain eicosanoids

*This omega-3 linolenic acid is known as alpha-linolenic acid and is the fatty acid referred to in this chapter. Another fatty acid, also with 18 carbons and three double bonds, belongs to the omega-6 family and is known as gamma-linolenic acid.

> FIGURE 5-19 The Pathway from One Omega-6 Fatty Acid to Another



The first number indicates the number of carbons and the second, the number of double bonds. Similar reactions occur when the body makes the omega-3 fatty acids EPA and DHA from linolenic acid.

essential fatty acids: fatty acids needed by the body but not made by it in amounts sufficient to meet physiological needs.

arachidonic (a-RACK-ih-DON-ic) **acid:** an omega-6 polyunsaturated fatty acid with 20 carbons and four double bonds; present in small amounts in meat and other animal products and synthesized in the body from linoleic acid.

conditionally essential nutrient: a nutrient that is normally nonessential, but must be supplied by the diet in special circumstances when the need for it exceeds the body's ability to produce it.

eicosapentaenoic acid (EPA): an omega-3 polyunsaturated fatty acid with 20 carbons and five double bonds; present in fatty fish and synthesized in limited amounts in the body from linolenic acid.

docosahexaenoic acid (DHA): an omega-3 polyunsaturated fatty acid with 22 carbons and six double bonds; present in fatty fish and synthesized in limited amounts in the body from linolenic acid.

eicosanoids (eye-COSS-uh-noyds): derivatives of 20-carbon fatty acids; biologically active compounds that help to regulate blood pressure, blood clotting, and other body functions. They include *prostaglandins* (PROS-tah-GLAND-ins), *thromboxanes* (throm-BOX-ains), and *leukotrienes* (LOO-ko-TRY-eens).



© UpperCut Images/Alamy

Fat supplies most of the energy during a long-distance run.

participate in the immune response to injury and infection, producing fever, inflammation, and pain. One of the ways aspirin relieves these symptoms is by slowing the synthesis of these eicosanoids.

Eicosanoids that derive from omega-3 fatty acids differ from those that derive from omega-6 fatty acids, with the omega-3 family providing greater health benefits. The omega-3 eicosanoids help lower blood pressure, prevent blood clot formation, protect against irregular heartbeats, and reduce inflammation, whereas the omega-6 eicosanoids tend to promote clot formation, inflammation, and blood vessel constriction.[13]

Omega-6 to Omega-3 Ratio Because omega-6 and omega-3 fatty acids compete for the same enzymes and their actions often oppose each other, researchers have studied whether there is an ideal ratio that best supports cardiovascular health. Suggested ratios range from 4:1 to 10:1; while some researchers support such recommendations, others find the ratio of little value in improving health or predicting risk.[14] Increasing the amount of omega-3 fatty acids in the diet is clearly beneficial, but reducing the amount of omega-6 fatty acids in the diet to improve the ratio may not be helpful. Omega-6 fatty acids protect heart health by lowering LDL cholesterol and improving insulin resistance.[15]

Fatty Acid Deficiencies Most diets in the United States and Canada meet the minimum essential fatty acid requirement adequately. Historically, deficiencies have developed only in infants and young children who have been fed fat-free milk and low-fat diets or in hospital clients who have been mistakenly fed formulas that provided no polyunsaturated fatty acids for long periods of time. Classic deficiency symptoms include growth retardation, reproductive failure, skin lesions, kidney and liver disorders, and subtle neurological and visual problems.

A Preview of Lipid Metabolism

This preview of fat metabolism describes how the cells store and release energy from fat. Chapter 7 provides details.

Storing Fat as Fat After meals, the blood delivers chylomicrons and VLDL loaded with triglycerides to the adipose cells for storage. An enzyme—**lipoprotein lipase (LPL)**—hydrolyzes triglycerides from these lipoproteins, releasing fatty acids, diglycerides, and monoglycerides into the adipose cells. Enzymes inside the adipose cells reassemble these fatty acids, diglycerides, and monoglycerides into triglycerides again for storage. As Figure 5-18 (p. 144) shows, triglycerides fill the adipose cells, storing a lot of energy in a relatively small space.

Using Fat for Energy Efficient energy metabolism depends on the energy nutrients—carbohydrate, fat, and protein—supporting one another. Glucose fragments combine with fat fragments during energy metabolism, and fat and carbohydrate help spare protein, providing energy so that protein can be used for other important tasks.

Fat supplies about 60 percent of the body's ongoing energy needs during rest. During prolonged light to moderately intense exercise or extended periods of food deprivation, fat stores may make a slightly greater contribution to energy needs.

During energy deprivation, several lipase enzymes (most notably **hormone-sensitive lipase**) inside the adipose cells respond by dismantling stored triglycerides and releasing the glycerol and fatty acids directly into the blood. Energy-hungry cells anywhere in the body can then capture these compounds and take them through a series of chemical reactions to yield energy, carbon dioxide, and water.

A person who fasts (drinking only water) will rapidly metabolize body fat. A pound of body fat provides 3500 kcalories, ♦ so you might think a fasting person who expends 2000 kcalories a day could lose more than half a pound of body fat each day.* Actually, the person has to obtain some energy from lean tissue because the brain, nerves, and red blood cells need glucose—and only the small glycerol molecule can be converted to glucose; fatty acids cannot be. (As Chapter 7 explains, only 3 of the 50 or

♦ 1 lb body fat = 3500 kcal

lipoprotein lipase (LPL): an enzyme that hydrolyzes triglycerides passing by in the bloodstream and directs their parts into the cells, where they can be metabolized for energy or reassembled for storage.

hormone-sensitive lipase: an enzyme inside adipose cells that responds to the body's need for fuel by hydrolyzing triglycerides so that their parts (glycerol and fatty acids) escape into the general circulation and thus become available to other cells for fuel. The signals to which this enzyme responds include epinephrine and glucagon, which oppose insulin (see Chapter 4).

*The reader who knows that 1 pound = 454 grams and that 1 gram of fat = 9 kcalories may wonder why a pound of body fat does not equal 4086 (9 × 454) kcalories. The reason is that body fat contains some cell water and other materials; it is not quite pure fat.

so carbon atoms in a molecule of fat can yield glucose.) Also, the complete breakdown of fat requires carbohydrate or protein. So, even on a total fast, a person cannot lose more than half a pound of pure fat per day. Still, in times of severe hunger and starvation, a fatter person can survive longer than a thinner person thanks to this energy reserve. But as Chapter 7 explains, fasting for too long will eventually cause death, even if the person still has ample body fat.

REVIEW IT Outline the major roles of fats in the body, including a discussion of essential fatty acids and the omega fatty acids.

In the body, triglycerides provide energy, insulate against temperature extremes, protect against shock, provide structural material for cell membranes, and participate in cell signaling pathways. Linoleic acid (18 carbons, omega-6) and linolenic acid (18 carbons, omega-3) are essential nutrients. They serve as structural parts of cell membranes and as precursors to the longer fatty acids that can make eicosanoids—powerful compounds that participate in blood pressure regulation, blood clot formation, and the immune response to injury and infection, among other functions. Because essential fatty acids are common in the diet and stored in the body, deficiencies are unlikely. The body can easily store unlimited amounts of fat if given excesses, and this body fat is used for energy when needed.



© Joseph De Sciose/Jupiterimages.com

Double thanks: The body's fat stores provide energy for a walk, and fat pads on the heels provide cushion against the hard pavement.

5.5 Health Effects and Recommended Intakes of Saturated Fats, *Trans* Fats, and Cholesterol

LEARN IT Explain the relationships among saturated fats, *trans* fat, and cholesterol and chronic diseases, noting recommendations.

Some fat in the diet is essential for good health. The current American diet, however, delivers excessive amounts of solid fats, representing an average of almost one-fifth of the day's total kcalories. Major sources of solid fats in the American diet include desserts, pizza, cheese, and processed and fatty meats (sausages, hot dogs, bacon, ribs). Because foods made with solid fats provide abundant energy, but few if any essential nutrients, they contribute to weight gain and make it difficult to meet nutrient needs. Solid fats also provide abundant saturated fat, *trans* fat, and cholesterol. Even without overweight or obesity, high intakes of solid fats increase the risk of some chronic diseases. The easiest way to control saturated fat, *trans* fat, cholesterol, and kcalories is to limit solid fats in the diet.

Health Effects of Saturated Fats, *Trans* Fats, and Cholesterol

Hearing a physician say, "Your blood lipid profile looks fine," is reassuring. The **blood lipid profile** ♦ reveals the concentrations of various lipids in the blood, notably triglycerides and cholesterol, and their lipoprotein carriers (VLDL, LDL, and HDL). This information alerts people to possible disease risks and perhaps to a need for changing their physical activity and eating habits. Both the amounts and types of fat in the diet influence the risk for disease.

♦ Desirable blood lipid profile:
- Total cholesterol: <200 mg/dL
- LDL cholesterol: <100 mg/dL
- HDL cholesterol: ≥60 mg/dL
- Triglycerides: <150 mg/dL

Heart Disease As mentioned earlier, elevated LDL cholesterol is a major risk factor for **cardiovascular disease (CVD).**[16] As LDL cholesterol accumulates in the arteries, blood flow becomes restricted and blood pressure rises. The consequences are deadly; in fact, heart disease is the nation's number-one killer of adults. LDL cholesterol is often used to predict the likelihood of a person's suffering a heart attack or stroke; the higher the LDL, the earlier and more likely the tragedy. Much of the effort to prevent heart disease focuses on lowering LDL cholesterol.

Saturated fats are most often implicated in raising LDL cholesterol. In general, the more saturated fat in the diet, the more LDL cholesterol in the blood. Not all saturated fats have the same cholesterol-raising effect, however. Most notable among the saturated fatty acids that raise blood cholesterol are lauric, myristic, and palmitic acids (12, 14, and 16 carbons, respectively). In contrast, stearic acid (18 carbons) seems to have little or no effect on blood cholesterol.[17] Making such

blood lipid profile: results of blood tests that reveal a person's total cholesterol, triglycerides, and various lipoproteins.

cardiovascular disease (CVD): diseases of the heart and blood vessels throughout the body. Atherosclerosis is the main cause of CVD. When the arteries that carry blood to the heart muscle become blocked, the heart suffers damage known as *coronary heart disease (CHD)*.
- **cardio** = heart
- **vascular** = blood vessels

distinctions may be impractical in diet planning, however, because these saturated fatty acids typically appear together in the same foods. In addition to raising blood cholesterol, saturated fatty acids contribute to heart disease by promoting blood clotting.[18] Fats from animal sources (meats, milk, and milk products) are the main sources of saturated fats ♦ in most people's diets.[19] Selecting lean cuts of meat, skinless poultry, and fat-free milk products helps to lower saturated fat intake and the risk of heart disease.

♦ Major sources of saturated fats:
- Whole milk, cream, butter, cheese, ice cream
- Fatty cuts of beef and pork
- Coconut, palm, and palm kernel oils (the tropical oils and products containing them such as candies, pastries, pies, doughnuts, and cookies)

♦ Major sources of *trans* fats:
- Cakes, cookies, doughnuts, pastry, crackers
- Margarine
- Deep-fried foods (vegetable shortening)
- Snack chips

♦ Major sources of cholesterol:
- Eggs
- Milk and milk products
- Meat, poultry, shellfish

Research also suggests an association between dietary *trans* fats and heart disease.[20] In the body, *trans* fats alter blood cholesterol the same way some saturated fats do: they raise LDL cholesterol and, at high intakes, lower HDL cholesterol. Limiting the intake of *trans* fats ♦ can improve blood cholesterol and lower the risk of heart disease. To that end, many restaurants and manufacturers have taken steps to eliminate or greatly reduce *trans* fats in foods.[21]

Although its effect is not as strong as that of saturated fat or *trans* fat, dietary cholesterol ♦ may also raise blood cholesterol. Less clear is its role in heart disease.[22]

Cancer The links between dietary fats and cancer are not as evident as they are for heart disease. Dietary fat does not seem to *initiate* cancer development but, instead, may *promote* cancer once it has arisen. Stronger risk factors for cancer include smoking, alcohol, and environmental contaminants. (Chapter 18 provides many more details about these risk factors and the development of cancer.)

The relationship between dietary fat and the risk of cancer differs for various types of cancers. In the case of breast cancer, evidence has been weak and inconclusive. Some studies indicate an association between dietary fat and breast cancer; more convincing evidence indicates that body fatness contributes to the risk. In the case of colon cancer, limited evidence suggests a harmful association with foods containing animal fats.

The relationship between dietary fat and the risk of cancer differs for various types and combinations of fats as well. The increased risk in cancer from fat appears to be due primarily to saturated fats or dietary fat from meats (which is mostly saturated). Fat from milk or fish has not been implicated in cancer risk.

♦ 1 g fat = 9 kcal
1 g carbohydrate or protein = 4 kcal

Obesity Fat contributes more than twice as many kcalories ♦ per gram as either carbohydrate or protein. Consequently, people who eat high-fat diets regularly may exceed their energy needs and gain weight, especially if they are inactive.[23] Because fat boosts energy intake, cutting fat from the diet can be an effective strategy in cutting kcalories. In some cases, though, choosing a fat-free food offers no kcalorie savings. Fat-free frozen desserts, for example, often have so much sugar added that the kcalorie count can be as high as in the regular-fat product. In this case, cutting fat and adding carbohydrate offers no kcalorie savings or weight-loss advantage. In fact, it may even raise energy intake and exacerbate weight problems. Later chapters revisit the role of dietary fat in the development of obesity.

Recommended Intakes of Saturated Fat, *Trans* Fat, and Cholesterol

♦ DRI and *Dietary Guidelines* for fat:
- 20 to 35% of energy intake

Defining the exact amount of saturated fat, *trans* fat, or cholesterol that begins to harm health is difficult.[24] For this reason, no RDA or Upper Level has been set. Instead, the DRI and *Dietary Guidelines* suggest a diet that provides 20 to 35 percent of the daily energy intake from fat, ♦ less than 10 percent of daily energy intake from saturated fat, as little *trans* fat as possible, and less than 300 milligrams cholesterol. These recommendations recognize that diets with up to 35 percent of kcalories from fat can be compatible with good health if energy intake is reasonable and saturated fat, *trans* fat, and cholesterol intakes are low. When total fat exceeds 35 percent, however, saturated fat usually rises to unhealthy levels.[25] For a 2000-kcalorie diet, 20 to 35 percent represents 400 to 700 kcalories from fat (roughly 45 to 75 grams).



> DIETARY GUIDELINES FOR AMERICANS 2010
Consume less than 10 percent of kcalories from saturated fat. Consume less than 300 milligrams per day of dietary cholesterol. Keep *trans*-fat consumption as low as possible by limiting foods that contain synthetic sources of *trans* fats, such as partially hydrogenated oils, and by limiting other solid fats.

According to surveys, diets in the United States provide about 34 percent of their total energy from fat, with saturated fat contributing about 11 percent of the total.[26] The average daily intake of *trans*-fatty acids in the United States is about 6 grams per day—mostly from products that have been hydrogenated. Cholesterol intakes in the United States average 230 milligrams a day for women and 362 for men.

Although it is very difficult to do, some people actually manage to eat too little fat—to their detriment. Among them are people with eating disorders, described in Highlight 8, and athletes. Athletes following a diet too low in fat (less than 20 percent of total kcalories) fall short on energy, vitamins, minerals, and essential fatty acids as well as on performance.[27] As a practical guideline, it is wise to include the equivalent of at least a teaspoon of fat in every meal—a little peanut butter on toast or mayonnaise in tuna salad, for example. Dietary recommendations that limit fat are designed for healthy people older than age 2; Chapter 16 discusses the fat needs of infants and young children.

REVIEW IT Explain the relationships among saturated fats, *trans* fat, and cholesterol and chronic diseases, noting recommendations.

Although some fat in the diet is necessary, too much fat adds kcalories without nutrients, which leads to obesity and nutrient inadequacies. Too much saturated fat, *trans* fat, and cholesterol increases the risk of heart disease and possibly cancer. For these reasons, health authorities recommend a diet moderate in total fat and low in saturated fat, *trans* fat, and cholesterol.

5.6 Health Effects and Recommended Intakes of Monounsaturated and Polyunsaturated Fats

LEARN IT Explain the relationships between monounsaturated and polyunsaturated fats and health, noting recommendations.

Whereas saturated fats, *trans* fats, and cholesterol are implicated in chronic diseases, monounsaturated and polyunsaturated fats seem to offer health benefits. For this reason, dietary recommendations suggest replacing sources of saturated fats, *trans* fats, and cholesterol with foods rich in monounsaturated and polyunsaturated fats—foods such as seafood, nuts, seeds, and vegetable oils.

Health Effects of Monounsaturated and Polyunsaturated Fats

Researchers examining eating patterns from around the world have noted that some diets support good health despite being high in fat. As Highlight 5 explains, the *type* of fat may be more important than the *amount* of fat.[28]

Heart Disease Replacing saturated fats with unsaturated fats ♦ reduces LDL cholesterol and lowers the risk of heart disease.[29] To replace saturated fats with unsaturated fats, sauté foods in olive oil instead of butter, garnish salads with sunflower seeds instead of bacon, snack on mixed nuts instead of potato chips, use avocado instead of cheese on a sandwich, and eat salmon instead of steak. Table 5-3 (p. 150) shows how these simple substitutions can lower the saturated fat and raise the unsaturated fat in a meal. Highlight 5 provides more details about the benefits of healthy fats in the diet.

Research on the different types of fats has spotlighted the many beneficial effects of the omega-3 ♦ polyunsaturated fatty acids.[30] Regular consumption of omega-3 fatty acids helps to prevent blood clots, protect against irregular heartbeats, improve blood lipids, and lower blood pressure, especially in people with hypertension or atherosclerosis.[31] In addition, omega-3 fatty acids support a healthy immune system and suppress inflammation.[32]



© Polara Studios, Inc.

Well-balanced, healthy meals provide some fat with an emphasis on monounsaturated and polyunsaturated fats.

♦ Major sources of unsaturated fats:

Monounsaturated fats
- Olive oil, canola oil, peanut oil, safflower oil
- Avocados

Polyunsaturated fats
- Vegetable oils (sesame, soy, corn, sunflower)
- Nuts and seeds

♦ Major sources of omega-3 fats:
- Vegetable oils (canola, soybean, flaxseed)
- Walnuts, flaxseeds
- Fatty fish (mackerel, salmon, sardines)

TABLE 5-3 Replacing Saturated Fat with Unsaturated Fat

Portion sizes have been adjusted so that each of these foods provides approximately 100 kcalories. Notice that for a similar number of kcalories and grams of fat, the second choices offer less saturated fat and more unsaturated fat.

Replace these foods . . .

	Saturated Fat (g)	Unsaturated Fat (g)	Total Fat (g)
Butter (1 tbs)	7	4	11
Bacon (2 slices)	3	6	9
Potato chips (10 chips)	2	5	7
Cheese (1 slice)	4	4	8
Steak (1½ oz)	2	3	5
Totals	**18**	**22**	**40**

. . . with these foods.

	Saturated Fat (g)	Unsaturated Fat (g)	Total Fat (g)
Olive oil (1 tbs)	2	9	11
Sunflower seeds (2 tbs)	1	7	8
Mixed nuts (2 tbs)	1	8	9
Avocado (6 slices)	2	8	10
Salmon (2 oz)	1	3	4
Totals	**7**	**35**	**42**

© Cengage Learning 2013

Cancer The omega-3 fatty acids of fatty fish may protect against some cancers as well, perhaps by suppressing inflammation.[33] Even when omega-3 fats do not protect against cancer development, there seems to be a significant reduction in cancer-related deaths.[34] Thus dietary advice to reduce cancer risks parallels that given to reduce heart disease risks: reduce saturated fats and increase omega-3 fatty acids. Evidence does not support omega-3 supplementation.

Omega-3 Supplements Omega-3 fatty acids are available in capsules of fish oil supplements, although routine supplementation is not recommended.[35] High intakes of omega-3 polyunsaturated fatty acids may increase bleeding time, interfere with wound healing, raise LDL cholesterol, and suppress immune function.* Such findings reinforce the concept that too much of a good thing can sometimes be harmful. People with heart disease, however, may benefit from doses greater than can be achieved through diet alone. Because high intakes of omega-3 fatty acids can cause excessive bleeding, supplements should be used only under close medical supervision.[36]

Recommended Intakes of Monounsaturated and Polyunsaturated Fats

The 20 to 35 percent of kcalories from fat recommendation provides for the essential fatty acids—linoleic acid and linolenic acid—and Adequate Intakes (AI) have been established for these two fatty acids. The DRI suggest that linoleic acid ♦ provide 5 to 10 percent of the daily energy intake and linolenic acid ♦ 0.6 to 1.2 percent.[37]

♦ Linoleic acid (omega-6) AI:

Men:
- 19–50 yr: 17 g/day
- 51+ yr: 14 g/day

Women:
- 19–50 yr: 12 g/day
- 51+ yr: 11 g/day

♦ Linolenic acid (omega-3) AI:
- Men: 1.6 g/day
- Women: 1.1 g/day



© Matthew Farrugio

Beware of fast-food meals delivering too much fat, especially saturated fat. This double bacon cheeseburger, fries, and milkshake provide more than 1600 kcalories, with almost 90 grams of fat and more than 30 grams of saturated fat—far exceeding dietary fat guidelines for the entire day.

From Guidelines to Groceries

Fats accompany protein in foods derived from animals such as meat, seafood, poultry, and eggs, and fats accompany carbohydrate in foods derived from plants such as avocados and coconuts. Fats carry with them the four fat-soluble vitamins—A, D, E, and K—together with many of the compounds that give foods their flavor, texture, and palatability. Fat is responsible for the delicious aromas associated with sizzling bacon, hamburgers on the grill, onions being sautéed, and vegetables in a stir-fry. The essential oils of many spices are fat-soluble. Of course, these wonderful characteristics lure people into eating too much from time to time. With careful selections, a diet can support good health and still meet fat recommendations.

As the photos in Figure 5-20 show, fat accounts for much of the energy in foods, and removing the fat from foods cuts energy and saturated fat intakes dramatically. To reduce dietary fat, eliminate fat as a seasoning and in cooking; remove the fat from high-fat foods; replace high-fat foods with low-fat alternatives; and emphasize whole grains, fruits, and vegetables. The "How To" feature on p. 152 suggests additional heart-healthy choices by food group.

In general, except for seafood, animal fats tend to have a higher proportion of saturated fatty acids. Except for the tropical oils, plant foods tend to have a higher proportion of monounsaturated and polyunsaturated fatty acids. Consumers can find

*Suppressed immune function is seen with daily intake of 0.9 to 9.4 gram EPA and 0.6 to 6.0 gram DHA for 3 to 24 weeks.

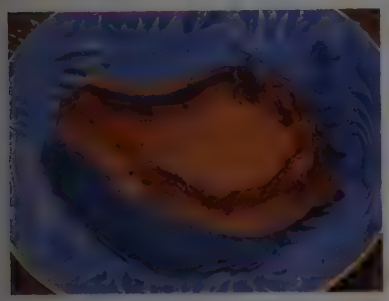
an abundant array of fresh, unprocessed foods that are naturally low in saturated fat, *trans* fat, cholesterol, and total fat. In addition, many familiar foods have been processed to provide less fat. For example, fat can be removed by skimming milk or trimming meats. Manufacturers can dilute fat by adding water or whipping in air. They can use fat-free milk in creamy desserts and lean meats in frozen entrées. Sometimes manufacturers simply prepare the products differently. For example, fat-free potato chips may be baked instead of fried. Such choices make healthy eating easy.

Protein Foods The fats in seafood, nuts, and seeds are considered oils, whereas the fats in meat, poultry, and eggs are considered solid fats because of their high fat, saturated fat, and cholesterol content. Because these meats provide high-quality protein and valuable vitamins and minerals, however, they can be included in a healthy diet if a person makes lean choices, ♦ prepares them using the suggestions outlined in the "How To" feature, and eats small portions. Selecting wild game or grass-fed cattle or bison instead of grain-fed livestock offers the nutrient advantages of being lower in fat and higher in omega-3 polyunsaturated fatty acids.[38] Another strategy to lower blood cholesterol is to prepare meals using soy protein instead of animal protein.[39] When preparing meat, fish, or poultry, consider grilling, baking, or broiling, but not frying. Fried fish does not benefit heart disease.[40] Fried fish from fast-food restaurants and frozen fried fish products are often low in omega-3 fatty acids and high in *trans*- and saturated fatty acids.

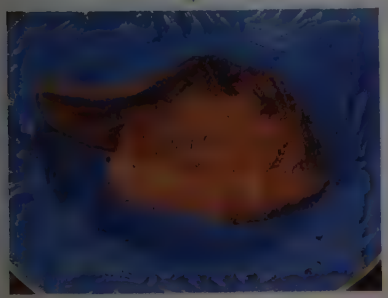
Table 5-4 (p. 154) provides sources of omega-3 and omega-6 fatty acids. Fatty fish are among the best sources of omega-3 fatty acids, and Highlight 5 features their role in supporting heart health.[41] The American Heart Association recommends two servings of fish a week, with an emphasis on fatty fish (salmon, herring, and mackerel, for example).[42] Two servings of fatty fish provide about 500 milligrams of omega-3 fatty acids. Eating fish supports heart health, especially when combined with physical activity. Fish provides many minerals (except iron) and vitamins.

♦ Protein foods
- Very lean options:
  Chicken (white meat, no skin); cod, flounder, trout; tuna (canned in water); legumes
- Lean options:
  Beef or pork "round" or "loin" cuts; chicken (dark meat, no skin); herring or salmon; tuna (canned in oil)
- Medium-fat options:
  Ground beef, eggs, tofu
- High-fat options:
  Sausage, bacon, luncheon meats, hot dogs, peanut butter, nuts

> **FIGURE 5-20 Cutting Fat Cuts kCalories—and Saturated Fat**

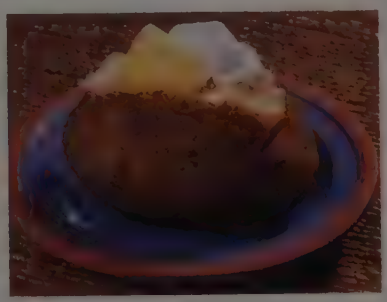


Pork chop with fat (340 kcal, 19 g fat, 7 g saturated fat)

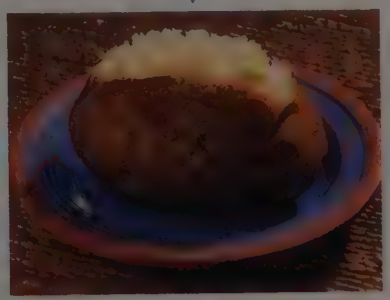


Pork chop with fat trimmed off (230 kcal, 9 g fat, 3 g saturated fat)

Savings:
110 kcal, 10 g fat, 4 g saturated fat



Potato with 1 tbs butter and 1 tbs sour cream (350 kcal, 14 g fat, 10 g saturated fat)



Plain potato (200 kcal, <1 g fat, 0 g saturated fat)

Savings:
150 kcal, 13 g fat, 10 g saturated fat



Whole milk, 1 c (150 kcal, 8 g fat, 5 g saturated fat)



Fat-free milk, 1 c (90 kcal, <1 g fat, <1 g saturated fat)

Savings:
60 kcal, 7 g fat, 4 g saturated fat

© Polara Studios, Inc.

>How To

Make Heart-Healthy Choices—by Food Group

In General

- Select the most nutrient-dense foods from all food groups.
- Consume fewer and smaller portions of foods and beverages that contain solid fats.
- Check the Nutrition Facts label to choose foods with little or no saturated fat and no *trans* fat.

Grains

- Select breads, cereals, and crackers that are low in saturated and *trans* fat (for example, bagels instead of croissants).
- Prepare pasta with a tomato sauce instead of a cheese or cream sauce.
- Limit intake of cookies, doughnuts, pastries, and croissants.

Vegetables and Fruits

- Enjoy the natural flavor of steamed or roasted vegetables (without butter) for dinner and fruits for dessert.
- Eat at least two vegetables (in addition to a salad) with dinner.
- Snack on raw vegetables or fruits instead of high-fat items like potato chips.
- Buy frozen vegetables without sauce.

Milk and Milk Products

- Switch from whole milk to reduced-fat, from reduced-fat to low-fat, and from low-fat to fat-free (nonfat).
- Use fat-free and low-fat cheeses (such as part-skim ricotta and low-fat mozzarella) instead of regular cheeses.
- Use fat-free or low-fat yogurt or sour cream instead of regular sour cream.
- Use evaporated fat-free milk instead of cream.
- Enjoy fat-free frozen yogurt, sherbet, or ice milk instead of ice cream.

Protein Foods

- Fat adds up quickly, even with lean meat; limit intake to about 6 ounces (cooked weight) daily.
- Eat at least two servings of fish per week (particularly fish such as mackerel, lake trout, herring, sardines, and salmon).
- Choose fish, poultry, or lean cuts of pork or beef; look for unmarbled cuts named *round* or *loin* (eye of round, top round, bottom round, round tip, tenderloin, sirloin, center loin, and top loin).
- Choose processed meats such as lunch meats and hot dogs that are low in saturated fat and cholesterol.
- Trim the fat from pork and beef; remove the skin from poultry.
- Grill, roast, broil, bake, stir-fry, stew, or braise meats; don't fry. When possible, place food on a rack so that fat can drain.
- Use lean ground turkey or lean ground beef in recipes; brown ground meats without added fat, then drain off fat.
- Select tuna, sardines, and other canned meats packed in water; rinse oil-packed items with hot water to remove much of the fat.
- Fill kabob skewers with lots of vegetables and slivers of meat; create main dishes and casseroles by combining a little meat, fish, or poultry with a lot of pasta, rice, or vegetables.
- Use legumes often.
- Eat a meatless meal or two daily.
- Use egg substitutes in recipes instead of whole eggs or use two egg whites in place of each whole egg.

Fats and Oils

- Use small amounts of vegetable oils in place of solid fats.
- Use butter or stick margarine sparingly; select soft margarines instead of hard margarines.
- Use fruit butters, reduced-kcalorie margarines, or butter replacers instead of butter.
- Use low-fat or fat-free mayonnaise and salad dressing instead of regular.
- Limit use of lard and meat fat.
- Limit use of products made with coconut oil, palm kernel oil, and palm oil (read labels on bakery goods, processed foods, popcorn oils, and nondairy creamers).
- Reduce use of hydrogenated shortenings and stick margarines and products that contain them (read labels on crackers, cookies, and other commercially prepared baked goods); use vegetable oils instead.

Miscellaneous

- Use a nonstick pan or coat the pan lightly with vegetable oil.
- Refrigerate soups and stews; when the fat solidifies, remove it before reheating.
- Use wine; lemon, orange, or tomato juice; herbs; spices; fruits; or broth instead of butter or margarine when cooking.
- Stir-fry in a small amount of oil; add moisture and flavor with broth, tomato juice, or wine.
- Use variety to enhance enjoyment of the meal: vary colors, textures, and temperatures—hot cooked versus cool raw foods—and use garnishes to complement food.
- Omit high-fat meat gravies and cheese sauces.
- Order pizzas with lots of vegetables, a little lean meat, and half the cheese.

SOURCE: Adapted from *Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)*, NIH publication no. 02-5215 (Bethesda, MD.: National heart, Lung, and Blood Institute, 2002), pp. V-25–V-27.

TRY IT Compare the total kcalories, grams of fat, and percent kcalories from fat for 1 cup of whole milk, reduced-fat milk, low-fat milk, and nonfat milk.

TABLE 5-4 Sources of Omega-3 and Omega-6 Fatty Acids

Omega-3	
Linolenic acid	Oils (canola, flaxseed, soybean, walnut, wheat germ, liquid or soft margarine made from canola or soybean oil) Nuts and seeds (flaxseeds, walnuts, soybeans) Vegetables (soybeans)
EPA and DHA	Human milk Fish and seafood: *>500 mg per 3.5 oz serving:* European seabass (bronzini), herring (Atlantic and Pacific), mackerel, oyster (Pacific wild), salmon (wild and farmed), sardines, toothfish (includes Chilian seabass), trout (wild and farmed) *150–500 mg per 3.5 oz serving:* black bass, catfish (wild and farmed), clam, cod (Atlantic), crab (Alaskan king), croakers, flounder, haddock, hake, halibut, oyster (eastern and farmed), perch, scallop, shrimp (mixed varieties), sole, swordfish, tilapia (farmed) *<150 mg per 3.5 oz serving:* cod (Pacific), grouper, lobster, mahimahi, monkfish, red snapper, skate, triggerfish, tuna, wahoo
Omega-6	
Linoleic acid	Seeds, nuts, vegetable oils (corn, cottonseed, safflower, sesame, soybean, sunflower), poultry fat

© Cengage Learning 2013

Source for fish data: K. L. Weaver and coauthors. The content of favorable and unfavorable polyunsaturated fatty acids found in commonly eaten fish, *Journal of the American Dietetic Association* 108 (2008): 1178–1185; P. M. Kris-Etherton, W. S. Harris, and L. J. Appel, Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease, *Circulation* 106 (2002): 2747–2757

Because fish is leaner than most other animal-protein sources it can help with weight-loss efforts. The combination of losing weight and eating fish improves blood lipids even more effectively than can be explained by either the weight loss or the omega-3 fats of the fish. Chapter 19 discusses the adverse consequences of mercury, ♦ an environmental contaminant common in some fish, and suggests that most healthy people who eat two servings of fish a week can maximize the health benefits while incurring minimal risks.

♦ Mercury in fish
- Relatively high:
  Tilefish (also called golden snapper or golden bass), swordfish, king mackerel, shark
- Relatively low:
  Cod, haddock, pollock, salmon, sole, tilapia
  Most shellfish

Recall that cholesterol is found in all foods derived from animals. Consequently, eating less fat from meats, eggs, milk, and milk products helps lower dietary cholesterol intake (as well as total and saturated fat intakes). Most foods that are high in cholesterol are also high in saturated fat, but eggs are an exception. An egg contains only 1 gram of saturated fat but has a little more than 200 milligrams of cholesterol—roughly two-thirds of the recommended daily limit. For people with a healthy lipid profile, eating one egg a day is not detrimental. People with high blood cholesterol, however, may benefit from limiting daily cholesterol intake to less than 200 milligrams.[43] When eggs are included in the diet, other sources of cholesterol may need to be limited on that day. Eggs are a valuable part of the diet because they are inexpensive, useful in cooking, and a source of high-quality protein, other nutrients, and phytochemicals.[44] To help consumers improve their omega-3 fatty acid intake, hens fed flaxseed produce eggs rich in omega-3 fatty acids (about 150 milligrams per egg). Including even one enriched egg in the diet daily can significantly increase a person's intake of omega-3 fatty acids. Food manufacturers have produced several fat-free, cholesterol-free egg substitutes.



> DIETARY GUIDELINES FOR AMERICANS 2010
Replace protein foods that are higher in solid fats (meat, poultry, and eggs) with choices that are lower in solid fats and higher in oils (seafood, nuts, and seeds).

Milk and Milk Products Like meats, milk and milk products ♦ should also be selected with an awareness of their fat, saturated fat, and cholesterol contents. Keep in mind that the fat in milk is a solid fat; it is apparent as butter, but less so when suspended in homogenized milk. Fat-free and low-fat milk products provide as much or more protein, calcium, and other nutrients as their whole-milk versions—but with little or no saturated fat. Selecting fermented milk products, such as yogurt, may also help to lower blood cholesterol. These foods increase the population and activity of bacteria in the colon that use cholesterol.

♦ Milk and milk products
- Fat-free and low-fat options:
  Fat-free or 1% milk or yogurt (plain); fat-free and low-fat cheeses
- Reduced-fat options:
  2% milk, low-fat yogurt (plain)
- High-fat options:
  Whole milk, regular cheeses

Vegetables, Fruits, and Grains Most vegetables and fruits naturally contain little or no fat. Although avocados and olives are exceptions, most of their fat is

unsaturated, which is not harmful to heart health. Most grains contain only small amounts of fat. Consumers need to read food labels, though, because many refined grain products such as fried taco shells, croissants, and biscuits are high in saturated fat, and pastries, crackers, and cookies may be high in *trans* fats. Similarly, many people add butter, margarine, or cheese sauce to grains and vegetables, which raises the saturated- and *trans*-fat contents. Because fruits are often eaten without added fat, a diet that includes several servings of fruit daily can help a person meet the dietary recommendations for fat.

A diet rich in vegetables, fruits, whole grains, and legumes also offers abundant vitamin C, folate, vitamin A, vitamin E, and dietary fiber—all important in supporting health. Consequently, such a diet protects against disease by reducing saturated fat, cholesterol, and total fat as well as by increasing nutrients. It also provides valuable phytochemicals, which help defend against heart disease.

♦ Solid fats include:
- Meat and poultry fats (as in poultry skin, luncheon meats, sausage)
- Milk fat (as in whole milk, cheese, butter)
- Shortening (as in fried foods and baked goods)
- Hard margarines

Solid Fats and Oils Because solid fats ♦ deliver an abundance of saturated fatty acids, they are considered discretionary kcalories. The fats of fish, nuts, and vegetable oils are *not* counted as discretionary kcalories because they provide valuable omega-3 fatty acids, essential fatty acids, and vitamin E. When discretionary kcalories are available, they may be used to add fats in cooking or at the table or to select higher fat items from the food groups.



> DIETARY GUIDELINES FOR AMERICANS 2010
Reduce intake of solid fats (major sources of saturated and *trans* fats). Replace solid fats with oils (major sources of polyunsaturated and monounsaturated fats) when possible.

Some solid fats, such as butter and the fat trimmed from meat, are easy to see. Others—such as the fat that "marbles" a steak or is hidden in foods such as cheese—are less apparent and can be present in foods in surprisingly high amounts. Any *fried* food contains abundant solid fats—potato chips, french fries, fried wontons, and fried fish. Many *baked* goods, too, are high in solid fats—pie crusts, pastries, crackers, biscuits, cornbread, doughnuts, sweet rolls, cookies, and cakes.

Reports on *trans*-fatty acids raise the question whether margarine or butter is a better choice for heart health. The American Heart Association has stated that because butter is rich in both saturated fat and cholesterol whereas margarine is made from vegetable fat with no dietary cholesterol, margarine is still preferable to butter. Be aware that soft margarines (liquid or tub) ♦ are less hydrogenated and relatively lower in *trans*-fatty acids; consequently, they do not raise blood cholesterol as much as the saturated fats of butter or the *trans* fats of hard (stick) margarines do. Many manufacturers are now offering nonhydrogenated margarines that are "*trans*-fat free." In addition, manufacturers have developed margarines fortified with plant sterols that lower blood cholesterol. (Highlight 13 explores these and other functional foods designed to support health.) Whichever you decide to use, remember to use them sparingly.

♦ When selecting margarine, look for:
- Soft (liquid or tub) instead of hard (stick)
- ≤2 g saturated fat
- Liquid vegetable oil (not hydrogenated or partially hydrogenated) as first ingredient
- "*Trans*-fat free"

Read Food Labels Labels list total fat, saturated fat, *trans* fat, and cholesterol contents of foods in addition to fat kcalories per serving. Because each package provides information for a single serving and because serving sizes are standardized, consumers can easily compare similar products.

Total fat, saturated fat, and cholesterol are also expressed as "% Daily Values" for a person consuming 2000 kcalories, ♦ using 30 percent of energy intake as the guideline for fat and 10 percent for saturated fat. The Daily Value for cholesterol is 300 milligrams regardless of energy intake. There is no Daily Value for *trans* fat, but consumers should try to keep intakes as low as possible and within the 10 percent allotted for saturated fat. People who consume more or less than 2000 kcalories daily can calculate their personal Daily Value for fat as described in the "How To" feature.

♦ Daily Values:
- 65 g fat (based on 30% of 2000 kcal diet)
- 20 g saturated fat (based on 10% of 2000 kcal diet)
- 300 mg cholesterol

>How To

Calculate a Personal Daily Value for Fat

The % Daily Value for fat on food labels is based on 65 grams. To know how your intake compares with this recommendation, you can either count grams until you reach 65 or add the "% Daily Values" until you reach 100 percent—if your energy intake is 2000 kcalories a day. If your energy intake is more or less, you can calculate your personal daily fat allowance in grams. Suppose your energy intake is 1800 kcalories per day and your goal is 30 percent kcalories from fat. Multiply your total energy intake by 30 percent, then divide by 9:

1800 total kcal × 0.30 from fat = 540 fat kcal
540 fat kcal ÷ 9 kcal/g = 60 g fat

(In familiar measures, 60 grams of fat is about the same as ⅔ stick of butter or ¼ cup of oil.)

The accompanying table shows the numbers of grams of fat allowed per day for various energy intakes. With one of these numbers in mind, you can quickly evaluate the number of fat grams in foods you are considering eating.

Energy (kcal/day)	20% kCal from Fat	35% kCal from Fat	Fat (g/day)
1200	240	420	27–47
1400	280	490	31–54
1600	320	560	36–62
1800	360	630	40–70
2000	400	700	44–78
2200	440	770	49–86
2400	480	840	53–93
2600	520	910	58–101
2800	560	980	62–109
3000	600	1050	67–117

TRY IT Calculate a personal daily fat allowance for a person with an energy intake of 2100 kcalories and a goal of 25 percent kcalories from fat.

Be aware that the "% Daily Value" for fat is not the same as "% kcalories from fat." This important distinction is explained in the "How To" feature on p. 156. Because recommendations apply to average daily intakes rather than individual food items, food labels do not provide "% kcalories from fat." Still, you can get an idea of whether a particular food is high or low in fat.

Fat Replacers Some foods are made with **fat replacers**—ingredients that provide some of the taste and texture of fats, but with fewer kcalories. Because the body may digest and absorb some of these fat replacers, they may contribute energy, although significantly less energy than fat's 9 kcalories per gram.

Some fat replacers are derived from carbohydrate, protein, or fat. Carbohydrate-based fat replacers are used primarily as thickeners or stabilizers in foods such as soups and salad dressings. Protein-based fat replacers provide a creamy feeling in the mouth and are often used in foods such as ice creams and yogurts. Fat-based replacers act as emulsifiers and are heat stable, making them most versatile in shortenings used in cake mixes and cookies.

Fat replacers offering the sensory and cooking qualities of fats but none of the kcalories are called **artificial fats.** A familiar example of an artificial fat that has been approved for use in snack foods such as potato chips, crackers, and tortilla chips is **olestra.** Olestra's chemical structure is similar to that of a regular fat (a triglyceride) but with important differences. A triglyceride is composed of a glycerol molecule with three fatty acids attached, whereas olestra is made of a sucrose molecule with six to eight fatty acids attached. Enzymes in the digestive tract cannot break the bonds of olestra, so unlike sucrose or fatty acids, olestra passes through the digestive system unabsorbed.

The FDA's evaluation of olestra's safety addressed two questions. First, is olestra toxic? Research on both animals and human beings supports the safety of olestra as a partial replacement for dietary fats and oils, with no reports of cancer or birth defects. Second, does olestra affect either nutrient absorption or the health

fat replacers: ingredients that replace some or all of the functions of fat and may or may not provide energy.

artificial fats: zero-energy fat replacers that are chemically synthesized to mimic the sensory and cooking qualities of naturally occurring fats but are totally or partially resistant to digestion.

olestra: a synthetic fat made from sucrose and fatty acids that provides 0 kcalories per gram; also known as *sucrose polyester.*

>How To

Understand "% Daily Value" and "% kCalories from Fat"

The "% Daily Value" that is used on food labels to describe the amount of fat in a food is not the same as the "% kcalories from fat" that is used in dietary recommendations to describe the amount of fat in the diet. They may appear similar, but their difference is worth understanding. Consider, for example, a piece of lemon meringue pie that provides 140 kcalories and 12 grams of fat. Because the Daily Value for fat is 65 grams for a 2000-kcalorie intake, 12 grams represent about 18 percent:

$$12\text{ g} \div 65\text{ g} = 0.18$$
$$0.18 \times 100 = 18\%$$

The pie's "% Daily Value" is 18 percent, or almost one-fifth, of the day's fat allowance.

Uninformed consumers may mistakenly believe that this food meets recommendations to limit fat to "20 to 35 percent kcalories," but it doesn't—for two reasons. First, the pie's 12 grams of fat contribute 108 of the 140 kcalories, for a total of 77 percent kcalories from fat:

$$12\text{ g fat} \times 9\text{ kcal/g} = 108\text{ kcal}$$
$$108\text{ kcal} \div 140\text{ kcal} = 77\%$$

Second, the "percent kcalories from fat" guideline applies to a day's total intake, not to an individual food. Of course, if every selection throughout the day exceeds 35 percent kcalories from fat, you can be certain that the day's total intake will, too.



© PhotoDisc/Getty Images

Whether a person's energy and fat allowance can afford a piece of a lemon meringue pie depends on the other food and activity choices made that day.

TRY IT Calculate the percent Daily Value and the percent kcalories from fat for ½ cup frozen yogurt that provides 115 kcalories and 4 grams of fat.

of the digestive tract? When olestra passes through the digestive tract unabsorbed, it binds with some of the fat-soluble vitamins, A, D, E, and K, and carries them out of the body, robbing the person of these valuable nutrients. To compensate for these losses, the FDA requires the manufacturer to fortify olestra with vitamins A, D, E, and K. Saturating olestra with these vitamins does not make the product a good source of vitamins, but it does block olestra's ability to bind with the vitamins from other foods. An asterisk in the ingredients list informs consumers that these added vitamins are "dietarily insignificant."

Consumers need to keep in mind that low-fat and fat-free foods still deliver kcalories. Alternatives to fat can help to lower energy intake and support weight loss only when they actually *replace* fat and energy in the diet.[45]

REVIEW IT Explain the relationships between monounsaturated and polyunsaturated fats and health, noting recommendations.

Some fat in the diet has health benefits, especially the monounsaturated and polyunsaturated fats that protect against heart disease and possibly cancer. For this reason, *Dietary Guidelines* recommend replacing saturated fats with monounsaturated and polyunsaturated fats, particularly omega-3 fatty acids from foods such as fatty fish, not from supplements. Many selection and preparation strategies can help bring these goals within reach, and food labels help to identify foods consistent with these guidelines.

If people were to make only one change in their diets, they would be wise to replace saturated fat with unsaturated fat. Sometimes these choices can be difficult, though, because fats make foods taste delicious. To maintain good health, must a person give up all high-fat foods forever—never again to eat marbled steak, hollandaise sauce, or go oey chocolate cake? Not at all. These foods bring pleasure to a meal and can be enjoyed as part of a healthy diet when eaten occasionally in small quantities; but they should not be everyday foods. The key dietary principle for fat is *moderation*, not *deprivation*. Appreciate the energy and enjoyment that fat provides, but take care not to exceed your needs.

Nutrition Portfolio

To maintain good health, eat enough, but not too much, fat and select the right kinds. Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Intake Spreadsheet report. Scroll down until you see: fat (g), sat fat (g), mono fat (g), poly fat (g), and chol (g), which stand for grams of total fat, saturated fat, monounsaturated fat, polyunsaturated fat, and cholesterol, respectively. Use these columns to answer the following questions:

- List the types and amounts of fats and oils you ate on that day, making note of which are saturated, monounsaturated, or polyunsaturated and how your choices could include fewer saturated options.
- List the types and amounts of milk and milk products, meats, fish, and poultry you eat daily, noting how your choices could include more low-fat options.
- Describe choices you can make in selecting and preparing foods to lower your intake of solid fats.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. V. Remig and coauthors, *Trans* fats in America: A review of their use, consumption, health implications, and regulation, *Journal of the American Dietetic Association* 110 (2010): 585–592.
2. I. A. Brouwer, A. J. Wanders, M. B. Katan, Effect of animal and industrial *trans* fatty acids on HDL and LDL cholesterol levels in humans—A quantitative review, *PLos One* 5 (2010): e9434; A. Motard-Bélanger and coauthors, Study of the effect of *trans* fatty acids from ruminants on blood lipids and other risk factors for cardiovascular disease, *American Journal of Clinical Nutrition* 87 (2008): 593–599; J. M. Chardigny and coauthors, Do *trans* fatty acids from industrially produced sources and from natural sources have the same effect on cardiovascular disease risk factors in healthy subjects? Results of the *trans* Fatty Acids Collaboration (TRABSFACT) Study, *American Journal of Clinical Nutrition* 87 (2008): 558–566.
3. S. W. Ing and M. A. Belury, Impact of conjugated linoleic acid on bone physiology: Proposed mechanism involving inhibition of adipogenesis, *Nutrition Reviews* 69 (2011): 123–131.
4. S. Klingberg and coauthors, Inverse relation between dietary intake of naturally occurring plant sterols and serum cholesterol in northern Sweden, *American Journal of Clinical Nutrition* 87 (2008): 993–1001.
5. A. V. Khera and coauthors, Cholesterol efflux capacity, high-density lipoprotein function, and atherosclerosis, *New England Journal of Medicine* 364 (2011): 127–135.
6. D. M. Muoio, Metabolism and vascular fatty acid transport, *New England Journal of Medicine* 363 (2010): 291–293.
7. M. Krawczyk, L. Bonfrate, and P. Portincasa, Nonalcoholic fatty liver disease, *Best Practice and Research, Clinical Gastroenterology* 24 (2010): 695–708; G. Tarantino, S. Savastano, and A. Colao, Hepatic steatosis, low-grade chronic inflammation and hormone/growth factor/adipokine imbalance, *World Journal of Gastroenterology* 16 (2010): 4773–4783.
8. Y. Deng and P. E. Scherer, Adipokines as novel biomarkers and regulators of the metabolic syndrome, *Annals of the New York Academy of Sciences* 1212 (2010): E1–E19.
9. N. Ouchi and coauthors, Adipokines in inflammation and metabolic disease, *Nature Reviews, Immunology* 11 (2011): 85–97; C. Stryjecki and D. M. Mutch, Fatty acid-gene interactions, adipokines and obesity, *European Journal of Clinical Nutrition* 65 (2011): 285–297; G. Govindarajan, M. A. Alpert, and L. Tejwani, Endocrine and metabolic effects of fat: Cardiovascular implications, *American Journal of Medicine* 121 (2008): 366–370.
10. R. N. Redinger, The physiology of adiposity, *Journal of the Kentucky Medical Association* 106 (2008): 53–62.
11. N. G. Bazan, M. F. Molina, and W. C. Gordon, Docosahexaenoic acid signalolipidomics in nutrition: Significance in aging, neuroinflammation, macular degeneration, Alzheimer's and other neurodegenerative diseases, *Annual Review of Nutrition* 31 (2011): 321–351; E. E. Birch and coauthors, The DIAMOND (DHA Intake and Measurement of Neural Development) Study: A double-masked, randomized controlled clinical trial of the maturation of infant visual acuity as a function of the dietary level of docosahexaenoic acid, *American Journal of Clinical Nutrition* 91 (2010): 848–859; R. K. McNamara and coauthors, Docosahexaenoic acid supplementation increases prefrontal cortex activation during sustained attention in healthy boys: A placebo-controlled, dose-ranging, functional magnetic resonance imaging study, *American Journal of Clinical Nutrition* 91 (2010): 1060–1067; S. E. Carlson, Early determinants of development: A lipid perspective, *American Journal of Clinical Nutrition* 89 (2009): 1523S–1529S.
12. A. H. Stark, M. A. Crawford, and R. Reifen, Update on alpha-linolenic acid, *Nutrition Reviews* 66 (2008): 326–332.
13. R. Wall and coauthors, Fatty acids from fish: The anti-inflammatory potential of long-chain omega-3 fatty acids, *Nutrition Reviews* 68 (2010): 280–289.
14. K. Zelman, The great fat debate: A closer look at the controversy—Questioning the validity of age-old dietary guidance, *Journal of the American Dietetic Association* 111 (2011): 655–658
15. P. Kris-Etherton, J. Fleming, W. S. Harris, The debate about n-6 polyunsaturated fatty acid recommendations for cardiovascular health, *Journal of the American Dietetic Association* 110 (2010): 201–204; W.S. Harris and coauthors, Omega-6 fatty acids and risk for cardiovascular disease: A Science Advisory from the American Heart Association Nutrition Subcommittee of the Council of Nutrition, Physical Activity, and Metabolism; Council on Cardiovascular Nursing, and Council on Epidemiology and Prevention, *Circulation* 108 (2009): 902–907; B. A. Griffin, How relevant is the ratio of dietary n-6 to n-3 polyunsaturated fatty acids to cardiovascular disease risk? Evidence from the OPTILIP study, *Current Opinion in Lipidology* 19 (2008): 57–62.

16. L. H. Kuller, The great fat debate: Reducing cholesterol, *Journal of the American Dietetic Association* 111 (2011): 663–664.
17. J. E. Hunter, J. Zhang, and P. M. Kris-Etherton, Cardiovascular disease risk of dietary stearic acid compared with *trans*, other saturated, and unsaturated fatty acids: A systematic review, *American Journal of Clinical Nutrition* 91 (2010): 46–63.
18. J. Delgado-Lista and coauthors, Chronic dietary fat intake modifies the postprandial response of hemostatic markers to a single fatty test meal, *American Journal of Clinical Nutrition* 87 (2008): 317–322.
19. Position of the American Dietetic Association and Dietitians of Canada: Dietary fatty acids, *Journal of the American Dietetic Association* 107 (2007): 1599–1611.
20. S. K. Wallace and D. Mozaffarian, *Trans*-fatty acids and nonlipid risk factors, *Current Atherosclerosis Reports* 11 (2009): 423–433.
21. M. J. Albers and coauthors, 2006 Marketplace survey of *trans*–fatty acid content of margarines and butters, cookies and snack cakes, and savory snacks, *Journal of the American Dietetic Association* 108 (2008): 367–370.
22. A. M. Brownawell and M. C. Falk, Cholesterol: Where science and public health policy intersect, *Nutrition Reviews* 68 (2010): 355–364; M. L. Fernandez and M. Calle, Revisiting dietary cholesterol recommendations: Does the evidence support a limit of 300 mg/d? *Current Atherosclerosis Reports* 12 (2010): 377–383.
23. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005).
24. P. R. Trumbo and T. Shimakawa, Tolerable upper intake levels for *trans* fat, saturated fat, and cholesterol, *Nutrition Reviews* 69 (2011): 270–278.
25. Committee on Dietary Reference Intakes, 2005.
26. US Department of Agricultural Research Service, Nutrient intakes from food: Mean amounts consumed per individual, 2007–2008, www.ars.usda.gov/ba/bhnrc/fsrg, updated August 2010.
27. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance, *Journal of the American Dietetic Association* 100 (2000): 1543–1556.
28. J. M. Lecerf, Fatty acids and cardiovascular disease, *Nutrition Reviews* 67 (2009): 273–283.
29. A. Astrup, The role of reducing intakes of saturated fats in the prevention of cardiovascular disease: Where does the evidence stand in 2010? *American Journal of Clinical Nutrition* 93 (2011): 684–688.
30. Z. Makhoul and coauthors, Associations of very high intakes of eicosapentaenoic and docosahexaenoic acids with biomarkers of chronic disease risk among Yup'ik Eskimos, *American Journal of Clinical Nutrition* 91 (2010): 777–785; P. P. Dimitrow and M. Jawien, Pleiotropic, cardioprotective effects of omega-3 polyunsaturated fatty acids, *Mini Reviews in Medicinal Chemistry* 9 (2009): 1030–1039; N. D. Riediger and coauthors, A systemic review of the roles of n-3 fatty acids in health and disease, *Journal of the American Dietetic Association* 109 (2009): 668–679.
31. A. C. Skulas-Ray and coauthors, Dose-response effects of omega-3 fatty acids on triglycerides, inflammation, and endothelial function in healthy persons with moderate hypertriglyceridemia, *American Journal of Clinical Nutrition* 93 (2011): 243–252; K. Musa-Velosa and coauthors, Long-chain omega-3 fatty acids eicosapentaenoic acid and docosahexaenoic acid dose-dependently reduce fasting serum triglycerides, *Nutrition Reviews* 68 (2010): 155–167; K. R. Motoyama and coauthors, Association of serum n-6 and n-3 polyunsaturated fatty acids with lipids in 3 populations of middle-aged men, *American Journal of Clinical Nutrition* 90 (2009): 49–55; S. Rajaram and coauthors, Walnuts and fatty fish influence different serum lipid fractions in normal to mildly hyperlipidemic individuals: A randomized controlled study, *American Journal of Clinical Nutrition* 89 (2009): 1657S–1663S; P. J. Smith and coauthors, Association between n-3 fatty acid consumption and ventricular ectopy after myocardial infarction, *American Journal of Clinical Nutrition* 89 (2009): 1315–1320.
32. M. Bouwens and coauthors, Fish-oil supplementation induces anti-inflammatory gene expression profiles in human blood mononuclear cells, *American Journal of Clinical Nutrition* 90 (2009): 415–424; M. K. Duda and coauthors, Fish oil, but not flaxseed oil, decreases inflammation and prevents pressure overload-induced cardiac dysfunction, *Cardiovascular Research* 81 (2009): 319–327.
33. T. M. Brasky and coauthors, Specialty supplements and breast cancer risk in the VITamins And Lifestyle (VITAL) Cohort, *Cancer Epidemiology, Biomarkers and Prevention* 19 (2010): 1696–1708.
34. K. M. Szymanski, D. C. Wheeler, and L. A. Mucci, Fish consumption and prostate cancer risk: A review and meta-analysis, *American Journal of Clinical Nutrition* 92 (2010): 1223–1233; J. E. Chavarro and coauthors, A 22-y prospective study of fish intake in relation to prostate cancer incidence and mortality, *American Journal of Clinical Nutrition* 88 (2008): 1297–1303.
35. P. M. Kris-Etherton and A. M. Hill, n-3 Fatty acids: Foods or supplements? *Journal of the American Dietetic Association* 108 (2008): 1125–1130.
36. Fish and omega-3 fatty acids, www.heart.org, updated September 2010.
37. Committee on Dietary Reference Intakes, 2005.
38. A. J. McAfee and coauthors, Red meat from animals offered a grass diet increases plasma and platelet *n*-3 PUFA in healthy consumers, *British Journal of Nutrition* 105 (2011): 80–89.
39. C. W. Xiao, J. Mei, and C. M. Wood, Effect of soy proteins and isoflavones on lipid metabolism and involved gene expression, *Frontiers in Bioscience* 13 (2008): 2660–2673.
40. K. He and coauthors, Intakes of long-chain n-3 polyunsaturated fatty acids and fish in relation to measurement of subclinical atherosclerosis, *American Journal of Clinical Nutrition* 88 (2008): 1111–1118.
41. E. B. Levitan, A. Wolk, and M. A. Mittleman, Fish consumption, marine omega-3 fatty acids, and incidence of heart failure: A population-based prospective study of middle-aged and elderly men, *European Heart Journal* 30 (2009): 1495–1500; A. Philibert and coauthors, Fish intake and serum fatty acid profiles from freshwater fish, *American Journal of Clinical Nutrition* 84 (2006): 1299–1307.
42. AHA Scientific statement: Diet and lifestyle recommendations revision 2006, *Circulation* 114 (2006): 82–96.
43. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III), *Third Report of the National Cholesterol Education Program* (NCEP), NIH publication no. 02–5215 (Bethesda, Md.: National Heart, Lung, and Blood Institute, 2002), pp. v–10.
44. Fernandez and Calle, 2010.
45. Position of the American Dietetic Association: Fat replacers, *Journal of the American Dietetic Association* 105 (2005): 266–275.

LEARN IT Identify which fats support health and which impair it.

High-Fat Foods—Friend or Foe?

Eat less fat. Eat more fatty fish. Give up butter. Use margarine. Give up margarine. Use olive oil. Steer clear of saturated. Seek out omega-3. Stay away from *trans*. Stick with monounsaturated and polyunsaturated. Keep fat intake moderate. Today's fat messages seem to be forever multiplying and changing. No wonder some people feel confused about dietary fat. The confusion stems in part from the complexities of fat and in part from the nature of recommendations. As Chapter 5 explained, "dietary fat" refers to several kinds of fats. Some fats support health whereas others impair it, and foods typically provide a mixture of fats in varying proportions. Researchers have spent decades sorting through the relationships among the various kinds of fat and their roles in supporting or harming health. Translating these research findings into dietary recommendations is challenging. Too little information can mislead consumers, but too much detail can overwhelm them. As research findings accumulate, recommendations slowly evolve and become more refined. Fortunately, that's where we are with fat recommendations today—refining them from the general to the specific. Though they may seem to be "forever multiplying and changing," in fact, they are becoming more meaningful.

This highlight begins with a look at the dietary guidelines for fat intake. It continues by identifying which foods provide which fats and presenting the Mediterranean diet, an example of an eating pattern that embraces the heart-healthy fats. It closes with strategies to help consumers choose the right amounts of the right kinds of fats for a healthy diet.

Guidelines for Fat Intake

Dietary recommendations for fat have shifted emphasis from lowering total fat, in general, to limiting saturated and *trans* fat, specifically. Instead of urging people to cut back on all fats, recommendations suggest carefully replacing the "bad" saturated fats with the "good" unsaturated fats and enjoying them in moderation. The goal is to create a diet moderate in kcalories that provides enough of the fats that support good health, but not too much of those that harm health. (Turn to pp. 147–150 for a review of the health consequences of each type of fat.)

With these findings and goals in mind, the Dietary Reference Intakes (DRI) committee suggests a healthy range of 20 to 35 percent of energy intake from fat. This range appears to be compatible with low rates of heart disease, diabetes, obesity, and cancer. Heart-healthy recommendations suggest that within this range, consumers should try to minimize their intakes of saturated fat, *trans* fat, and cholesterol and use monounsaturated and polyunsaturated fats instead.

Asking consumers to limit their total fat intake is less than perfect advice, but it is straightforward—find the fat and cut back. Asking consumers to keep their intakes of saturated fats, *trans* fats, and cholesterol low and to use monounsaturated and polyunsaturated fats instead is more on target with heart health, but it also makes diet planning a bit more challenging. To make appropriate selections, consumers must first learn which foods contain which fats.



© John A. Rizzo/Jupiterimages

High-Fat Foods and Heart Health

Avocados, bacon, walnuts, potato chips, and mackerel are all high-fat foods, yet some of these foods have detrimental effects on heart health when consumed in excess, whereas others seem neutral or even beneficial. This section presents some of the accumulating evidence that help distinguish which high-fat foods belong in a healthy diet and which ones need to be kept to a minimum. As you will see, fat in the diet can be compatible with heart health, but only if most of it is unsaturated.

Cook with Olive Oil

As it turns out, the traditional diets of Greece and other countries in the Mediterranean region offer an excellent example of eating patterns that use "good" fats liberally. The primary fat in these diets is olive oil, which seems to play a key role in providing health benefits.[1] A classic study of the world's people, the Seven Countries Study, found that death rates from heart disease were strongly associated with diets high in saturated fats but only weakly linked with total fat.[2] In fact, the two countries with the highest fat intakes, Finland and the Greek island of Crete, had the highest (Finland) and lowest (Crete) rates of heart disease deaths. In both countries, the people consumed 40 percent or more of their kcalories from fat. Clearly, a high-fat diet is not the primary problem.[3] When researchers refocused their attention on the *type* of fat, they began to notice the benefits of olive oil.

A diet that uses olive oil instead of other cooking fats, especially butter, stick margarine, and meat fats, may offer numerous health benefits. Olive oil and other oils rich in monounsaturated fatty acids help to protect against heart disease by:[4]

- Lowering total and LDL cholesterol and not lowering HDL cholesterol or raising triglycerides
- Lowering LDL cholesterol susceptibility to oxidation

- Lowering blood-clotting factors
- Providing phytochemicals that act as antioxidants (see Highlight 11)
- Lowering blood pressure
- Interfering with the inflammatory response

When compared with other fats, olive oil seems to be a wise choice, but controlled clinical trials are too scarce to support population-wide recommendations to switch to a high-fat diet rich in olive oil. Importantly, olive oil is not a magic potion; drizzling it on foods does not make them healthier. Like other fats, olive oil delivers 9 kcalories per gram, which can contribute to weight gain in people who fail to balance their energy intake with physical activity. Its role in a healthy diet is to *replace* the saturated fats. Other vegetable oils, such as canola or safflower oil, are also generally low in saturated fats and high in unsaturated fats. For this reason, heart-healthy diets use these unsaturated vegetable oils to replace the more saturated fats of butter, hydrogenated stick margarine, lard, or shortening. (Remember that the tropical oils—coconut, palm, and palm kernel—are too saturated to be included with the heart-healthy vegetable oils.)

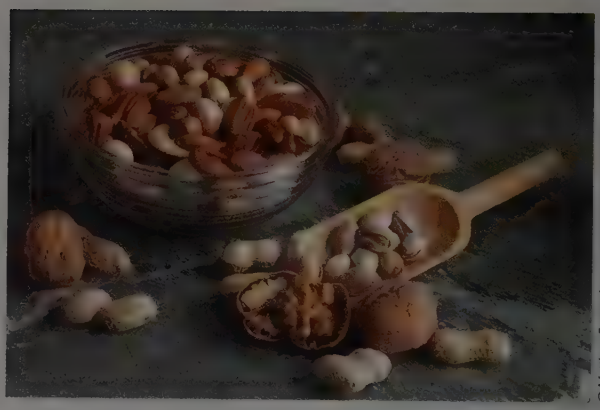
Nibble on Nuts

Tree nuts and peanuts are traditionally excluded from low-fat diets, and for good reasons. Nuts provide up to 80 percent of their kcalories from fat, and a quarter cup (about an ounce) of mixed nuts provides more than 200 kcalories. Frequent nut consumption (1-ounce serving of nuts on five or more days a week), however, protects against heart disease.[5] Benefits are seen for a variety of nuts commonly eaten in the United States: almonds, Brazil nuts, cashews, hazelnuts, macadamia nuts, pecans, pistachios, walnuts, and even peanuts. On average, these nuts contain mostly monounsaturated fat (59 percent), some polyunsaturated fat (27 percent), and little saturated fat (14 percent). Nuts also provide valuable fiber, vegetable protein, vitamin E, minerals, and phytochemicals.



© Matthew Farruggio

Olives and their oil may benefit heart health.



© Matthew Farruggio

For heart health, snack on a few nuts instead of potato chips. Because nuts are energy dense (high in kcalories per ounce), it is especially important to keep portion size in mind when eating them.

Including nuts may be a wise diet strategy against heart disease. Nuts may protect against heart disease by:[6]

- Lowering blood cholesterol
- Lowering blood pressure
- Limiting oxidative stress and inflammation

Some research suggests that a diet that includes nuts may benefit other diseases as well.[7]

Before advising consumers to include nuts in their diets, however, a caution is in order. As mentioned, most of the energy nuts provide comes from fats. Consequently, they deliver many kcalories per bite. Incorporating nuts in the diet, however, does not necessarily lead to weight gains and may even help with weight control.[8] Consumers can enjoy nuts without increasing total kcalories by using nuts *instead of, not in addition to,* other foods (such as meats, potato chips, oils, margarine, and butter).

Feast on Fish

Research into the health benefits of the long-chain omega-3 polyunsaturated fatty acids began with a simple observation: the native peoples of Alaska, northern Canada, and Greenland, who eat a traditional diet rich in omega-3 fatty acids, notably EPA (eicosapentaenoic acid) and DHA (docosaheaenoic acid), have a remarkably low rate of heart disease even though their diets are relatively high in fat.[9] These omega-3 fatty acids help to protect against heart disease by:[10]

- Reducing blood triglycerides
- Stabilizing plaque
- Lowering blood pressure
- Reducing inflammation
- Serving as precursors to eicosanoids

For people with hypertension or atherosclerosis, these actions can be life saving.

Research studies have provided strong evidence that increasing omega-3 fatty acids in the diet supports heart health and lowers the rate of deaths from heart disease. For this reason, the American Heart Association recommends including fish in a heart-healthy diet. People who eat some fish each week can lower their risks of heart attack and stroke.

Fish is the best source of EPA and DHA in the diet, but it is also a source of mercury, an environmental contaminant. Most fish contain at least trace amounts of mercury, but some have especially high levels. For this reason, the FDA advises pregnant and lactating women, women of childbearing age who may become pregnant, and young children to include fish in their diets, but to avoid:

- Tilefish (also called golden snapper or golden bass), swordfish, king mackeral, marlin, and shark

And to limit average weekly consumption of:

- A variety of ocean fish and shellfish to 12 ounces (cooked or canned)
- White (albacore) tuna to 6 ounces (cooked or canned)

Commonly eaten seafood relatively low in mercury include shrimp, catfish, pollock, salmon, and canned light tuna.

In addition to the direct toxic effects of mercury, some (but not all) research suggests that mercury may diminish the health benefits of omega-3 fatty acids. Such findings serve as a reminder that our health depends on the health of our planet. The protective effect of fish in the diet is available, provided that the fish and their surrounding waters are not heavily contaminated. (Chapter 19 discusses the adverse consequences of mercury, and Chapter 20 presents the relationships between diet and the environment in more detail.)

In an effort to limit exposure to pollutants, some consumers choose farm-raised fish. Compared with fish caught in the wild, farm-raised fish tend to be lower in mercury, but they are also lower in omega-3 fatty acids. When selecting fish, keep the diet strategies of variety and moderation in mind. Varying choices and eating moderate amounts helps to limit the intake of contaminants such as mercury.


© www.comstock.com

Fish is a good source of the omega-3 fatty acids.

High-Fat Foods and Heart Disease

The number-one dietary determinant of LDL cholesterol is saturated fat. Each 1 percent increase in energy from saturated fatty acids in the diet produces a 2 percent jump in heart disease risk by elevating LDL cholesterol. Conversely, reducing saturated fat intake by 1 percent can be expected to produce a 2 percent drop in heart disease risk by the same mechanism. Even a 2 percent drop in LDL represents a significant improvement for heart health.[11] Like saturated fats, *trans* fats also raise heart disease risk by elevating LDL cholesterol. A heart-healthy diet limits foods rich in these two types of fat.

Limit Fatty Meats, Whole-Milk Products, and Tropical Oils

The major sources of saturated fats in the US diet are fatty meats, whole milk, tropical oils, and products made from any of these foods. To limit saturated fat intake, consumers must choose carefully among these high-fat foods. More than a third of the fat in most meats is saturated. Similarly, more than half of the fat is saturated in whole milk and other high-fat milk products, such as cheese, butter, cream, half-and-half, cream cheese, sour cream, and ice cream. The tropical oils of palm, palm kernel, and coconut, which are rarely used by consumers in the kitchen, are used heavily by food manufacturers, and are commonly found in many commercially prepared foods.

When choosing meats, milk products, and commercially prepared foods, look for those lowest in saturated fat. Labels provide a useful guide for comparing products in this regard, and Appendix H lists the saturated fat in several thousand foods.

Even with careful selections, a nutritionally adequate diet will provide some saturated fat. Zero saturated fat is not possible even when experts design menus with the mission to keep saturated fat as low as possible.[12] Because most saturated fats come from animal foods, vegetarian diets can, and usually do, deliver fewer saturated fats than mixed diets.

Limit Hydrogenated Foods

Chapter 5 explained that solid shortening and margarine are made from vegetable oil that has been hardened through hydrogenation. This process both saturates some of the unsaturated fatty acids and introduces *trans*-fatty acids. Many convenience foods contain *trans* fats, including:

- Fried foods such as french fries, chicken, and other commercially fried foods
- Commercial baked goods such as cookies, doughnuts, pastries, breads, and crackers
- Snack foods such as chips
- Imitation cheeses

To keep *trans*-fat intake low, use these foods sparingly.

Table H5-1 summarizes which foods provide which fats. Substituting unsaturated fats for saturated fats at each meal and snack can help protect against heart disease. Figure H5-1 compares two meals and shows how such substitutions can lower saturated fat and raise unsaturated fat—even when total fat and kcalories remain unchanged.

The Mediterranean Diet

The links between good health and traditional Mediterranean eating patterns of the mid-1900s were introduced earlier with regard to olive oil. For people who eat these diets, the incidence of heart disease, some cancers, diabetes, and other chronic inflammatory diseases is low, and life expectancy is high.[13] Some research suggests that the health benefits of the Mediterranean eating pattern are partially due to its favorable effects on body weight.[14]

Although each of the many countries that border the Mediterranean Sea has its own culture, traditions, and dietary habits, their similarities are much greater than the use of olive oil alone. In fact, no one factor alone can be credited with reducing disease risks—the association holds true only when the overall eating pattern is present. Apparently, each of the foods contributes small benefits that harmonize to produce either a substantial cumulative or synergistic effect.

The Mediterranean eating pattern features fresh, whole foods. The people select crusty breads, whole grains, potatoes, and pastas; a variety of vegetables (including wild greens) and legumes; feta and mozzarella cheeses and yogurt; nuts; and fruits (especially grapes and figs). They eat some fish, other seafood, poultry, a few eggs, and little meat. Along with olives and olive oil, their principal sources of fat are nuts and fish; they rarely use butter or encounter hydrogenated fats. They commonly use herbs and spices instead of salt. Consequently, traditional Mediterranean diets are:

- Low in saturated fat
- Very low in *trans* fat
- Rich in monounsaturated and polyunsaturated fat
- Rich in complex carbohydrate and fiber
- Rich in nutrients and phytochemicals that support good health

As a result, lipid profiles improve, inflammation diminishes, and the risk of heart disease declines.

People following the traditional Mediterranean diet can receive as much as 40 percent of a day's kcalories from fat, but their limited consumption of milk and milk products and meats provides less than 10 percent from saturated fats. In addition, because the animals in the Mediterranean region pasture-graze, the meat, milk and milk products, and eggs are richer in omega-3 fatty acids than those from animals fed grain.

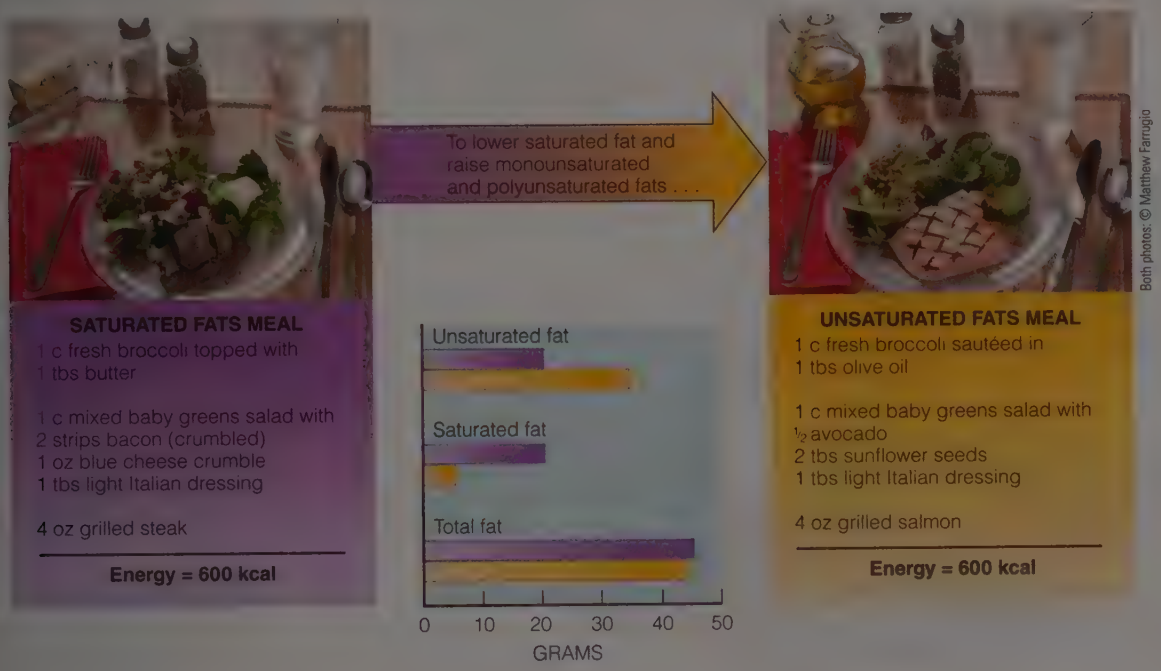
TABLE H5-1 Major Sources of Various Fatty Acids

Healthful Fatty Acids		
Monounsaturated	**Omega-6 Polyunsaturated**	**Omega-3 Polyunsaturated**
Avocado	Margarine (nonhydrogenated)	Fatty fish (herring, mackerel, salmon, tuna)
Oils (canola, olive, peanut, sesame)	Oils (corn, cottonseed, safflower, soybean)	Flaxseed
Nuts (almonds, cashews, filberts, hazelnuts, macadamia nuts, peanuts, pecans, pistachios)	Nuts (pine nuts, walnuts)	Nuts (walnuts)
Olives	Mayonnaise	
Peanut butter	Salad dressing	
Seeds (sesame)	Seeds (pumpkin, sunflower)	
Harmful Fatty Acids		
Saturated	***Trans***	
Bacon	Fried foods (hydrogenated shortening)	
Butter	Margarine (hydrogenated or partially hydrogenated)	
Chocolate	Nondairy creamers	
Coconut	Many fast foods	
Cream cheese	Shortening	
Cream, half-and-half	Commercial baked goods (including doughnuts, cakes, cookies)	
Lard		
Meat	Many snack foods (including microwave popcorn, chips, crackers)	
Milk and milk products (whole)		
Oils (coconut, palm, palm kernel)		
Shortening		
Sour cream		

NOTE: Keep in mind that foods contain a mixture of fatty acids.

> **FIGURE H5-1 Two Meals Compared: Replacing Saturated Fat with Unsaturated Fat**

Examples of ways to replace saturated fats with unsaturated fats include sautéing vegetables in olive oil instead of butter, garnishing salads with avocado and sunflower seeds instead of bacon and blue cheese, and eating salmon instead of steak. Each of these meals provides roughly the same number of kcalories and grams of fat, but the one on the left has almost four times as much saturated fat and only half as many omega-3 fatty acids.



Other foods typical of the Mediterranean, such as wild plants and snails, provide omega-3 fatty acids as well. All in all, the traditional Mediterranean diet has gained a reputation for its health benefits as well as its delicious flavors. By following a Mediterranean eating pattern, consumers improve their blood lipid profile, insulin resistance, blood pressure, and body weight.[15] Consumers need to beware that the typical Mediterranean-style cuisine available in US restaurants, however, has been adjusted to popular tastes. Quite often, these meals are much higher in saturated fats and meats—and much lower in the potentially beneficial constituents—than the traditional fare. Unfortunately, it appears that people in the Mediterranean region who are replacing some of their traditional dietary habits with those of the United States are losing the health benefits previously enjoyed.[16] Figure H5-2 (p. 164) presents a Mediterranean Diet Pyramid. Notice the emphasis on abundant plant foods.

Conclusion

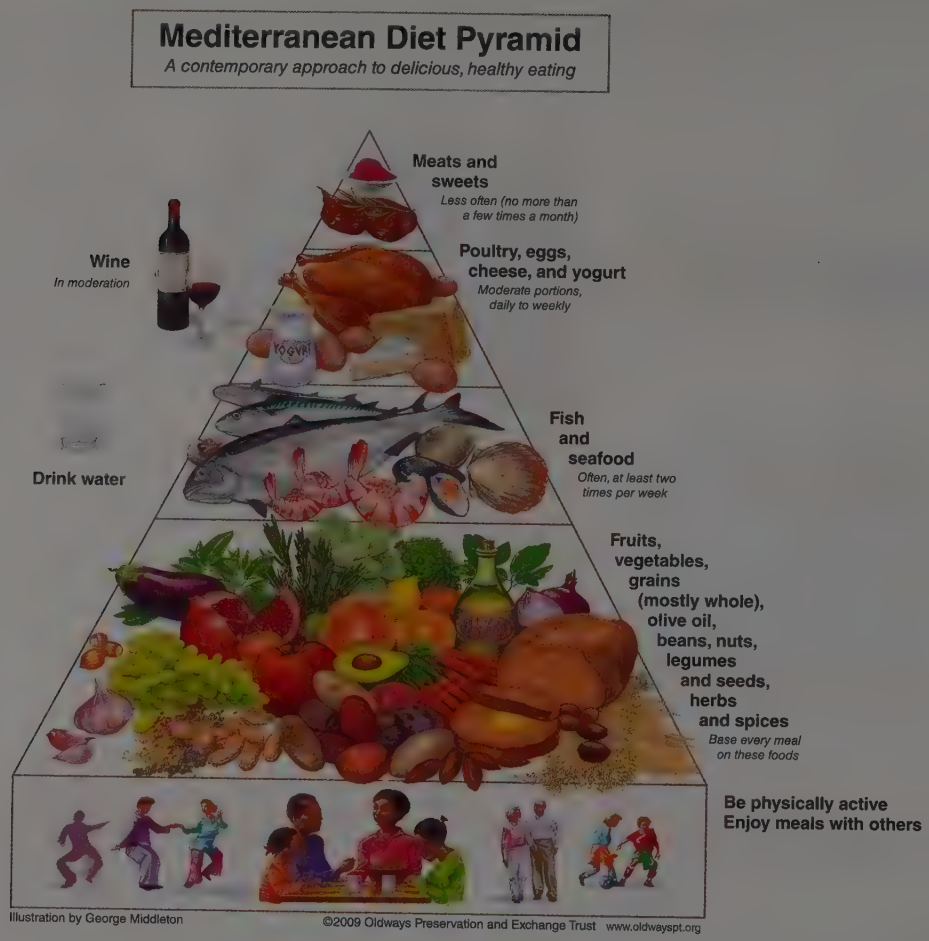
Are some fats "good," and others "bad" from the body's point of view? The saturated and *trans* fats indeed seem mostly bad for the health of the heart. Aside from providing energy, which unsaturated fats can do equally well, *saturated* and *trans* fats bring no indispensable benefits to the body. Furthermore, no harm can come from consuming diets low in them. Still, foods rich in these fats are often delicious, giving them an occasional place in the diet.

In contrast, the unsaturated fats are mostly good for the heart health when consumed in moderation. To date, their one proven fault seems to be that they, like all fats, provide abundant energy to the body and so may promote obesity if they drive kcalorie intakes higher than energy needs.[17] Obesity, in turn, often begets many body ills, as Chapter 8 describes.

Clearly, different fatty acids have different actions in the body and risks of chronic diseases.[18] When judging foods by their fatty acids, keep in mind that the fat in foods is a mixture of "good" and "bad," providing both unsaturated and saturated fatty acids. Even predominantly monounsaturated olive oil delivers some saturated fat. Consequently, even when a person chooses foods with mostly unsaturated fats, saturated fat can still add up if total fat is high.

Adopting the Mediterranean eating pattern may serve those who enjoy a little more fat in the diet. Including vegetables, fruits, whole grains, and legumes as part of a balanced daily diet is a good idea, as is *replacing* saturated fats such as butter, shortening, and meat fat with unsaturated fats such as olive oil and the oils from nuts and fish.[19] These foods provide beneficial fatty acids, fiber, vitamins, minerals, and phytochemicals as well as little salt, saturated fat, and *trans* fat—all valuable in protecting the body's health. In addition, take care to select portion sizes that will best meet energy needs. And enjoy some physical activity daily. Remember that even a healthy eating pattern can be detrimental if eaten in excess.[20]

> FIGURE H5-2 Mediterranean Diet Pyramid



REFERENCES

1. B. Bendinelli and coauthors, Fruit, vegetables, and olive oil and risk of coronary heart disease in Italian women: The EPICOR Study, *American Journal of Clinical Nutrition* 93 (2011): 275–283; M. I. Covas, V. Konstantinidou, and M. Fitó, Olive oil and cardiovascular health, *Journal of Cardiovascular Pharmacology* 54 (2009): 477–482.
2. A. Keys, *Seven Countries: A Multivariate Analysis of Death and Coronary Heart Disease* (Cambridge: Harvard University Press, 1980).
3. W. C. Willet, The great fat debate: Total fat and health, *Journal of the American Dietetic Association* 111 (2011): 660–662.
4. D. Bester and coauthors, Cardiovascular effects of edible oils: A comparison between four popular edible oils, *Nutrition Research Reviews* 23 (2010): 334–348.
5. J. Sabaté and M. Wien, Nuts, blood lipids and cardiovascular disease, *Asia Pacific Journal of Clinical Nutrition* 19 (2010): 131–136.
6. C. E. Berryman and coauthors, Effects of almond consumption on the reduction of LDL-cholesterol: A discussion of potential mechanisms and future research directions, *Nutrition Reviews* 69 (2011): 171–185; E. Ros, L. C. Tapsell, and J. Sabaté, Nuts and berries for heart health, *Current Atherosclerosis Reports* 12 (2010): 397–406; J. Sabaté, K. Oda, and E. Ros, Nut consumption and blood lipid levels: A pooled analysis of 25 intervention trials, *Archives of Internal Medicine* 170 (2010): 821–827; P. López-Uriarte and coauthors, Nuts and oxidation: A systematic review, Nutrition Reviews 67 (2009): 497–508; D. K. Banel and F. B. Hu, Effects of walnut consumption on blood lipids and other cardiovascular risk factors: A meta-analysis and systematic review, *American Journal of Clinical Nutrition* 90 (2009): 56–63.
7. J. Sabaté and Y. Ang, Nuts and health outcomes: New epidemiologic evidence, *American Journal of Clinical Nutrition* 89 (2009): 1643S–1648S.
8. M. Bes-Rastrollow and coauthors, Prospective study of nut consumption, long-term weight change, and obesity risk in women, *American Journal of Clinical Nutrition* 89 (2009): 1913–1919.
9. A. Bersamin and coauthors, Westernizing diets influence fat intake, red blood cell fatty acid composition, and health in remote Alaskan native communities in the Center for Alaska Native Health Study, *Journal of the American Dietetic Association* 108 (2008): 266–273.
10. A. C. Skulas-Ray and coauthors, Dose-response effects of omega-3 fatty acids on triglycerides, inflammation, and endothelial function in healthy persons with moderate hypertriglyceridemia, *American Journal of Clinical Nutrition* 93 (2011): 243–252; P. C. Calder and P. Yaqoob, Omega-3 (n-3) fatty

acids, cardiovascular disease and stability of atherosclerotic plaques, *Journal of Molecular Cell Biology* 56 (2010): 28–37; F. Dangardt and coauthors, Omega-3 fatty acid supplementation improves vascular function and reduces inflammation in obese adolescents, *Atherosclerosis* 212 (2010): 580–585; M. N. DiMinno and coauthors, Exploring newer cardioprotective strategies: ω-3 Fatty acids in perspective, *Journal of Thrombosis and Haemostasis* 104 (2010): 664–680.

11. *Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)*, publication NIH no. 02-5215 (Bethesda, Md.: National Heart, Lung, and Blood Institute, 2002), pp. v–8.
12. *Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)*, 2002; Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005).
13. K. Esposito and coauthors, Prevention and control of type 2 diabetes by Mediterranean diet: A systematic review, *Diabetes Research and Clinical Practice* 89 (2010): 97–102; P. P. McKeown and coauthors, Session 4: CVD, diabetes and cancer: Evidence for the use of the Mediterranean diet in patients with CHD, *Proceedings of the Nutrition Society* 69 (2010): 45–60; F. Sofi and coauthors, Accruing evidence on benefits of adherence to the Mediterranean diet on health: An updated systematic review and meta-analysis, *American Journal of Clinical Nutrition* 92 (2010): 1189–1196; L. Verberne and coauthors, Association between the Mediterranean diet and cancer risk: A review of observational studies, *Nutrition and Cancer* 62 (2010): 860–870; G. Buckland and coauthors, Adherence to the Mediterranean diet and risk of coronary heart disease in the Spanish EPIC Cohort Study, *American Journal of Epidemiology* 170 (2009): 1518–1529; N. Babio, M. Bulló, and J. Salas-Salvadó, Mediterranean diet and metabolic syndrome: The evidence, *Public Health Nutrition* 12 (2009): 1607–1617; M. A. Martinez-Gonzalez and coauthors, Mediterranean food pattern and the primary prevention of chronic disease: Recent developments, *Nutrition Reviews* 67 (2009): S111–S116; M. E. Rumawas and coauthors, Mediterranean-style dietary pattern, reduced risk of metabolic syndrome traits, and incidence in the Framingham Offspring Cohort, *American Journal of Clinical Nutrition* 90 (2009): 1608–1614; P. Sjögren and coauthors, Mediterranean and carbohydrate-restricted diets and mortality among elderly men: A cohort study in Sweden, *American Journal of Clinical Nutrition* 92 (2010): 967–974; C. LaVecchia, Association between Mediterranean dietary patterns and cancer risk, *Nutrition Reviews* 67 (2009): S126–S129.
14. J. J. Beunza and coauthors, Adherence to the Mediterranean diet, long-term weight change, and incident overweight or obesity: The Seguimiento Universidad de Navarra (SUN) cohort, *American Journal of Clinical Nutrition* 92 (2010): 1484–1493; C. M. Kastorini and coauthors, Mediterranean diet and coronary heart disease: Is obesity a link?: A systematic review, *Nutrition, Metabolism & Cardiovascular Diseases* 20 (2010): 536–551; D. Romaguera and coauthors, Mediterranean dietary patterns and prospective weight change in participants of the EPIC-PANACEA project, *American Journal of Clinical Nutrition* 92 (2010): 912–921; Babio, Bulló, and Salas-Salvadó, 2009.
15. R. Estruch, Anti-inflammatory effects of the Mediterranean diet: The experience of the PREDIMED study, *Proceedings of the Nutrition Society* 69 (2010): 333–340; Babio, Bulló, and Salas-Salvadó, 2009; S. Piscopo, The Mediterranean diet as a nutrition education, health promotion and disease prevention tool, *Public Health Nutrition* 12 (2009): 1648–1655.
16. P. A. Gilbert and S. Khokhar, Changing dietary habits of ethnic groups in Europe and implications for health, *Nutrition Reviews* 66 (2008): 203–215.
17. Committee on Dietary Reference Intakes, 2005, pp. 796–797.
18. J. M. Lecerf, Fatty acids and cardiovascular disease, *Nutrition Reviews* 67 (2009): 273–283; J. Y. Lee, L. Zhao, and D. H. Hwang, Modulation of pattern recognition receptor-mediated inflammation and risk of chronic diseases by dietary fatty acids, *Nutrition Reviews* 68 (2009): 38–61.
19. D. Mozaffarian, The great fat debate: Taking the focus off of saturated fat, *Journal of the American Dietetic Association* 111 (2011): 665–666.
20. A. H. Lichtenstein, The great fat debate: The importance of message translation, *Journal of the American Dietetic Association* 111 (2011): 667–670.



CENGAGE LEARNING'S GLOBAL NUTRITION — GLOBAL NUTRITION RESOURCE CENTER

The quality of proteins derived from animal sources versus plant sources differs greatly. Go to Nutrition Basics and Tools → Proteins to learn about protein quality. How can the protein quality of vegetarian diets be improved?

6

Protein: Amino Acids

LEARNING GPS

6.1 The Chemist's View of Proteins 168

LEARN IT Recognize the chemical structures of amino acids and proteins.

- Amino Acids 168
- Proteins 169

6.2 Digestion and Absorption of Proteins 171

LEARN IT Summarize protein digestion and absorption.

- Protein Digestion 171
- Protein Absorption 171

6.3 Proteins in the Body 173

LEARN IT Describe how the body makes proteins and uses them to perform various roles.

- Protein Synthesis 173
- Roles of Proteins 175
- A Preview of Protein Metabolism 178

6.4 Protein in Foods 181

LEARN IT Explain the differences between high-quality and low-quality proteins, including notable food sources of each.

- Protein Quality 181
- Complementary Proteins 181

6.5 Health Effects and Recommended Intakes of Protein 182

LEARN IT Identify the health benefits of, and recommendations for, protein.

- Health Effects of Protein 182
- Recommended Intakes of Protein 184
- From Guidelines to Groceries 185
- Read Food Labels 186
- Protein and Amino Acid Supplements 186

Highlight 6 Nutritional Genomics 190

LEARN IT Explain how nutrients influence gene activity (nutrigenomics) and how genes influence the activities of nutrients (nutrigenetics).

Nutrition in Your Life

The versatility of proteins in the body is impressive. They help your muscles to contract, your blood to clot, and your eyes to see. They keep you alive and well by facilitating chemical reactions and defending against infections. Without them, your bones, skin, and hair would have no structure. No wonder they were named *proteins*, meaning "of prime importance." Does that mean proteins deserve top billing in your diet as well? Are the best sources of protein beef, beans, or broccoli? Learn which foods will supply you with enough, but not too much, high-quality protein. In the Nutrition Portfolio at the end of this chapter, you can determine whether your diet is meeting your protein needs.

A few misconceptions surround the roles of protein in the body and the importance of protein in the diet. For example, people who associate meat with protein and protein with strength may eat steak to build muscles. Their thinking is only partly correct, however. Protein is a vital structural and working substance in all cells—not just muscle cells. To build strength, muscles cells need physical activity and all the nutrients—not just protein. Furthermore, protein is found in milk, eggs, legumes, and many grains and vegetables—not just meat. By overvaluing protein and overemphasizing meat in the diet, a person may mistakenly crowd out other, equally important nutrients and foods. As this chapter describes the various roles of protein in the body and food sources in the diet, keep in mind that protein is one of many nutrients needed to maintain good health.

6.1 The Chemist's View of Proteins

LEARN IT Recognize the chemical structures of amino acids and proteins.

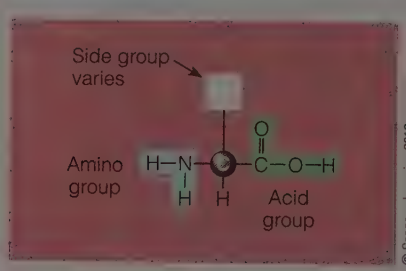
Chemically, **proteins** contain nitrogen (N) atoms in addition to the same atoms as carbohydrates and lipids—carbon (C), hydrogen (H), and oxygen (O). These nitrogen atoms give the name *amino* (nitrogen containing) to the amino acids that make the links in the chains of proteins.

♦ Chemical bonds:
- H forms one bond
- O forms two bonds
- N forms three bonds
- C forms four bonds

Amino Acids

All **amino acids** have the same basic structure—a central carbon (C) atom with a hydrogen atom (H), an amino group (NH_2), and an acid group (COOH) attached to it. Remember, however, that carbon atoms must have four bonds, ♦ so a fourth attachment is necessary. This fourth site distinguishes each amino acid from the others. Attached to the central carbon at the fourth bond is a distinct atom, or group of atoms, known as the *side group* or *side chain* (see Figure 6-1).

> **FIGURE 6-1 Amino Acid Structure**
All amino acids have a central carbon with an amino group (NH_2), an acid group (COOH), a hydrogen (H), and a side group attached. The side group is a unique chemical structure that differentiates one amino acid from another.



© Cengage Learning 2013

Unique Side Groups The side groups on the central carbon vary from one amino acid to the next, making proteins more complex than either carbohydrates or lipids. A polysaccharide (starch, for example) may be several thousand units long, but each unit is a glucose molecule just like all the others. A protein, on the other hand, is made up of about 20 different amino acids, each with a different side group. Table 6-1 lists the amino acids most common in proteins.*

The simplest amino acid, glycine, has a hydrogen atom as its side group. A slightly more complex amino acid, alanine, has an extra carbon with three hydrogen atoms. Other amino acids have more complex side groups (see Figure 6-2 for examples). Thus, although all amino acids share a common structure, they differ in size, shape, electrical charge, and other characteristics because of differences in these side groups.

Nonessential Amino Acids More than half of the amino acids are *nonessential*, meaning that the body can synthesize them for itself. Proteins in foods usually deliver these amino acids, but it is not essential that they do so. The body can make all **nonessential amino acids**, given nitrogen to form the amino group and fragments from carbohydrate or fat to form the rest of the structure.

TABLE 6-1 Amino Acids

Proteins are made up of about 20 common amino acids. The first column lists the *essential amino acids* for human beings (those the body cannot make—that must be provided in the diet). The second column lists the *nonessential amino acids*. In special cases, some nonessential amino acids may become *conditionally essential*. In a newborn, for example, only five amino acids are truly nonessential; the other nonessential amino acids are conditionally essential until the metabolic pathways are developed enough to make those amino acids in adequate amounts.

Essential Amino Acids		Nonessential Amino Acids	
Histidine	(HISS-tuh-deen)	Alanine	(AL-ah-neen)
Isoleucine	(eye-so-LOO-seen)	Arginine	(ARJ-ih-neen)
Leucine	(LOO-seen)	Asparagine	(ah-SPAR-ah-geen)
Lysine	(LYE-seen)	Aspartic acid	(ah-SPAR-tic acid)
Methionine	(meh-THIGH-oh-neen)	Cysteine	(SIS-teh-een)
Phenylalanine	(fen-il-AL-ah-neen)	Glutamic acid	(GLU-tam-ic acid)
Threonine	(THREE-oh-neen)	Glutamine	(GLU-tah-meen)
Tryptophan	(TRIP-toe-fan, TRIP-toe-fane)	Glycine	(GLY-seen)
Valine	(VAY-leen)	Proline	(PRO-leen)
		Serine	(SEER-een)
		Tyrosine	(TIE-roe-seen)

© Cengage Learning 2013

*These 20 amino acids can all be commonly found in proteins. In addition, other amino acids do not occur in proteins but can be found individually (for example, taurine and ornithine). Some amino acids occur in related forms (for example, proline can acquire an OH group to become hydroxyproline).

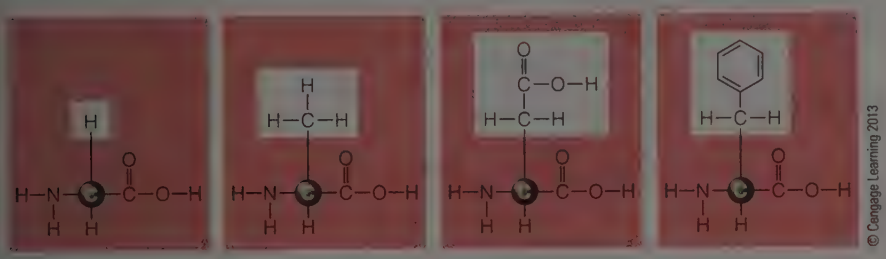
proteins: compounds composed of carbon, hydrogen, oxygen, and nitrogen atoms, arranged into amino acids linked in a chain. Some amino acids also contain sulfur atoms.

amino (a-MEEN-oh) **acids:** building blocks of proteins. Each contains an amino group, an acid group, a hydrogen atom, and a distinctive side group, all attached to a central carbon atom.
- **amino** = containing nitrogen

nonessential amino acids: amino acids that the body can synthesize (see Table 6-1).

> FIGURE 6-2 Examples of Amino Acids

Note that all amino acids have a common chemical structure but that each has a different side group. Appendix C presents the chemical structures of the 20 amino acids most common in proteins.



Glycine Alanine Aspartic acid Phenylalanine

© Cengage Learning 2013

Essential Amino Acids There are nine amino acids that the human body either cannot make at all or cannot make in sufficient quantity to meet its needs. These nine amino acids must be supplied by the diet; they are *essential*. The first column in Table 6-1 presents the **essential amino acids**. Some researchers refer to essential amino acids as *indispensable* and to nonessential amino acids as *dispensable*.

Conditionally Essential Amino Acids Sometimes a nonessential amino acid becomes essential under special circumstances. For example, the body normally uses the essential amino acid phenylalanine to make tyrosine (a nonessential amino acid). But if the diet fails to supply enough phenylalanine, or if the body cannot make the conversion for some reason (as happens in the inherited disease phenylketonuria, described in Highlight 6), then tyrosine becomes a **conditionally essential amino acid**.

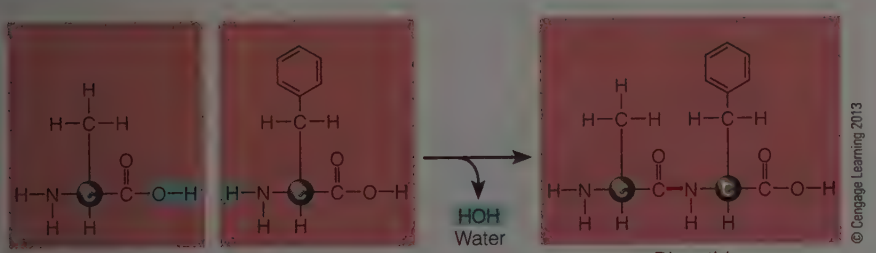
Proteins

Cells link amino acids end-to-end in a variety of sequences to form thousands of different proteins. A **peptide bond** unites each amino acid to the next.

Amino Acid Chains Condensation reactions connect amino acids, just as they combine two monosaccharides to form a disaccharide and three fatty acids with a glycerol to form a triglyceride. Two amino acids bonded together form a **dipeptide** (see Figure 6-3). By another such reaction, a third amino acid can be added to the chain to form a **tripeptide**. As additional amino acids join the chain, a **polypeptide** is formed. Most proteins are a few dozen to several hundred amino acids long. Figure 6-4 (p. 170) illustrates the protein insulin.

Primary Structure—Amino Acid Sequence The primary structure of a protein is determined by the sequence of amino acids. If a person could walk along a carbohydrate molecule like starch, the first stepping stone would be a glucose. The

> FIGURE 6-3 Condensation of Two Amino Acids to Form a Dipeptide



Amino acid + Amino acid → Dipeptide

An OH group from the acid end of one amino acid and an H atom from the amino group of another join to form a molecule of water.

A peptide bond (highlighted in red) forms between the two amino acids, creating a dipeptide.

© Cengage Learning 2013

essential amino acids: amino acids that the body cannot synthesize in amounts sufficient to meet physiological needs (see Table 6-1).

conditionally essential amino acid: an amino acid that is normally nonessential, but must be supplied by the diet in special circumstances when the need for it exceeds the body's ability to produce it.

peptide bond: a bond that connects the acid end of one amino acid with the amino end of another, forming a link in a protein chain.

dipeptide (dye-PEP-tide): two amino acids bonded together.

- **di** = two
- **peptide** = amino acid

tripeptide: three amino acids bonded together.

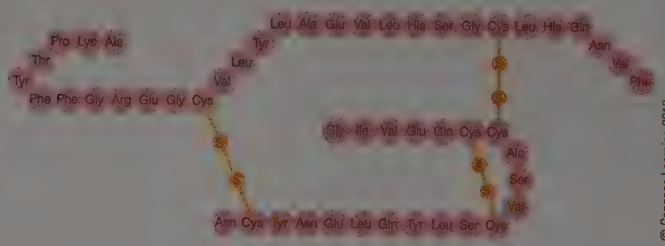
- **tri** = three

polypeptide: many (10 or more) amino acids bonded together.

- **poly** = many

> FIGURE 6-4 Amino Acid Sequence of Human Insulin

Human insulin is a relatively small protein that consists of 51 amino acids in two short polypeptide chains. (For amino acid abbreviations, see Appendix C.) Two bridges link the two chains. A third bridge spans a section within the short chain. Known as *disulfide bridges*, these links form between the cysteine (Cys) amino acids, whose side group contains sulfur (S).



© Cengage Learning 2013

next stepping stone would also be a glucose, and it would be followed by a glucose, and yet another glucose. But if a person were to walk along a polypeptide chain, each stepping stone would be one of 20 different amino acids. The first stepping stone might be the amino acid methionine. The second might be an alanine. The third might be a glycine, the fourth a tryptophan, and so on. Walking along another polypeptide path, a person might step on a phenylalanine, then a valine, then a glutamine. In other words, amino acid sequences within proteins vary.

The amino acids can act somewhat like the letters in an alphabet. If you had only the letter G, all you could write would be a string of Gs: G–G–G–G–G–G–G. But with 20 different letters available, you can create poems, songs, and novels. Similarly, the 20 amino acids can be linked together in a variety of sequences—even more than are possible for letters in a word or words in a sentence. Thus the variety of possible sequences for polypeptide chains is tremendous.

Secondary Structure—Polypeptide Shapes The secondary structure of proteins is determined not by chemical bonds as between the amino acids but by weak electrical attractions within the polypeptide chain. As positively charged hydrogens attract nearby negatively charged oxygens, sections of the polypeptide chain twist into a helix or fold into a pleated sheet, for example. These shapes give proteins strength and rigidity.

Tertiary Structure—Polypeptide Tangles The tertiary structure of proteins occurs as long polypeptide chains twist and fold into a variety of complex, tangled shapes. The unique side group of each amino acid gives it characteristics that attract it to, or repel it from, the surrounding fluids and other amino acids. Some amino acid side groups are attracted to water molecules; they are *hydrophilic*. Other side groups are repelled by water; they are *hydrophobic*. As amino acids are strung together to make a polypeptide, the chain folds so that its hydrophilic side groups are on the outer surface near water; the hydrophobic groups tuck themselves inside, away from water. Similarly, the disulfide bridges in insulin (see Figure 6-4) determine its tertiary structure. The extraordinary and unique shapes of proteins enable them to perform their various tasks in the body. Some form globular or spherical structures that can carry and store materials within them, and some, such as those of tendons, form linear structures that are more than 10 times as long as they are wide. The intricate shape a protein finally assumes gives it maximum stability.



© Matthew Farruggio

Cooking an egg denatures its proteins.

Quaternary Structure—Multiple Polypeptide Interactions Some polypeptides are functioning proteins just as they are; others need to associate with other polypeptides to form larger working complexes. The quaternary structure of proteins involves the interactions between two or more polypeptides. One molecule of **hemoglobin**—the large, globular protein molecule that, by the billions, packs the red blood cells and carries oxygen—is made of four associated polypeptide chains, each holding the mineral iron (see Figure 6-5).

Protein Denaturation When proteins are subjected to heat, acid, or other conditions that disturb their stability, they undergo **denaturation**—that is, they uncoil and lose their shapes and, consequently, also lose their ability to function. Past a certain point, denaturation is irreversible. Familiar examples of denaturation include the hardening of an egg when it is cooked, the curdling of milk when acid is added, and the stiffening of egg whites when they are whipped. In the body, proteins are denatured when they are exposed to stomach acid.

hemoglobin (HE-moh-GLO-bin): the globular protein of the red blood cells that carries oxygen from the lungs to the cells throughout the body.

- **hemo** = blood
- **globin** = globular protein

denaturation (dee-NAY-chur-AY-shun): the change in a protein's shape and consequent loss of its function brought about by heat, agitation, acid, base, alcohol, heavy metals, or other agents.

REVIEW IT Recognize the chemical structures of amino acids and proteins. Chemically speaking, proteins are more complex than carbohydrates or lipids; they are made of some 20 different amino acids, 9 of which the body cannot make (the essential amino acids). Each amino acid contains an amino group, an acid group, a hydrogen atom, and a distinctive side group, all attached to a central carbon atom. Peptide bonds link amino acids together in a series of condensation reactions to create proteins. The distinctive sequence of amino acids in each protein determines its unique shape and function.

6.2 Digestion and Absorption of Proteins

LEARN IT Summarize protein digestion and absorption.

Proteins in foods do not become body proteins directly. Instead, foods supply the amino acids from which the body makes its own proteins. When a person eats foods containing protein, enzymes break the long polypeptides into short polypeptides, the short polypeptides into tripeptides and dipeptides, and, finally, the tripeptides and dipeptides into amino acids.

Protein Digestion Figure 6-6 (p. 172) illustrates the digestion of protein through the GI tract. Proteins are crushed and moistened in the mouth, but the real action begins in the stomach.

In the Stomach The major event in the stomach is the partial breakdown (hydrolysis) of proteins. Hydrochloric acid uncoils (denatures) each protein's tangled strands so that digestive enzymes can attack the peptide bonds. The hydrochloric acid also converts the inactive form of the enzyme pepsinogen to its active form, **pepsin.*** Pepsin cleaves proteins—large polypeptides—into smaller polypeptides and some amino acids.

In the Small Intestine When polypeptides enter the small intestine, several pancreatic and intestinal **proteases** hydrolyze them further into short peptide chains, tripeptides, dipeptides, and amino acids.** Then **peptidase** enzymes on the membrane surfaces of the intestinal cells split most of the dipeptides and tripeptides into single amino acids. Only a few peptides escape digestion and enter the blood intact. Figure 6-6 (p. 172) includes names of the digestive enzymes for protein and describes their actions.

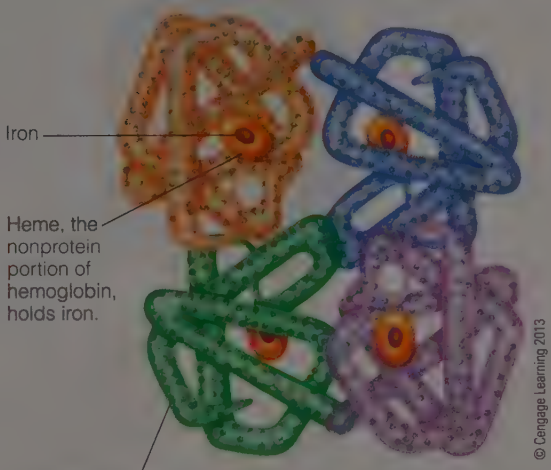
Protein Absorption A number of specific carriers transport amino acids (and some dipeptides and tripeptides) into the intestinal cells. Once inside the intestinal cells, amino acids may be used for energy or to synthesize needed compounds. Amino acids that are not used by the intestinal cells are transported across the cell membrane into the surrounding fluid where they enter the capillaries on their way to the liver.

Consumers lacking nutrition knowledge may fail to realize that most proteins are broken down to amino acids before absorption. They may be misled by advertisements urging them to "Take this enzyme supplement to help you digest your food." Or "Don't eat this food that contains these enzymes that will digest cells in your body." In reality, though, enzymes in supplements and foods are proteins that are digested to amino acids, just as all proteins are. Even the digestive enzymes—which function optimally at their specific pH—are denatured and digested when the pH of their environment changes. The enzyme pepsin, for example, which works best in the low pH of the stomach becomes inactive and digested when it enters the higher pH of the small intestine.

Another misconception is that eating predigested proteins (amino acid supplements) saves the body from having to digest proteins and keeps the digestive system from "overworking." Such a belief grossly underestimates the body's abilities. As a matter of fact, the digestive system handles whole proteins *better* than predigested ones because it dismantles and absorbs the amino acids at rates that are optimal for the body's use. (The last section of this chapter discusses protein and amino acid supplements further.)

> **FIGURE 6-5 The Structure of Hemoglobin**

The globular hemoglobin protein is made of four polypeptide chains (quaternary structure).



© Cengage Learning 2013

The shape of each polypeptide chain is determined by an amino acid sequence (primary structure) that twists into a helix (secondary structure) and bends itself into a ball shape (tertiary structure).

pepsin: a gastric enzyme that hydrolyzes protein. Pepsin is secreted in an inactive form, *pepsinogen*, which is activated by hydrochloric acid in the stomach.

proteases (PRO tee aces) enzymes that hydrolyze protein.

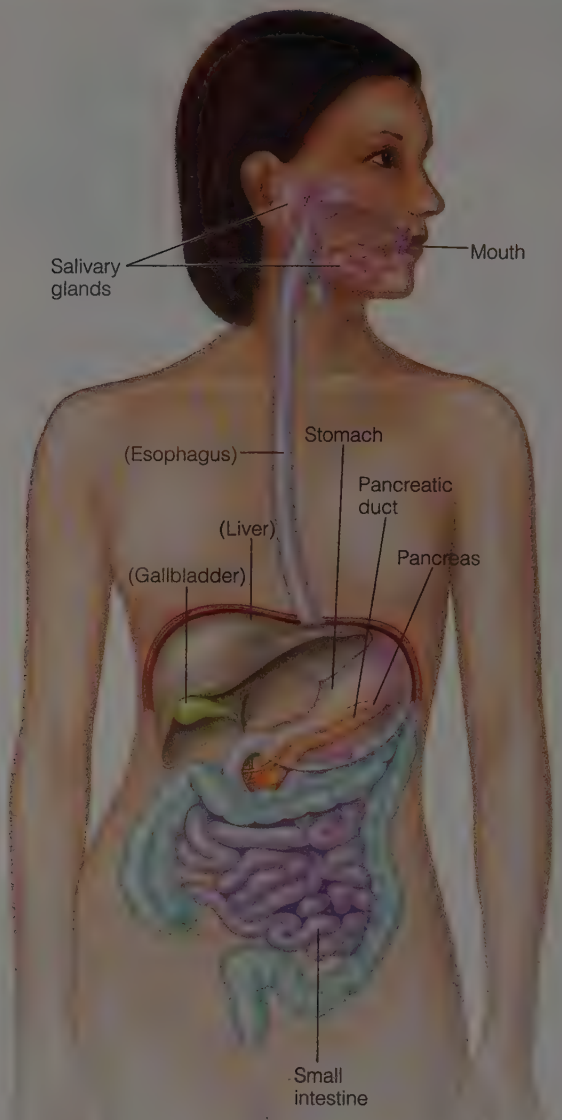
peptidase: a digestive enzyme that hydrolyzes peptide bonds. *Tripeptidases* cleave tripeptides; *dipeptidases* cleave dipeptides. *Endopeptidases* cleave peptide bonds within the chain to create smaller fragments, whereas *exopeptidases* cleave bonds at the ends to release free amino acids.

- **tri** = three
- **di** = two
- **endo** = within
- **exo** = outside

*The inactive form of an enzyme is called a *proenzyme* or a *zymogen* (ZYE-moh-jen).

**A string of four to nine amino acids is an *oligopeptide* (OL-ee-go-PEP-tide); *oligo* means few.

> FIGURE 6-6 *Animated* Protein Digestion in the GI Tract



PROTEIN

Mouth and salivary glands

Chewing and crushing moisten protein-rich foods and mix them with saliva to be swallowed

HYDROCHLORIC ACID AND THE DIGESTIVE ENZYMES

Stomach

Hydrochloric acid (HCl) uncoils protein strands and activates stomach enzymes:

Protein —(Pepsin, HCl)→ Smaller polypeptides

In the stomach:

Hydrochloric acid (HCl)
- Denatures protein structure
- Activates pepsinogen to pepsin

Pepsin
- Cleaves proteins to smaller polypeptides and some free amino acids
- Inhibits pepsinogen synthesis

Small intestine and pancreas

Pancreatic and small intestinal enzymes split polypeptides further:

Polypeptides —(Pancreatic and intestinal proteases)→ Tripeptides, dipeptides, amino acids

Then enzymes on the surface of the small intestinal cells hydrolyze these peptides and the cells absorb them:

Peptides —(Intestinal tripeptidases and dipeptidases)→ Amino acids (absorbed)

In the small intestine:

Enteropeptidase
- Converts pancreatic trypsinogen to trypsin

Trypsin
- Inhibits trypsinogen synthesis
- Cleaves peptide bonds next to the amino acids lysine and arginine
- Converts pancreatic procarboxypeptidases to carboxypeptidases
- Converts pancreatic chymotrypsinogen to chymotrypsin

Chymotrypsin
- Cleaves peptide bonds next to the amino acids phenylalanine, tyrosine, tryptophan, methionine, asparagine, and histidine

Carboxypeptidases
- Cleave amino acids from the acid (carboxyl) ends of polypeptides

Elastase and collagenase
- Cleave polypeptides into smaller polypeptides and tripeptides

Intestinal tripeptidases
- Cleave tripeptides to dipeptides and amino acids

Intestinal dipeptidases
- Cleave dipeptides to amino acids

Intestinal aminopeptidases
- Cleave amino acids from the amino ends of small polypeptides (oligopeptides)

© Cengage Learning 2013

REVIEW IT *Summarize protein digestion and absorption.*

Digestion is facilitated mostly by the stomach's acid and enzymes, which first denature dietary proteins, then cleave them into smaller polypeptides and some amino acids. Pancreatic and intestinal enzymes split these polypeptides further, to oligopeptides, tripeptides, and dipeptides, and then split most of these to single amino acids. Then carriers in the membranes of intestinal cells transport the amino acids into the cells, where they are released into the bloodstream.

6.3 Proteins in the Body

LEARN IT Describe how the body makes proteins and uses them to perform various roles.

The human body has an estimated 20,000 to 25,000 genes that code for hundreds of thousands of proteins. Relatively few proteins have been studied in detail, although this number is growing rapidly with the surge in knowledge gained from sequencing the human genome. The relatively few proteins described in this chapter illustrate the versatility, uniqueness, and importance of proteins. As you will see, each protein has a specific function, and that function is determined during protein synthesis.

Protein Synthesis

Each human being is unique because of small differences in the body's proteins. These differences are determined by the amino acid sequences of proteins, which, in turn, are determined by genes. The following paragraphs describe in words the ways cells synthesize proteins; Figure 6-7 (p. 174) provides a pictorial description. Protein synthesis depends on a diet that provides adequate protein and essential amino acids.

The instructions for making every protein in a person's body are transmitted by way of the genetic information received at conception. This body of knowledge, which is filed in the DNA (deoxyribonucleic acid) within the nucleus of every cell, never leaves the nucleus.

Delivering the Instructions Transforming the information in DNA into the appropriate sequence of amino acids needed to make a specific protein requires two major steps. ♦ In the first step, known as **transcription**, a stretch of DNA is used as a template to make messenger RNA. Messenger RNA then carries the code across the nuclear membrane into the body of the cell, where it seeks out and attaches itself to one of the ribosomes (a protein-making machine, which is itself composed of RNA and protein). There the second step, known as **translation**, takes place. Situated on a ribosome, messenger RNA specifies the sequence in which the amino acids line up for the synthesis of a protein.

♦ DNA $\xrightarrow{\text{transcription}}$ RNA $\xrightarrow{\text{translation}}$ protein

Lining Up the Amino Acids Other forms of RNA, called transfer RNA, collect amino acids from the cell fluid and take them to messenger RNA. Each of the 20 amino acids has a specific transfer RNA. Thousands of transfer RNA, each carrying its amino acid, cluster around the ribosomes, awaiting their turn to unload. When the messenger RNA calls for a specific amino acid, the transfer RNA carrying that amino acid moves into position. Then the next loaded transfer RNA moves into place and then the next and the next. In this way, the amino acids line up in the sequence that is genetically determined, and enzymes bind them together. Finally, the completed protein strand is released, and the transfer RNA are freed to return for another load of amino acids.

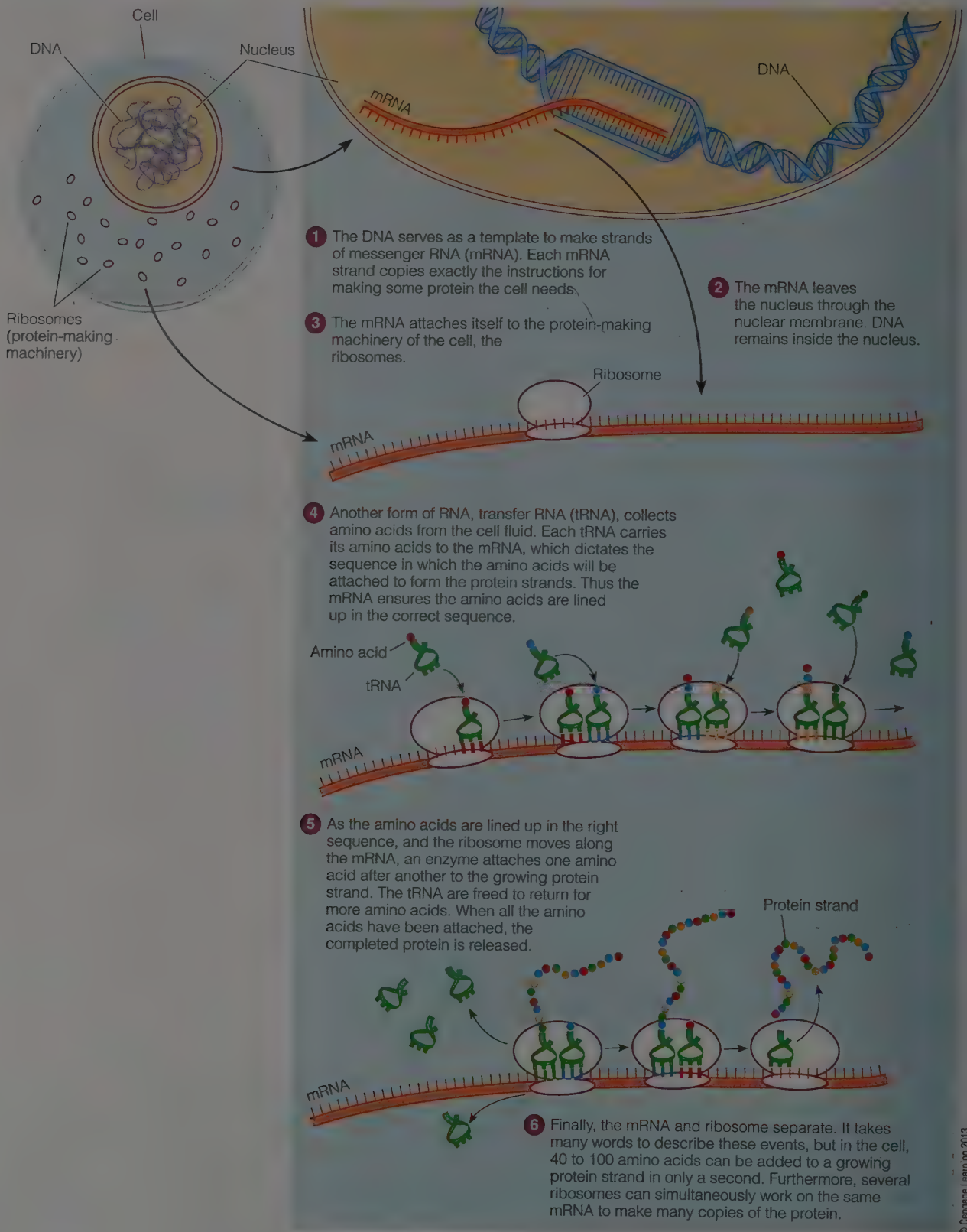
Sequencing Errors The sequence of amino acids in each protein determines its shape, which supports a specific function. An error in the amino acid sequence results in an altered protein—sometimes with dramatic consequences. The protein hemoglobin offers one example of such a genetic variation. In a person with **sickle-cell anemia**, two of hemoglobin's four polypeptide chains (described earlier on pp. 170–171) have the normal sequence of amino acids, but the other two chains do not—they have the amino acid valine in a position that is normally occupied by glutamic acid (see Figure 6-8, p. 175). This single alteration in the amino acid sequence changes the characteristics and shape of hemoglobin so much that it loses its ability to carry oxygen effectively. The red blood cells filled with this abnormal hemoglobin stiffen into elongated sickle, or crescent, shapes instead of maintaining their normal pliable disc shape—hence the name, sickle-cell anemia. Sickle-cell anemia raises energy needs, causes many medical problems, and can be fatal.[1] Caring for children with sickle-cell anemia includes diligent attention to their water needs because dehydration can trigger a crisis.

transcription: the process of messenger RNA being made from a template of DNA.

translation: the process of messenger RNA directing the sequence of amino acids and synthesis of proteins.

sickle-cell anemia: a hereditary form of anemia characterized by abnormal sickle- or crescent-shaped red blood cells. Sickled cells interfere with oxygen transport and blood flow. Symptoms are precipitated by dehydration and insufficient oxygen (as may occur at high altitudes) and include hemolytic anemia (red blood cells burst), fever, and severe pain in the joints and abdomen.

> **FIGURE 6-7** ***Animated*** **Protein Synthesis**



© Cengage Learning 2013

Gene Expression When a cell makes a protein as described earlier, scientists say that the gene for that protein has been "expressed." Cells can regulate **gene expression** to make the type of protein, in the amounts and at the rate, they need. Nearly all of the body's cells possess the genes for making all human proteins, but each type of cell makes only the proteins it needs. For example, cells of the pancreas express the gene for insulin; in other cells, that gene is idle. Similarly, the cells of the pancreas do not make the protein hemoglobin, which is needed only by the red blood cells.

Recent research has unveiled some of the fascinating ways nutrients regulate gene expression and protein synthesis (see Highlight 6). Because diet plays an ongoing role in our lives from conception to death, it has a major influence on gene expression and disease development. The benefits of polyunsaturated fatty acids in defending against heart disease, for example, are partially explained by their role in influencing gene expression for lipid enzymes. Later chapters provide additional examples of relationships among nutrients, genes, and disease development.

Roles of Proteins

Whenever the body is growing, repairing, or replacing tissue, proteins are involved. Sometimes their role is to facilitate or to regulate; other times it is to become part of a structure. Versatility is a key feature of proteins.

As Structural Materials From the moment of conception, proteins form the building blocks of muscles, blood, and skin—in fact, protein is the major structural component of all the body's cells. To build a bone or a tooth, for example, cells first lay down a **matrix** of the protein **collagen** and then fill it with crystals of calcium, phosphorus, magnesium, fluoride, and other minerals.

Collagen also provides the material of ligaments and tendons and the strengthening "glue" between the cells of the artery walls that enables the arteries to withstand the pressure of the blood surging through them with each heartbeat. Also made of collagen are scars that knit the separated parts of torn tissues together.

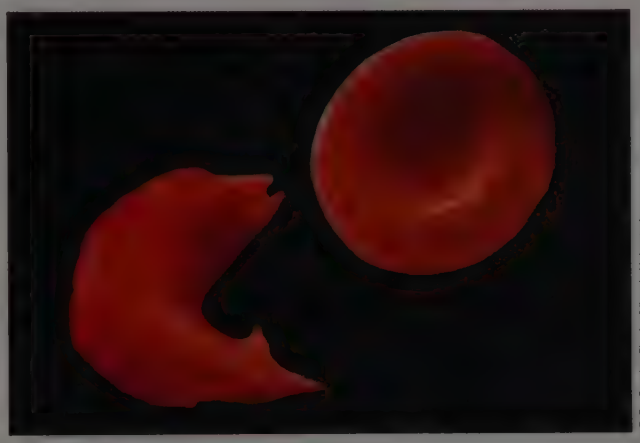
Proteins are also needed for replacing dead or damaged cells. The average life span of a skin cell is only about 30 days. As old skin cells are shed, new cells made largely of protein grow from underneath to replace them. Cells in the deeper skin layers synthesize new proteins to form hair and fingernails. Muscle cells make new proteins to grow larger and stronger in response to exercise. Cells of the GI tract are replaced every few days. Both inside and outside, the body continuously uses protein to create new cells that replace those that have been lost.

As Enzymes Some proteins act as **enzymes.** Digestive enzymes have appeared in every chapter since Chapter 3, but digestion is only one of the many processes facilitated by enzymes. Enzymes not only break down substances, but they also build substances (such as bone) and transform one substance into another (amino acids into glucose, for example). Breaking down reactions are *catabolic*, whereas building up reactions are *anabolic*. (Chapter 7 provides more details.) Figure 6-9 diagrams a synthesis reaction.

An analogy may help to clarify the role of enzymes. Enzymes are comparable to the clergy and judges who make and dissolve marriages. When a minister marries two people, they become a couple, with a new bond between them. They are joined together—but the minister remains unchanged. The minister represents enzymes that synthesize large compounds from smaller ones. One minister can

> FIGURE 6-8 ***Animated*** **Sickle Cell Compared with Normal Red Blood Cell**

Normally, red blood cells are disc-shaped, but in the inherited disorder sickle-cell anemia, red blood cells are sickle- or crescent-shaped. This alteration in shape occurs because valine replaces glutamic acid in the amino acid sequence of two of hemoglobin's polypeptide chains. As a result of this one alteration, the hemoglobin has a diminished capacity to carry oxygen.



© Dr. Stanley Flegler/Visuals Unlimited

Sickle-shaped blood cell Normal red blood cell

Amino acid sequence of normal hemoglobin:

Val–His–Leu–Thr–Pro–Glu–Glu

Amino acid sequence of sickle-cell hemoglobin:

Val–His–Leu–Thr–Pro–Val–Glu

gene expression: the process by which a cell converts the genetic code into RNA and protein.

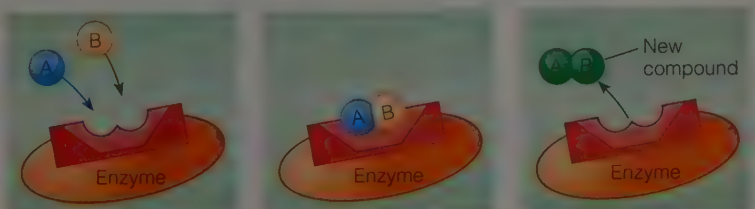
matrix (MAY-tricks): the basic substance that gives form to a developing structure; in the body, the formative cells from which teeth and bones grow.

collagen (KOL-ah-jen): the structural protein from which connective tissues such as scars, tendons, ligaments, and the foundations of bones and teeth are made.

enzymes: proteins that facilitate chemical reactions without being changed in the process; protein catalysts.

> FIGURE 6-9 **Enzyme Action**

Each enzyme facilitates a specific chemical reaction. In this diagram, an enzyme enables two compounds to make a more complex structure, but the enzyme itself remains unchanged.



© Cengage Learning 2013

The separate compounds, A and B, are attracted to the enzyme's active site, making a reaction likely.

The enzyme forms a complex with A and B.

The enzyme is unchanged, but A and B have formed a new compound, AB.

TABLE 6-2 Examples of Hormones and Their Actions

Hormones	Actions
Growth hormone	Promotes growth
Insulin and glucagon	Regulate blood glucose (see Chapter 4)
Thyroxin	Regulates the body's metabolic rate (see Chapter 8)
Calcitonin and parathyroid hormone	Regulate blood calcium (see Chapter 12)
Antidiuretic hormone	Regulates fluid and electrolyte balance (see Chapter 12)

NOTE: Hormones are chemical messengers that are secreted by endocrine glands in response to altered conditions in the body. Each travels to one or more specific target tissues or organs, where it elicits a specific response. For descriptions of many hormones important in nutrition, see Appendix A.

© Cengage Learning 2013

perform thousands of marriage ceremonies, just as one enzyme can expedite billions of reactions.

Similarly, a judge who lets married couples separate may decree many divorces before retiring. The judge represents enzymes that hydrolyze larger compounds to smaller ones; for example, the digestive enzymes. The point is that, like the minister and the judge, enzymes themselves are not altered by the reactions they facilitate. They are catalysts, permitting reactions to occur more quickly and efficiently than if substances depended on chance encounters alone.

As Hormones The body's many hormones are messenger molecules, and *some* hormones are proteins. (Recall from Chapter 5 that some hormones, such as estrogen and testosterone, are made from the lipid cholesterol.) Various endocrine glands in the body release hormones in response to changes that challenge the body. The blood carries the hormones from these glands to their target tissues, where they elicit the appropriate responses to restore and maintain normal conditions.

The hormone insulin provides a familiar example. After a meal, when blood glucose rises, the pancreas releases insulin. Insulin stimulates the transport proteins of the muscles and adipose tissue to pump glucose into the cells faster than it can leak out. After acting on the message, the cells destroy the insulin. As blood glucose falls, the pancreas slows its release of insulin. Many other proteins act as hormones, regulating a variety of actions in the body (see Table 6-2 for examples).



SPL/Photo Researchers, Inc.

In critical illness and protein malnutrition, blood vessels become "leaky" and allow plasma proteins to move into the tissues. Because proteins attract water, the tissues swell, causing edema.

As Regulators of Fluid Balance Proteins help to maintain the body's **fluid balance.** Normally, proteins are found primarily within the cells and in the plasma (essentially blood without its red blood cells). Being large, proteins do not normally cross the walls of the blood vessels. During times of critical illness or protein malnutrition, however, plasma proteins leak out of the blood vessels into the spaces between the cells. Because proteins attract water, fluid accumulates and causes swelling. Swelling due to an excess of fluid in the tissues is known as **edema.** The protein-related causes of edema include:

- Excessive protein losses caused by inflammation and critical illnesses
- Inadequate protein synthesis caused by liver disease
- Inadequate dietary intake of protein

Whatever the cause of edema, the result is the same: a diminished capacity to deliver nutrients and oxygen to the cells and to remove wastes from them. As a consequence, cells fail to function adequately.

As Acid-Base Regulators Proteins also help to maintain the balance between **acids** and **bases** within the body fluids. Normal body processes continuously produce acids and bases, which the blood carries to the kidneys and lungs for excretion. The challenge is to maintain acid-base balance as conditions continually change.

An acid solution contains an abundance of hydrogen ions (H^+); the greater the concentration of hydrogen ions, the more acidic the solution and the lower the pH. Proteins, which have negative charges on their surfaces, attract hydrogen ions, which have positive charges. By accepting and releasing hydrogen ions, proteins act as **buffers,** maintaining the acid-base balance of the blood and body fluids.

The blood's acid-base balance is tightly controlled to maintain pH within the narrow range of between 7.35 and 7.45. Outside this range, either **acidosis** or **alkalosis** can lead to coma and death, largely by denaturing proteins. Denaturing a protein changes its shape and renders it useless. To give just one example, denatured hemoglobin loses its capacity to carry oxygen.

As Transporters Some proteins move about in the body fluids, carrying nutrients and other molecules. The protein hemoglobin carries oxygen from the lungs to

fluid balance: maintenance of the proper types and amounts of fluid in each compartment of the body fluids (see also Chapter 12).

edema (eh-DEEM-uh): the swelling of body tissue caused by excessive amounts of fluid in the interstitial spaces; seen in protein deficiency (among other conditions).

acids: compounds that release hydrogen ions in a solution.

bases: compounds that accept hydrogen ions in a solution.

buffers: compounds that keep a solution's pH constant when acids or bases are added.

acidosis (assi-DOE-sis): higher-than-normal acidity in the blood and body fluids.

alkalosis (alka-LOE-sis): higher-than-normal alkalinity (base) in the blood and body fluids.

the cells. The lipoproteins transport lipids around the body. Special transport proteins carry vitamins and minerals.

The transport of the mineral iron provides an especially good illustration of these proteins' specificity and precision. When iron is absorbed, it is captured in an intestinal cell by a protein. Before leaving the intestinal cell, iron is attached to another protein that carries it through the bloodstream to the cells. Once iron enters a cell, it is attached to a storage protein that will hold the iron until it is needed. When it is needed, iron is incorporated into proteins in the red blood cells and muscles that assist in oxygen transport and use. (Chapter 13 provides more details on how these protein carriers transport and store iron.)

Some transport proteins reside in cell membranes and act as "pumps," picking up compounds on one side of the membrane and releasing them on the other as needed. Each transport protein is specific for a certain compound or group of related compounds. Figure 6-10 illustrates how a membrane-bound transport protein helps to maintain the sodium and potassium concentrations in the fluids inside and outside cells. The balance of these two minerals is critical to nerve transmissions and muscle contractions; imbalances can cause irregular heartbeats, muscular weakness, kidney failure, and even death.

As Antibodies Proteins also defend the body against disease. A virus—whether it is one that causes flu, smallpox, measles, or the common cold—enters the cells and multiplies there. One virus may produce 100 replicas of itself within an hour or so. Each replica can then burst out and invade 100 different cells, soon yielding 10,000 viruses, which invade 10,000 cells. Left free to do their worst, they will soon overwhelm the body with disease.

Fortunately, when the body detects these invading **antigens**, it manufactures **antibodies**, giant protein molecules designed specifically to combat them. The antibodies work so swiftly and efficiently that in a healthy individual, most diseases never get started. Without sufficient protein, though, the body cannot maintain its army of antibodies to resist infectious diseases.

Each antibody is designed to destroy a specific antigen. Once the body has manufactured antibodies against a particular antigen (such as the measles virus), it "remembers" how to make them. Consequently, the next time the body encounters that same antigen, it produces antibodies even more quickly. In other words, the body develops a molecular memory, known as **immunity**. (Chapter 16 describes food allergies—the immune system's response to food antigens.)

As a Source of Energy and Glucose Without energy, cells die; without glucose, the brain and nervous system falter. Even though proteins are needed to do the

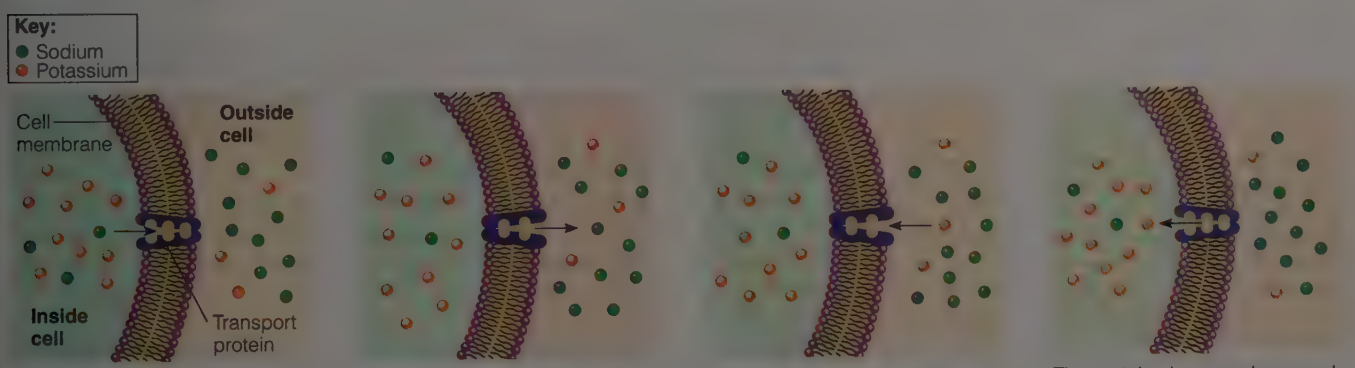
antigens: substances that elicit the formation of antibodies or an inflammation reaction from the immune system. A bacterium, a virus, a toxin, and a protein in food that causes allergy are all examples of antigens.

antibodies: large proteins of the blood and body fluids, produced by the immune system in response to the invasion of the body by foreign molecules (usually proteins called *antigens*). Antibodies combine with and inactivate the foreign invaders, thus protecting the body.

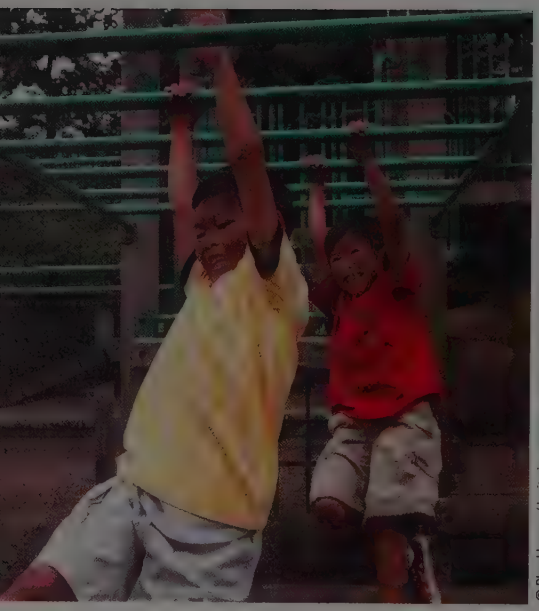
immunity: the body's ability to defend itself against diseases (see also Chapter 18).

> FIGURE 6-10 ***Animated*** **An Example of a Transport Protein**

This transport protein resides within a cell membrane and acts as a two-door passageway. Molecules enter on one side of the membrane and exit on the other, but the protein doesn't leave the membrane. This example shows how the transport protein moves sodium and potassium in opposite directions across the membrane to maintain a high concentration of potassium and a low concentration of sodium within the cell. This active transport system requires energy.



© Cengage Learning 2013



© Blend Images/Jupiterimages.com

Growing children end each day with more bone, blood, muscle, and skin cells than they had at the beginning of the day.

work that only they can perform, they will be sacrificed to provide energy and glucose during times of starvation or insufficient carbohydrate intake. The body will break down its tissue proteins to make amino acids available for energy or glucose production (a process known as *gluconeogenesis*). In this way, protein can maintain blood glucose levels, but at the expense of losing lean body tissue. Chapter 7 provides many more details on energy metabolism.

Other Roles As mentioned earlier, proteins form integral parts of most body structures such as skin, muscles, and bones. They also participate in some of the body's most amazing activities such as blood clotting and vision. When a tissue is injured, a rapid chain of events leads to the production of fibrin, a stringy, insoluble mass of protein fibers that forms a solid clot from liquid blood. Later, more slowly, the protein collagen forms a scar to replace the clot and permanently heal the wound. The light-sensitive pigments in the cells of the eye's retina are molecules of the protein opsin. Opsin responds to light by changing its shape, thus initiating the nerve impulses that convey the sense of sight to the brain.

The amino acids are as versatile as the proteins. In addition to serving as building blocks for proteins in the body, amino acids have multiple roles in regulating pathways that support growth, reproduction, metabolism, and immunity.[2]

A Preview of Protein Metabolism

This section previews protein metabolism; Chapter 7 provides a full description. Cells have several metabolic options, depending on their protein and energy needs.

Protein Turnover and the Amino Acid Pool Within each cell, proteins are continually being made and broken down, a process known as **protein turnover.** Protein breakdown releases amino acids.* These amino acids mix with amino acids from dietary protein to form an **"amino acid pool"** within the cells and circulating blood. The rate of protein degradation and the amount of protein intake may vary, but the pattern of amino acids within the pool remains fairly constant. Regardless of their source, any of these amino acids can be used to make body proteins or other nitrogen-containing compounds, or they can be stripped of their nitrogen and used for energy (either immediately or stored as fat for later use).

♦ Nitrogen balance:
- Nitrogen equilibrium (zero nitrogen balance): N in = N out
- Positive nitrogen: N in > N out
- Negative nitrogen: N in < N out

Nitrogen Balance Protein turnover and **nitrogen balance** go hand in hand. ♦ In healthy adults, protein synthesis balances with degradation, and protein intake from food balances with nitrogen excretion in the urine, feces, and sweat. When nitrogen intake equals nitrogen output, the person is in nitrogen equilibrium, or zero nitrogen balance. Researchers use nitrogen balance studies to estimate protein requirements.**

If the body synthesizes more than it degrades, then protein is added and nitrogen status becomes positive. Nitrogen status is positive in growing infants, children, adolescents, pregnant women, and people recovering from protein deficiency or illness; their nitrogen intake exceeds their nitrogen excretion. They are retaining protein in new tissues as they add blood, bone, skin, and muscle cells to their bodies.

If the body degrades more than it synthesizes, then protein is being lost and nitrogen status becomes negative. Nitrogen status is negative in people who are starving or suffering other severe stresses such as burns, injuries, infections, and fever; their nitrogen excretion exceeds their nitrogen intake. During these times, the body loses nitrogen as it breaks down muscle and other body proteins for energy.

Using Amino Acids to Make Other Compounds Amino acids can be used to make compounds other than proteins. For example, the amino acid tyrosine is used to make the **neurotransmitters** norepinephrine and epinephrine, which relay nervous system messages throughout the body. Tyrosine can also be used to make the pigment melanin, which is responsible for brown hair, eye, and skin color, or

protein turnover: the degradation and synthesis of protein.

amino acid pool: the supply of amino acids derived from either food proteins or body proteins that collect in the cells and circulating blood and stand ready to be incorporated in proteins and other compounds or used for energy.

nitrogen balance: the amount of nitrogen consumed (N in) as compared with the amount of nitrogen excreted (N out) in a given period of time.

neurotransmitters: chemicals that are released at the end of a nerve cell when a nerve impulse arrives there. They diffuse across the gap to the next cell and alter the membrane of that second cell to either inhibit or excite it.

*Amino acids or proteins that derive from within the body are *endogenous* (en-DODGE-eh-nus). In contrast, those that derive from foods are *exogenous* (eks-ODGE-eh-nus).

**The genetic materials DNA and RNA contain nitrogen, but the quantity is insignificant compared with the amount in protein. Protein is 16 percent nitrogen. Said another way, the average protein weighs about 6.25 times as much as the nitrogen it contains, so scientists can estimate the amount of protein in a sample of food, body tissue, or other material by multiplying the weight of the nitrogen in it by 6.25.

the hormone thyroxin, which helps to regulate the metabolic rate. For another example, the amino acid tryptophan serves as a precursor for the vitamin niacin and for **serotonin,** a neurotransmitter important in sleep regulation, appetite control, and sensory perception.

Using Amino Acids for Energy and Glucose As mentioned earlier, when glucose or fatty acids are limited, cells are forced to use amino acids for energy and glucose. The body does not have a specialized storage site for protein as it does for carbohydrate and fat. Glucose is stored as glycogen in the liver and fat as triglycerides in adipose tissue, but protein is not stored as such. When the need arises, the body breaks down its working and structural proteins and uses the amino acids for energy or glucose. Thus, over time, energy deprivation (fasting or starvation) always causes wasting of lean body tissue as well as fat loss. An adequate supply of carbohydrates and fats spares amino acids from being used for energy and allows them to perform their unique roles.

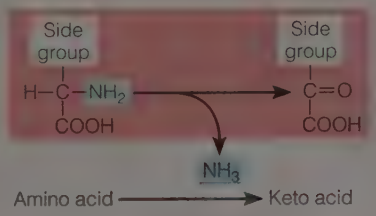
Using Amino Acids to Make Fat Amino acids may be converted to fat when energy and protein intakes exceed needs and carbohydrate intake is adequate. In this way, protein-rich foods can contribute to weight gain.

Deaminating Amino Acids When amino acids are broken down (as occurs when they are used for energy or to make glucose or fat), they are first deaminated—stripped of their nitrogen-containing amino groups (see Figure 6-11). Two products result from **deamination:** one is **ammonia** (NH_3); the other product is the carbon structure without its amino group—often a **keto acid.** Keto acids may enter a number of metabolic pathways—for example, they may be used for energy or for the production of glucose, ketones, cholesterol, or fat.* They may also be used to make nonessential amino acids.

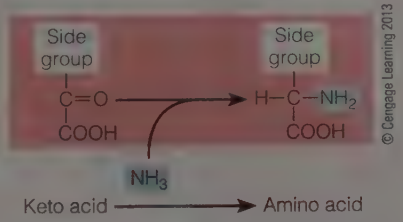
Using Amino Acids to Make Proteins and Nonessential Amino Acids As mentioned, cells can assemble amino acids into the proteins they need to do their work. If an essential amino acid is missing, the body may break down some of its own proteins to obtain it. If a particular nonessential amino acid is not readily available, cells can make it from a keto acid—if a nitrogen source is available. Cells can also make a nonessential amino acid by transferring an amino group from one amino acid to its corresponding keto acid, as shown in Figure 6-12. Through many such **transamination** reactions, involving many different keto acids, the liver cells can synthesize the nonessential amino acids.

Converting Ammonia to Urea As mentioned earlier, deamination produces ammonia. Ammonia is a toxic compound chemically identical to the strong-smelling ammonia in bottled cleaning solutions. Because ammonia is a base, excessive

> FIGURE 6-11 Deamination and Synthesis of a Nonessential Amino Acid

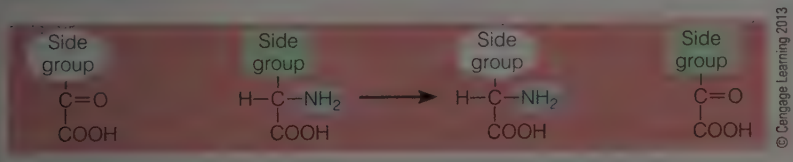


The deamination of an amino acid produces ammonia (NH_3) and a keto acid.



Given a source of NH_3, the body can make nonessential amino acids from keto acids.

> FIGURE 6-12 Transamination and Synthesis of a Nonessential Amino Acid



The body can transfer amino groups (NH_2) from an amino acid to a keto acid, forming a new *nonessential* amino acid and a new keto acid. Transamination reactions require the vitamin B_6 coenzyme.

*Chemists sometimes classify amino acids according to the destinations of their carbon fragments after deamination. If the fragment leads to the production of glucose, the amino acid is called *glucogenic;* if it leads to the formation of ketone bodies, fats, and sterols, the amino acid is called *ketogenic.* There is no sharp distinction between glucogenic and ketogenic amino acids, however. A few are both, most are considered glucogenic, only one (leucine) is clearly ketogenic.

serotonin: a neurotransmitter important in sleep regulation, appetite control, and sensory perception, among other roles. Serotonin is synthesized in the body from the amino acid tryptophan with the help of vitamin B_6.

deamination (dee-AM-ih-NAY-shun) removal of the amino (NH_2) group from a compound such as an amino acid.

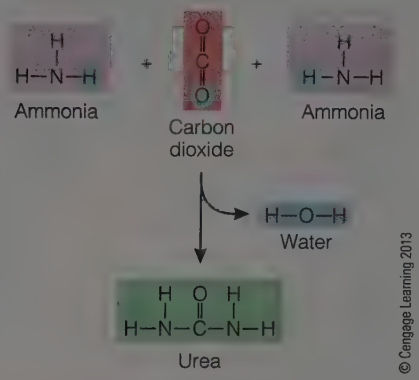
ammonia: a compound with the chemical formula NH_3; produced during the deamination of amino acids.

keto (KEY-toe) **acid:** an organic acid that contains a carbonyl group (C=O).

transamination (TRANS-am-ih-NAY-shun): the transfer of an amino group from one amino acid to a keto acid, producing a new nonessential amino acid and a new keto acid.

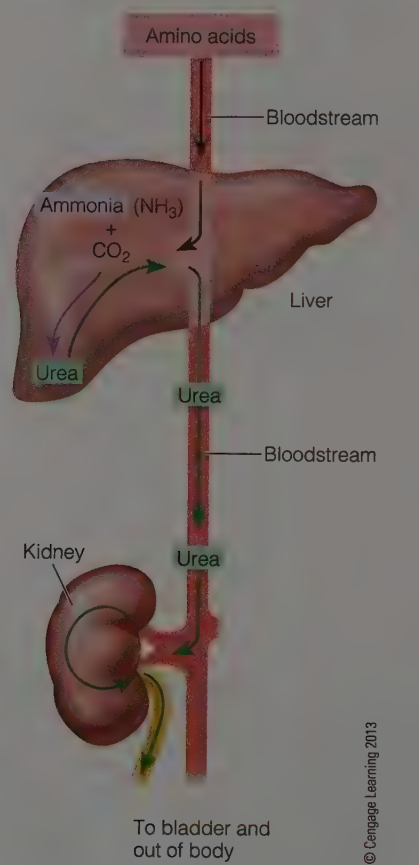
> FIGURE 6-13 Urea Synthesis

Ammonia is produced when amino acids are deaminated. The liver detoxifies ammonia by combining it with another waste product, carbon dioxide, to produce urea. See Appendix C for details.



> FIGURE 6-14 Urea Excretion

When amino acids are deaminated (stripped of their nitrogen), ammonia is released. The liver converts ammonia to urea, and the kidneys excrete urea. In this way the body disposes of excess nitrogen. (Figure 12-2 provides details of how the kidneys work.)



urea (you-REE-uh): the principal nitrogen-excretion product of protein metabolism. Two ammonia fragments are combined with carbon dioxide to form urea.

quantities upset the blood's critical acid-base balance. To prevent such a crisis, the liver combines ammonia with carbon dioxide to make **urea**, a much less toxic compound. Figure 6-13 provides a greatly oversimplified diagram of urea synthesis; details are shown in Appendix C. The production of urea increases as dietary protein increases, until production hits its maximum rate at intakes approaching 250 grams per day. (For perspective, the average daily intake of protein in the United States is 78 grams.[3])

Excreting Urea Liver cells release urea into the blood, where it circulates until it passes through the kidneys (see Figure 6-14). The kidneys then filter urea out of the blood for excretion in the urine. Normally, the liver efficiently captures all the ammonia, makes urea from it, and releases the urea into the blood; then the kidneys clear all the urea from the blood. This division of labor allows easy diagnosis of diseases of both organs. In liver disease, blood ammonia is high; in kidney disease, blood urea is high.

Urea is the body's principal vehicle for excreting unused nitrogen, and the amount of urea produced increases with protein intake. To keep urea in solution, the body needs water. For this reason, a person who regularly consumes a high-protein diet (say, 100 grams a day or more) must drink plenty of water to dilute and excrete urea from the body. Without extra water, a person on a high-protein diet risks dehydration because the body uses its water to rid itself of urea. This explains some of the water loss that accompanies high-protein diets. Such losses may make high-protein diets *appear* to be effective, but water loss, of course, is of no value to the person who wants to lose body fat (as Highlight 8 explains).

REVIEW IT Describe how the body makes proteins and uses them to perform various roles.

Cells synthesize proteins according to genetic information that dictates the sequence in which amino acids are linked together. Each protein plays a specific role. Table 6-3 summarizes some of the many roles proteins play and conveys a sense of the immense variety and importance of proteins in the body.

Proteins are constantly being synthesized and broken down as needed. The body's assimilation of amino acids into proteins and its release of amino acids via protein breakdown and excretion can be tracked by measuring nitrogen balance, which should be positive during growth and steady in adulthood. An energy deficit or an inadequate protein intake may force the body to use amino acids as fuel, creating a negative nitrogen balance. Protein eaten in excess of need is broken down and stored as body fat.

TABLE 6-3 Protein Functions in the Body

Structural materials	Proteins form integral parts of most body tissues and provide strength and shape to skin, tendons, membranes, muscles, organs, and bones.
Enzymes	Proteins facilitate chemical reactions.
Hormones	Proteins regulate body processes. (Some, but not all, hormones are proteins.)
Fluid balance	Proteins help to maintain the volume and composition of body fluids.
Acid-base balance	Proteins help to maintain the acid-base balance of body fluids by acting as buffers.
Transportation	Proteins transport substances, such as lipids, vitamins, minerals, and oxygen, around the body.
Antibodies	Proteins inactivate foreign invaders, thus protecting the body against diseases.
Energy and glucose	Proteins provide some fuel, and glucose if needed, for the body's energy needs.
Other	The protein fibrin creates blood clots; the protein collagen forms scars; the protein opsin participates in vision.

© Cengage Learning 2013

6.4 Protein in Foods

LEARN IT Explain the differences between high-quality and low-quality proteins, including notable food sources of each.

In the United States and other countries where nutritious foods are abundant, most people eat protein in such large quantities that they receive all the amino acids they need. In countries where food is scarce and the people eat only marginal amounts of protein-rich foods, however, the *quality* of the protein becomes crucial.

Protein Quality

The protein quality of the diet determines, in large part, how well children grow and how well adults maintain their health. Put simply, **high-quality proteins** provide enough of all the essential amino acids needed to support the body's work, and low-quality proteins don't. Two factors influence protein quality—the protein's digestibility and its amino acid composition.

Digestibility

As explained earlier, proteins must be digested before they can provide amino acids. **Protein digestibility** depends on such factors as the protein's source and the other foods eaten with it. The digestibility of most animal proteins is high (90 to 99 percent); plant proteins are less digestible (70 to 90 percent for most, but more than 90 percent for soy and legumes).

Amino Acid Composition

To make proteins, a cell must have all the needed amino acids available simultaneously. The liver can make any nonessential amino acid that may be in short supply so that the cells can continue linking amino acids into protein strands. If an essential amino acid is missing, though, a cell must dismantle its own proteins to obtain it. Therefore, to prevent protein breakdown in the body, dietary protein must supply at least the nine essential amino acids plus enough nitrogen-containing amino groups and energy for the synthesis of the nonessential ones. If the diet supplies too little of any essential amino acid, protein synthesis will be limited. The body makes whole proteins only; if one amino acid is missing, the others cannot form a "partial" protein. An essential amino acid supplied in less than the amount needed to support protein synthesis is called a **limiting amino acid.**

Reference Protein

The quality of a food protein is determined by comparing its amino acid composition with the essential amino acid requirements of preschool-age children. Such a standard is called a **reference protein.** The rationale behind using the requirements of this age group is that if a protein will effectively support a young child's growth and development, then it will meet or exceed the requirements of older children and adults.

High-Quality Proteins

As mentioned earlier, a high-quality protein contains all the essential amino acids in relatively the same amounts and proportions that human beings require; it may or may not contain all the nonessential amino acids. Proteins that are low in an essential amino acid cannot, by themselves, support protein synthesis. Generally, foods derived from animals (meat, seafood, poultry, eggs, and milk and milk products) provide high-quality proteins, although gelatin is an exception. Gelatin lacks tryptophan and cannot support growth and health as a diet's sole protein. Proteins from plants (vegetables, nuts, seeds, grains, and legumes) have more diverse amino acid patterns and tend to be limiting in one or more essential amino acids. Some plant proteins are notoriously low quality (for example, corn protein). A few others are high quality (for example, soy protein).

Researchers have developed several methods for evaluating the quality of food proteins and identifying high-quality proteins. Appendix D provides details.

Complementary Proteins

In general, plant proteins are lower quality than animal proteins, and plants also offer less protein (per weight or measure of food). For this reason, many vegetarians improve the quality of proteins in their diets by combining plant-protein foods that have different but complementary amino acid

high-quality proteins: dietary proteins containing all the essential amino acids in relatively the same amounts that human beings require. They may also contain nonessential amino acids.

protein digestibility: a measure of the amount of amino acids absorbed from a given protein intake.

limiting amino acid: the essential amino acid found in the shortest supply relative to the amounts needed for protein synthesis in the body. Four amino acids are most likely to be limiting:

- Lysine
- Methionine
- Threonine
- Tryptophan

reference protein: a standard against which to measure the quality of other proteins.



© Polara Studios, Inc.

Black beans and rice, a favorite Hispanic combination, together provide a balanced array of amino acids.

patterns. This strategy yields **complementary proteins** that together contain all the essential amino acids in quantities sufficient to support health. The protein quality of the combination is greater than either food alone (see Figure 6-15).

Many people have long believed that combining plant proteins at every meal is critical to protein nutrition. For most healthy vegetarians, though, it is *not* necessary to balance amino acids at each meal if protein intake is varied and energy intake is sufficient.[4] Vegetarians can receive all the amino acids they need over the course of a day by eating a variety of whole grains, legumes, seeds, nuts, and vegetables. Protein deficiency will develop, however, when fruits and certain vegetables make up the core of the diet, severely limiting both the *quantity* and *quality* of protein. Highlight 2 describes how to plan a nutritious vegetarian diet.

REVIEW IT Explain the differences between high-quality and low-quality proteins, including notable food sources of each.

A diet that supplies all of the essential amino acids in adequate amounts ensures protein synthesis. The best guarantee of amino acid adequacy is to eat foods containing high-quality proteins or mixtures of foods containing complementary proteins that can each supply the amino acids missing in the other. In addition to its amino acid content, the quality of protein is measured by its digestibility and its ability to support growth. Such measures are of great importance in dealing with malnutrition worldwide, but in countries where protein deficiency is not common, the protein quality of individual foods deserves little emphasis.

FIGURE 6-15 Complementary Proteins

In general, legumes provide plenty of isoleucine (Ile) and lysine (Lys) but fall short in methionine (Met) and tryptophan (Trp). Grains have the opposite strengths and weaknesses, making them a perfect match for legumes.

	Ile	Lys	Met	Trp
Legumes	✓	✓		
Grains			✓	✓
Together	✓	✓	✓	✓

© Cengage Learning 2013

6.5 Health Effects and Recommended Intakes of Protein

LEARN IT Identify the health benefits of, and recommendations for, protein.

As you know by now, protein is indispensable to life. This section examines the health effects and recommended intakes of protein.

Health Effects of Protein It should come as no surprise that protein deficiency can have devastating effects on people's health. But like the other nutrients, protein in excess can also be harmful. High-protein diets have been implicated in several chronic diseases, including heart disease, cancer, osteoporosis, obesity, and kidney stones, but evidence is insufficient to establish an Upper Level (UL).[5]

Protein Deficiency In protein deficiency, as occurs when the diet supplies too little protein or lacks a specific essential amino acid relative to the others (a limiting amino acid), the synthesis of body proteins decreases and degradation increases to provide the needed amino acids. Without proteins to perform their critical roles, many of the body's activities come to a halt. The consequences of protein deficiency include slowed growth, impaired brain and kidney functions, poor immunity, and inadequate nutrient absorption.

The term *protein-energy malnutrition* has traditionally been used to describe the condition that develops when the diet delivers too little protein, too little energy, or both. The causes and consequences are complex, but clearly, such malnutrition reflects insufficient food intake. Importantly, not only are protein and energy inadequate, but so are many, if not all, of the vitamins and minerals. For this reason, severe malnutrition and its clinical forms—marasmus and kwashiorkor—are included in Chapter 20's discussion of world hunger.

Heart Disease In the United States and other developed countries, protein is so abundant that problems of excess are more common than deficiency. A high-protein diet may contribute to the progression of heart disease. As Chapter 5 mentions, foods rich in animal protein also tend to be rich in saturated fats. Consequently, it is not surprising to find a correlation between animal-protein intake (red meats and milk products) and heart disease.[6] On the other hand, substituting vegetable protein for animal protein may improve blood pressure and blood lipids and decrease heart disease mortality.[7]

complementary proteins: two or more dietary proteins whose amino acid assortments complement each other in such a way that the essential amino acids missing from one are supplied by the other.

Research suggests that elevated levels of the amino acid homocysteine may be an independent risk factor for heart disease, heart attacks, and sudden death in patients with heart disease.[8] Researchers do not yet fully understand the many factors—including a diet high in saturated fatty acids—that can raise homocysteine in the blood or whether elevated levels are a cause or an effect of heart disease.[9] Elevated homocysteine is associated with increased oxidative stress and inflammation. Until researchers can determine the exact role homocysteine plays in heart disease, they are following several leads in pursuit of the answers. Coffee's role in heart disease has been controversial, but research suggests it is among the most influential factors in raising homocysteine, which may explain some of the adverse health effects of heavy consumption. Elevated homocysteine levels are among the many adverse health consequences of smoking cigarettes and drinking alcohol as well. Homocysteine is also elevated with inadequate intakes of B vitamins and can usually be lowered with fortified foods or supplements of vitamin B_{12}, vitamin B_6, and folate.[10] Lowering homocysteine, however, may not help in lowering risks or preventing heart attacks.[11] Supplements of the B vitamins do not always benefit those with heart disease and, in fact, may actually increase risks.[12]

In contrast to homocysteine, the amino acid arginine may help protect against heart disease by lowering blood pressure and homocysteine levels.[13] Additional research is needed to confirm the benefits of arginine. In the meantime, it is unwise for consumers to use supplements of arginine, or any other amino acid for that matter (as pp. 186–187 explain). Physicians, however, may consider the benefits of adding arginine supplements to their heart patients' treatment plan.

Cancer Protein does not seem to increase the risk of cancer, but some protein-rich foods do. For example, evidence suggests a strong correlation between high intakes of red meat and processed meats with cancer of the colon.[14]* Chapter 18 discusses dietary links with cancer, and Chapter 19 presents food safety issues of processed meats.

Adult Bone Loss (Osteoporosis) Chapter 12 presents calcium metabolism, and Highlight 12 elaborates on the main factors that influence osteoporosis. This section briefly describes the relationships between protein intake and bone loss. When protein intake is high, calcium excretion increases. Whether excess protein depletes the bones of their chief mineral may depend upon the ratio of calcium intake to protein intake. After all, bones need both protein and calcium. An ideal ratio has not been determined, but a young woman whose intake meets recommendations for both nutrients has a calcium-to-protein ratio of more than 20 to 1 (milligrams to grams), which probably provides adequate protection for the bones. For most women in the United States, however, average calcium intakes are lower and protein intakes are higher, yielding a 9-to-1 ratio, which may produce calcium losses significant enough to compromise bone health. In other words, the problem may reflect too little calcium, not too much protein. In establishing recommendations, the DRI Committee considered protein's effect on calcium metabolism and bone health, but it did not find sufficient evidence to warrant an adjustment for calcium or a UL for protein.[15]

Some (but not all) research suggests that animal protein may be more detrimental to calcium metabolism and bone health than vegetable protein. Importantly, adequate protein does not harm bones and may even improve bone mineral density, whereas *inadequate* intakes of protein may compromise bone health.[16] Osteoporosis is particularly common in elderly women and in adolescents with anorexia nervosa—groups who typically receive less protein than they need. For these people, increasing protein intake may be just what they need to protect their bones.[17]

Weight Control Fad weight-loss diets that encourage a high-protein, low-carbohydrate diet may be effective, but only because they are low-kcalorie diets. Diets that provide adequate protein (at least 65 to 70 grams a day), moderate fat, and sufficient energy

*Processed meats include ham, bacon, pastrami, salami, sausage, bratwurst, and hot dogs that have been preserved by smoking, curing, salting, or adding preservatives.

from carbohydrates can better support weight loss and good health. Including protein at each meal may help with weight loss by providing satiety.[18] Selecting too many protein-rich foods may crowd out fruits, vegetables, and whole grains, making the diet inadequate in other nutrients.

Kidney Disease Excretion of the end products of protein metabolism depends, in part, on an adequate fluid intake and healthy kidneys. A high protein intake does not cause kidney disease, but it does increase the work of the kidneys.[19] It may also accelerate kidney deterioration in people with chronic kidney disease. Restricting dietary protein may help to slow the progression of kidney disease in people who have this condition.

Recommended Intakes of Protein

As mentioned earlier, the body continuously breaks down and loses some protein and it cannot store proteins or amino acids. To replace protein, the body needs dietary protein for two reasons. First, dietary protein is the only source of the *essential* amino acids, and second, it is the only practical source of *nitrogen* with which to build the nonessential amino acids and other nitrogen-containing compounds the body needs.

Given recommendations that fat should contribute 20 to 35 percent of total food energy and carbohydrate should contribute 45 to 65 percent, that leaves 10 to 35 percent for protein. In a 2000-kcalorie diet, that represents 200 to 700 kcalories from protein, or 50 to 175 grams. Average intakes in the United States and Canada fall within this range.

♦ RDA for protein:
- 0.8 g/kg/day
- 10 to 35% of energy intake

Protein RDA The protein RDA ♦ for adults is 0.8 grams per kilogram of healthy body weight per day. For infants and children, the RDA is slightly higher. The table on the inside front cover lists the RDA for males and females at various ages in two ways—grams per day based on reference body weights and grams per kilogram of body weight per day. Some evidence suggests that intakes greater than the protein RDA may be beneficial.[20]

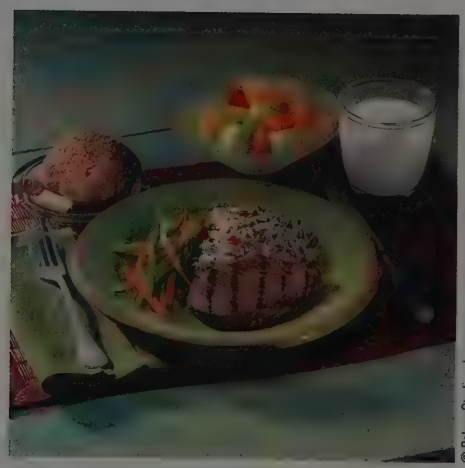
The RDA covers the needs for replacing worn-out tissue, so it increases for larger people; it also covers the needs for building new tissue during growth, so it increases for infants, children, adolescents, and pregnant and lactating women. The accompanying "How To" feature explains how to calculate your RDA for protein.

♦ Protein recommendations for athletes: 1.2–1.7 g/kg/day

The protein RDA is the same for athletes as for others, even though athletes may need more protein and many fitness authorities recommend a higher range of protein intakes for athletes pursuing different activities ♦ (see Table 14-5 in Chapter 14 for details).[21] Most athletes in training typically don't need to actually increase their protein intakes, however, because the additional foods they eat to meet their high energy needs deliver protein as well. Importantly, these higher recommendations still fall within the 10 to 35 percent Acceptable Macronutrient Distribution Range (AMDR).

In setting the RDA, the DRI Committee assumes that people are healthy and do not have unusual metabolic needs for protein, that the protein eaten will be of mixed quality (from both high- and low-quality sources), and that the body will use the protein efficiently. In addition, the committee assumes that the protein is consumed along with sufficient carbohydrate and fat to provide adequate energy and that other nutrients in the diet are also adequate.

Adequate Energy Note the qualification "adequate energy" in the preceding statement, and consider what happens if energy intake falls short of needs. An intake of 50 grams of protein provides 200 kcalories, which represents 10 percent of the total energy from protein, if the person receives 2000 kcalories a day. But if the person cuts energy intake drastically—to, say, 800 kcalories a day—then an intake of 200 kcalories from protein is suddenly 25 percent of the total; yet it's still the same amount of protein (number of grams). The protein intake is reasonable, but the energy intake is not. The low energy intake forces the body to use the protein to meet energy needs rather than to replace lost body protein. Similarly, if the person's energy intake is high—say, 4000 kcalories—the 50 gram



© Polara Studios, Inc.

For many people, this 5-ounce steak provides almost all of the meat and much of the protein recommended for a day's intake.

>How To

Calculate Recommended Protein Intakes

To figure your protein RDA:

- Look up the healthy weight for a person of your height (inside back cover). If your present weight falls within that range, use it for the following calculations. If your present weight falls outside the range, use the midpoint of the healthy weight range as your reference weight.
- Convert pounds to kilograms, if necessary (pounds divided by 2.2 equals kilograms).
- Multiply kilograms by 0.8 to get your RDA in grams per day. (Teens 14 to 18 years old, multiply by 0.85.) Example:

Weight = 150 lb

150 lb ÷ 2.2 lb/kg = 68 kg (rounded off)

68 kg × 0.8 g/kg = 54 g protein (rounded off)

TRY IT Calculate your protein RDA.

protein intake represents only 5 percent of the total; yet it *still* is a reasonable protein intake. Again, the energy intake is unreasonable for most people, but in this case, it permits the protein to be used to meet the body's needs.

Be careful when judging protein (or carbohydrate or fat) intake as a percentage of energy. Always consider the number of grams as well, and compare it with the RDA or another standard stated in grams. A recommendation stated as a percentage of energy intake is useful only if the energy intake is within reason.

From Guidelines to Groceries A diet following the USDA Food Patterns can easily supply the recommended amount of protein. In selecting foods for protein, keep in mind the principles of variety and moderation.

Protein Foods An ounce of most protein foods delivers about 7 grams of protein. The USDA Food Patterns encourage a variety by sorting protein foods into three subgroups (review Figure 2-2, p. 43 and Table 2-4, p. 44). Over a week's time, the total recommended intake of protein foods should be about 20 percent from seafood; almost 70 percent from meat, poultry, and eggs; and 10 percent from nuts, seeds, and legumes.

Either plant or animal sources of protein can support a healthy eating pattern, but some protein foods—notably those derived from animals—may be high in saturated fat. To minimize saturated fat intake, select lean meats and poultry. Trim fat from meats before cooking and drain fat from meat after cooking. Remove skin from poultry before eating. Include plant sources of protein as well. By select a variety of protein foods, consumers can improve their nutrient intake and incur health benefits. For example, Highlight 5 describes how nuts and fish can reduce the risks of heart disease when consumed in place of other protein foods.



> DIETARY GUIDELINES FOR AMERICANS 2010

Choose a variety of foods from the protein foods group, which includes seafood, lean meat and poultry, eggs, beans and peas, soy products, and unsalted nuts and seeds. Increase the amount and variety of seafood consumed by choosing seafood in place of some meat and poultry. Replace protein foods that are higher in solid fats with choices that are lower in solid fats and kcalories.

Milk and Milk Products The only other food group to provide significant amounts of protein per serving is the milk and milk products group. A serving (a cup) of milk or yogurt provides about 8 grams of protein.



© Polara Studios, Inc.

Vegetarians obtain their protein from whole grains, legumes, nuts, vegetables, and, in some cases, eggs and milk products.

Fruits, Vegetables, and Grains Fruits do not contain protein. A serving of vegetables or grains provides 2 to 3 grams of protein, respectively.

♦ Daily Value:
- 50 g protein (based on 10% of 2000 kcal diet)

Read Food Labels

Food labels state the quantity of protein in grams. The "% Daily Value" ♦ for protein is not mandatory on all labels but is required whenever a food makes a protein claim or is intended for consumption by children younger than 4 years old.* Whenever the Daily Value percentage is declared, researchers must determine the *quality* of the protein. Thus, when a % Daily Value is stated for protein, it reflects both quantity and quality.

To illustrate how easy it is to get enough protein, consider the amounts recommended by the USDA Food Pattern for a 2000-kcalorie diet. Six ounces of grains provide about 18 grams of protein; 2½ cups of vegetables deliver about 10 grams; 3 cups of milk offer 24 grams; and 5½ ounces of protein foods supply 38 grams. This totals 90 grams of protein—higher than the protein RDA for most people and yet still lower than the average intake of people in the United States.

People in the United States and Canada typically get more protein than they need. If they have an adequate *food* intake, they have a more-than-adequate protein intake. The key diet-planning principle to emphasize for protein is moderation. Even though most people receive plenty of protein, some feel compelled to take supplements as well, as the next section describes.

Protein and Amino Acid Supplements

Websites, health-food stores, and popular magazine articles advertise a wide variety of protein supplements, and people take these supplements for many different reasons. Athletes take protein powders to build muscle. Dieters take them to spare their bodies' protein while losing weight. Women take them to strengthen their fingernails. People take individual amino acids, too—to cure herpes, to make themselves sleep better, to lose weight, and to relieve pain and depression.** Like many other magic solutions to health problems, protein and amino acid supplements don't work these miracles.

Protein Powders Because the body builds muscle protein from amino acids, many athletes take protein powders with the false hope of stimulating muscle growth. Muscle work builds muscle; protein supplements do not, and athletes do not need them. Getting enough protein to support protein synthesis in the muscles is certainly important, but ingesting "more than enough" protein does not further enhance muscle growth or function.[22] (Highlight 14 presents more information on other supplements athletes commonly use.) Protein powders can supply amino acids to the body, but nature's protein sources—lean meat, milk, eggs, and legumes—supply all these amino acids and more.

Whey protein appears to be particularly popular among athletes hoping to achieve greater muscle gains. A waste product of cheese manufacturing, whey protein is a common ingredient in many low-cost protein powders. When combined with strength training, whey supplements may increase protein synthesis slightly, but they do not seem to enhance athletic performance. To build stronger muscles, athletes need to eat food with adequate energy and protein to support the weight-training work that does increase muscle mass. Those who still think they need more whey can drink a glass of milk; one cup provides 1.5 grams of whey.

Amino Acid Supplements Single amino acids do not occur naturally in foods and offer no benefit to the body; in fact, they may be harmful. The body was not designed to handle the high concentrations and unusual combinations of amino acids found in supplements. Large doses of amino acids cause diarrhea. An excess of

whey protein: a by-product of cheese production; falsely promoted as increasing muscle mass. Whey is the watery part of milk that separates from the curds.

*For labeling purposes, the Daily Values for protein are as follows: for infants, 14 grams; for children younger than age 4, 16 grams; for older children and adults, 50 grams; for pregnant women, 60 grams; and for lactating women, 65 grams.

**Canada requires single amino acid supplements to be sold as drugs; they are, however, allowed to be used as food additives.

one amino acid can create such a demand for a carrier that it limits the absorption of another amino acid, presenting the possibility of a deficiency. Those amino acids winning the competition enter in excess, creating the possibility of toxicity.[23] Toxicity of single amino acids in animal studies raises concerns about their use in human beings. Anyone considering taking amino acid supplements should be cautious not to exceed levels normally found in foods.[24]

Most healthy athletes eating well-balanced diets do not need amino acid supplements. Advertisers point to research that identifies the **branched-chain amino acids** as the main ones used as fuel by exercising muscles. What the ads leave out is that compared to glucose and fatty acids, branched-chain amino acids provide very little fuel and that ordinary foods provide them in abundance anyway. Large doses of branched-chain amino acids can raise plasma ammonia concentrations, which can be toxic to the brain. Branched-chain amino acid supplements may be beneficial in conditions such as liver disease, but otherwise, they are not routinely recommended.[25]

In two cases, recommendations for single amino acid supplements have led to widespread public use—lysine to prevent or relieve the infections that cause herpes cold sores on the mouth or genital organs, and tryptophan to relieve depression and insomnia. In both cases, enthusiastic popular reports preceded careful scientific experiments and health recommendations. Research is insufficient to determine whether lysine suppresses herpes infections, but it appears safe (up to 3 grams per day) when taken in divided doses with meals.

Tryptophan may be effective with respect to inducing drowsiness, but caution is still advised. About 25 years ago, more than 1500 people who elected to take tryptophan supplements developed a rare blood disorder known as eosinophilia-myalgia syndrome (EMS). EMS is characterized by severe muscle and joint pain, extremely high fever, and, in more than three dozen cases, death. Treatment for EMS usually involves physical therapy and low doses of corticosteroids to relieve symptoms temporarily. The Food and Drug Administration implicated impurities in the supplements, issued a recall of all products containing manufactured tryptophan, and warned that high-dose supplements of tryptophan might provoke symptoms of EMS even in the absence of impurities.

REVIEW IT Identify the health benefits of, and recommendations for, protein.
Protein deficiency impairs the body's ability to grow and function optimally. Excesses of protein offer no advantage; in fact, overconsumption of protein-rich foods may incur health problems as well. The optimal diet is adequate in energy from carbohydrate and fat and delivers 0.8 grams of protein per kilogram of healthy body weight each day. US and Canadian diets are typically more than adequate in this respect. Normal, healthy people do not need protein or amino acid supplements.

As is true for the other nutrients as well, it is safest to obtain amino acids and protein from foods, eaten with abundant carbohydrate and some fat to facilitate their use in the body. With all that we know about science, it is hard to improve on nature.

Nutrition Portfolio

Foods that derive from animals—meats, fish, poultry, eggs, and milk products—provide plenty of protein but are often accompanied by fat. Those that derive from plants—whole grains, vegetables, and legumes—may provide less protein but also less fat.

Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Intake Spreadsheet report. Scroll down until you see: protein (g).

- Which of your food choices provided you with the most protein on that day? Does that food also have a lot of fat? Refer to the fat (g) column for this information.

branched-chain amino acids: the essential amino acids leucine, isoleucine, and valine, which are present in large amounts in skeletal muscle tissue; falsely promoted as fuel for exercising muscles.

- Describe your dietary sources of proteins and whether you use mostly plant-based or animal-based protein foods in your diet.

Now take a look at the Intake vs. Goals report.

- How do your protein needs compare with your protein intake? Consider whether you receive enough, but not too much, protein daily. Remember, 100 percent means your intake is meeting your needs based on your intake and profile information.
- If your protein intake exceeds 100 percent, consider the possible negative consequences of a high protein intake over many years.
- Debate the risks and benefits of taking protein or amino acid supplements.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. M. T. Gladwin and E. Vichinsky, Pulmonary complications of sickle cell disease, *New England Journal of Medicine* 359 (2008): 2254–2265.
2. S. Tesseraud and coauthors, Role of sulfur amino acids in controlling nutrient metabolism and cell functions: Implications for nutrition, *British Journal of Nutrition* 101 (2009): 1132–1139; G. Wu, Amino acids: Metabolism, functions, and nutrition, *Amino Acids* 37 (2009): 1–17.
3. US Department of Agriculture, Agricultural Research Service, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville, MD) and US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics (Hyattsville, MD), *What We Eat in America,* NHANES 2007–2008, accessed at www.ars.usda.gov/ba/bhnrc/fsrg, published 2010.
4. Position of the American Dietetic Association and Dietitians of Canada: Vegetarian diets, *Journal of the American Dietetic Association* 109 (2009): 1266–1282.
5. Committee on Dietary Reference Intakes, *Dietary Reference Intakes: Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005), p. 694.
6. S. R. Preis and coauthors, Dietary protein and risk of ischemic heart disease in middle-aged men, *American Journal of Clinical Nutrition* 92 (2010): 1265–1272.
7. D. G. Hackam and coauthors, The 2010 Canadian Hypertension Education Program recommendations for the management of hypertension: Part 2—Therapy, *Canadian Journal of Cardiology* 26 (2010): 249–258.
8. L. L. Humphrey and coauthors, Homocysteine level and coronary heart disease incidence: A systematic review and meta-analysis, *Mayo Clinic Proceedings* 83 (2008): 1203–1212.
9. R. Clarke and coauthors, Homocysteine and vascular disease: Review of published results of the homocysteine-lowering trials, *Journal of Inherited Metabolic Disease* 34 (2011): 83–91.
10. P. Tighe and coauthors, A dose-finding trial of the effect of long-term folic acid intervention: Implications for food fortification policy, *American Journal of Clinical Nutrition* 93 (2011): 11–18.
11. Clarke and coauthors, 2011; S. Eilat-Adar and U. Goldbourt, Nutritional recommendations for preventing coronary heart disease in women: Evidence concerning whole foods and supplements, *Nutrition, Metabolism, and Cardiovascular Disease* 20 (2010): 459–466; A. J. Martí-Carvajal and coauthors, Homocysteine lowering interventions for preventing cardiovascular events, *Cochrane Database of Systematic Reviews* 4 (2009): CD006612.
12. L. Chao-Qiang, *MAT1A* variants are associated with hypertension, stroke, and markers of DNA damage and are modulated by plasma vitamin B-6 and folate, *American Journal of Clinical Nutrition* 91 (2010): 1377–1386; J. M. Armitage and coauthors, Effects of homocysteine-lowering with folic acid plus vitamin B_{12} vs placebo on mortality and major morbidity in myocardial infarction survivors: A randomized trial, *Journal of the American Medical Association* 303 (2010): 2486–2494; M. Ebbing and coauthors, Cancer incidence and mortality after treatment with folic acid and vitamin B_{12}, *Journal of the American Medical Association* 302 (2009): 2119–2126.
13. U. N. Das and coauthors, L-arginine, NO and asymmetrical dimethylarginine in hypertension and type 2 diabetes, *Frontiers in Bioscience* 16 (2011): 13–20; D. Tousoulis and coauthors, Novel therapeutic strategies targeting vascular endothelium in essential hypertension, *Expert Opinion on Investigational Drugs* 19 (2010): 1395–1412.
14. A. T. Chan and E. L. Giovannucci, Primary prevention of colorectal cancer, *Gastroenterology* 138 (2010): 2029–2043.
15. Committee on Dietary Reference Intakes, 2005, p. 841; Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Calcium and Vitamin D* (Washington, D.C.: National Academies Press, 2011).
16. M. P. Thorpe and E. M. Evans, Dietry protein and bone health: Harmonizing conflicting theories, *Nutrition Reviews* 9 (2011): 215–230; J. J. Cao, L. K. Johnson, and J. R. Hunt, A diet high in meat protein and potential renal acid load increases fractional calcium absorption and urinary calcium excretion without affecting markers of bone resorption or formation in postmenopausal women, *Journal of Nutrition* 141 (2011): 391–397; J. M. Beasley and coauthors, Is protein intake associated with bone mineral density in young women? *American Journal of Clinical Nutrition* 91 (2010): 1311–1316; A. L. Darling and coauthors, Dietary protein and bone health: A systematic review and meta-analysis, *American Journal of Clinical Nutrition* 90 (2009): 1674–1692; M. S. Westerterp-Plantenga and coauthors, Dietary protein, weight loss, and weight maintenance, *Annual Review of Nutrition* 29 (2009): 21–41.
17. J. J. Cao and F. H. Nielsen, Acid diet (high-meat protein) effects on calcium metabolism and bone health, *Current Opinion in Clinical Nutrition and Metabolic Care* 13 (2010): 698–702; A. D. Conigrave, E. M. Brown, and R. Rizzoli, Dietary protein and bone health: Roles of amino acid-sensing receptors in the control of calcium metabolism and bone homeostasis, *Annual Review of Nutrition* 28 (2008): 131–155.
18. Westerterp-Plantenga and coauthors, 2009; R. F. Kushner and B. Doerfler, Low-carbohydrate, high-protein diets revisited, *Current Opinion in Gastroenterology* 24 (2008): 198–203.
19. H. Frank and coauthors, Effect of short-term high-protein compared with normal-protein diets on renal hemodynamics and associated variables in healthy young men, *American Journal of Clinical Nutrition* 90 (2009): 1509–1516.
20. R. R. Wolfe and S. L. Miller, The recommended dietary allowance of protein: A misunderstood concept, *Journal of the American Medical Association* 299 (2008): 2891–2893.

21. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine, Nutrition and athletic performance, *Journal of the American Dietetic Association* 109 (2009): 509–527.
22. T. B. Symons and coauthors, A moderate serving of high-quality protein maximally stimulates skeletal muscle protein synthesis in young and elderly subjects, *Journal of the American Dietetic Association* 109 (2009): 1582–1586.
23. Wu, 2009.
24. Committee on Dietary Reference Intakes, *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements* (Washington, D.C.: National Academies Press, 2006), p. 152.
25. S. Takeshita and coauthors, A snack enriched with oral branched-chain amino acids prevents a fall in albumin in patients with liver cirrhosis undergoing chemoembolization for hepatocellular carcinoma, *Nutrition Research* 29 (2009): 89–93; T. Kawaguchi and coauthors, Branched-chain amino acid–enriched supplementation improves insulin resistance in patients with chronic liver disease, *International Journal of Molecular Medicine* (2008): 105–112.

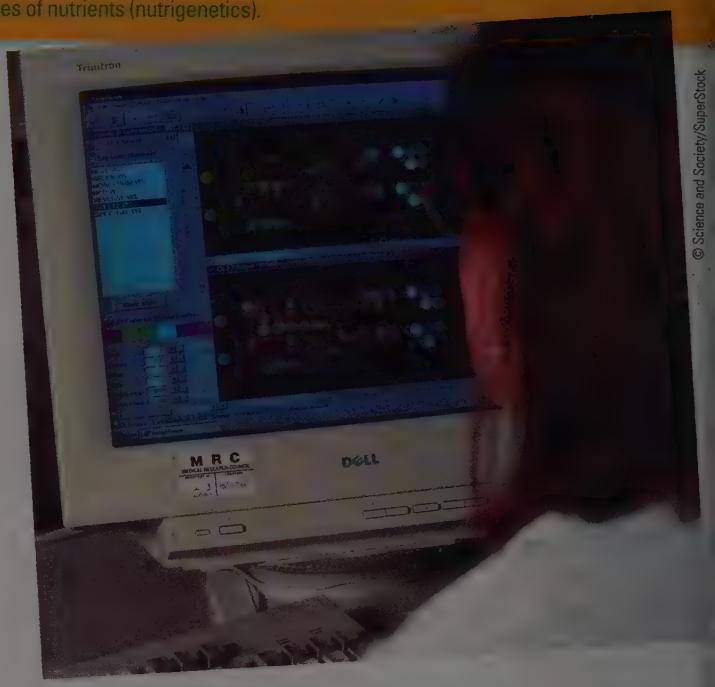
 LEARN IT Explain how nutrients influence gene activity (nutrigenomics) and how genes influence the activities of nutrients (nutrigenetics).

Nutritional Genomics

Imagine this scenario: A physician scrapes a sample of cells from inside your cheek and submits it to a **genomics** lab. The lab returns a report based on your genetic profile that reveals which diseases you are most likely to develop, and your physician recommends specific lifestyle changes and medical treatments that can help you maintain good health. You may also be given a prescription for an individualized diet and dietary supplements that will best meet your personal nutrient requirements. This scenario may one day become a common reality as scientists uncover the relationships among **genetics,** diet, and disease.[1] Such genetic testing holds great promise, but consumers need to know that current genetic test kits commonly available to the public are unproven and may create more problems than they resolve.[2]

Figure H6-1 introduces **nutritional genomics,** a new field of study that examines how nutrients influence gene activity *(nutrigenomics)* and how **genes** influence the activities of nutrients *(nutrigenetics).*[3] The accompanying glossary defines related terms.

The recent surge in genomics research grew from the Human Genome Project, an international effort by industry and government scientists to identify and describe all of the genes in the **human genome**—that is, all the genetic information contained within a person's cells. Completed in 2003, this project developed many of the research technologies needed to study genes and genetic variation. Scientists are now working on the human **proteome** and hope to identify each of the proteins made by the genes, the genes associated with aging and diseases, and the dietary and lifestyle choices that most influence the expression of those genes. Such information will have major implications for society in general, and for health care in particular.[4]



© Science and Society/SuperStock

A Genomics Primer

Figure H6-2 (p. 192) shows the relationships among the materials that comprise the genome. As Chapter 6's discussion of protein synthesis points out, genetic information is encoded in DNA molecules within the nucleus of cells. The **DNA (deoxyribonucleic acid)** molecules and associated proteins are packed within 46 **chromosomes.** The genes are segments of a DNA strand that can eventually be translated into one or more proteins. The sequence of **nucleotide bases** within each gene determines the amino acid sequence of a particular protein. Scientists currently estimate that there are between 20,000 and 25,000 protein-coding genes in the human genome.

As Figure 6-7 (p. 174) explains, when cells make proteins, a DNA sequence is used to make messenger **RNA (ribonucleic acid).** The **nucleotide** sequence in messenger RNA then determines the amino acid sequence to make a protein. This process—from genetic information to protein synthesis—is known as **gene expression.** Gene expression can be determined by measuring the amounts of messenger RNA in a tissue sample. **Microarray technology** (see photo above) allows researchers to detect messenger RNA and analyze the

GLOSSARY

chromosomes: structures within the nucleus of a cell made of DNA and associated proteins. Human beings have 46 chromosomes in 23 pairs. Each chromosome has many genes.

DNA (deoxyribonucleic acid): the double helix molecules of which genes are made.

epigenetics: the study of heritable changes in gene function that occur without a change in the DNA sequence.

gene expression: the process by which a cell converts the genetic code into RNA and protein.

genes: sections of chromosomes that contain the instructions needed to make one or more proteins.

genetics: the study of genes and inheritance.

genomics: the study of all the genes in an organism and their interactions with environmental factors.

human genome (GEE-nome): the complete set of genetic material (DNA) in a human being.

methylation: the addition of a methyl group (CH_3).

microarray technology: research tools that analyze the expression of thousands of genes simultaneously and search for particular gene changes associated with a disease. DNA microarrays are also called *DNA chips.*

mutations: permanent changes in the DNA that can be inherited.

nucleotide bases: the nitrogen-containing building blocks of DNA and RNA—cytosine (C), thymine (T), uracil (U), guanine (G), and adenine (A). In DNA, the base pairs are A–T and C–G and in RNA, the base pairs are A–U and C–G.

nucleotides: the subunits of DNA and RNA molecules, composed of a phosphate group, a 5-carbon sugar (deoxyribose for DNA and ribose for RNA), and a nitrogen-containing base.

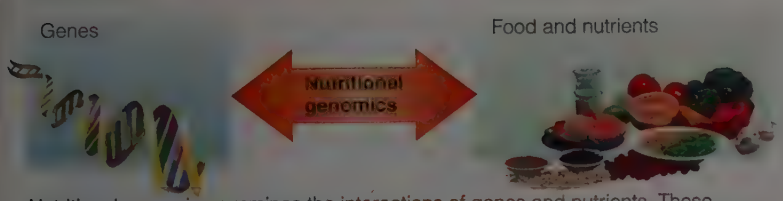
nutritional genomics: the science of how nutrients affect the activities of genes (*nutrigenomics*) and how genes affect the activities of nutrients (*nutrigenetics*).

phenylketonuria (FEN-il-KEY-toe-NEW-ree-ah) or **PKU:** an inherited disorder characterized by failure to metabolize the amino acid phenylalanine to tyrosine.

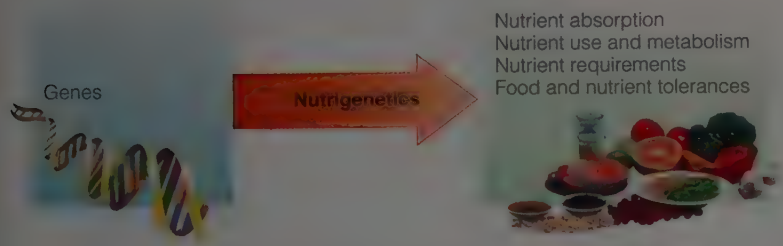
proteome: all proteins in a cell. The study of all proteins produced by a species is called *proteomics.*

RNA (ribonucleic acid): a compound similar to DNA, but RNA is a single strand with a ribose sugar instead of a deoxyribose sugar and uracil instead of thymine as one of its bases.

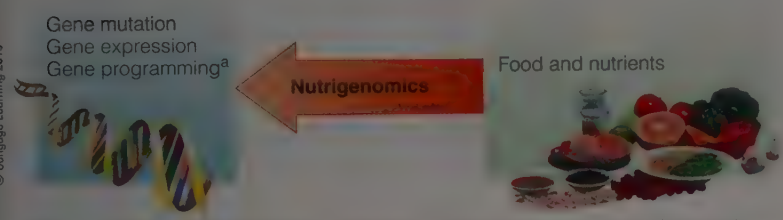
> FIGURE H6-1 Nutritional Genomics



Nutritional genomics examines the interactions of genes and nutrients. These interactions include both nutrigenetics and nutrigenomics.



Nutrigenetics (or nutritional genetics) examines how genes influence the activities of nutrients.



Nutrigenomics, which includes epigenetics, examines how nutrients influence the activities of genes.

[a]Chapter 15 introduces programming and describes how a mother's nutrition can permanently change gene expression in the fetus with consequences for future generations.

© Cengage Learning 2013

expression of thousands of genes simultaneously. These patterns of gene expression help to explain the development of diseases and relationships between diseases.[5]

Simply having a certain gene does not determine that its associated trait will be expressed; the gene has to be activated. (Similarly, owning lamps does not ensure you will have light in your home unless you turn them on.) Nutrients are among many environmental factors that play key roles in either activating or silencing genes. Switching genes on and off does not change the DNA itself, but it can have dramatic consequences for a person's health.

The area of study that examines how environmental factors influence gene expression without changing the DNA is known as **epigenetics.**[6] To turn genes on, enzymes attach proteins near the beginning of a gene. If enzymes attach a methyl group (CH_3) instead, the protein is blocked from binding to the gene and the gene remains switched off. Other factors influence gene expression as well, but methyl groups are currently the most well understood.[7] They also are known to have dietary connections.

The accompanying photo of two mice illustrates epigenetics and how diet can influence genetic traits such as hair color and body weight. Both mice have a gene that tends to produce fat, yellow pups, but their mothers were given different diets during pregnancy. The mother of the mouse on the right was given a dietary supplement containing the B vitamins folate and vitamin B_{12}. These nutrients silenced the gene for "yellow and fat," resulting in brown pups with normal appetites. As Chapter 10 explains, one of the main roles of these B vitamins is to transfer methyl groups. In the case of the supplemented mice, methyl groups migrated onto DNA and silenced several genes, thus producing brown coats and protecting against the development of obesity (and consequently, some related diseases). Keep in mind that these changes occurred epigenetically. In other words, the DNA sequence within the genes of the mice remained the same. Nutrition and other environmental factors can influence genes in a way that creates inheritable changes in the body's metabolism and susceptibility to disease.[8] In this way, the dietary habits of parents, and even grandparents, can influence future generations.

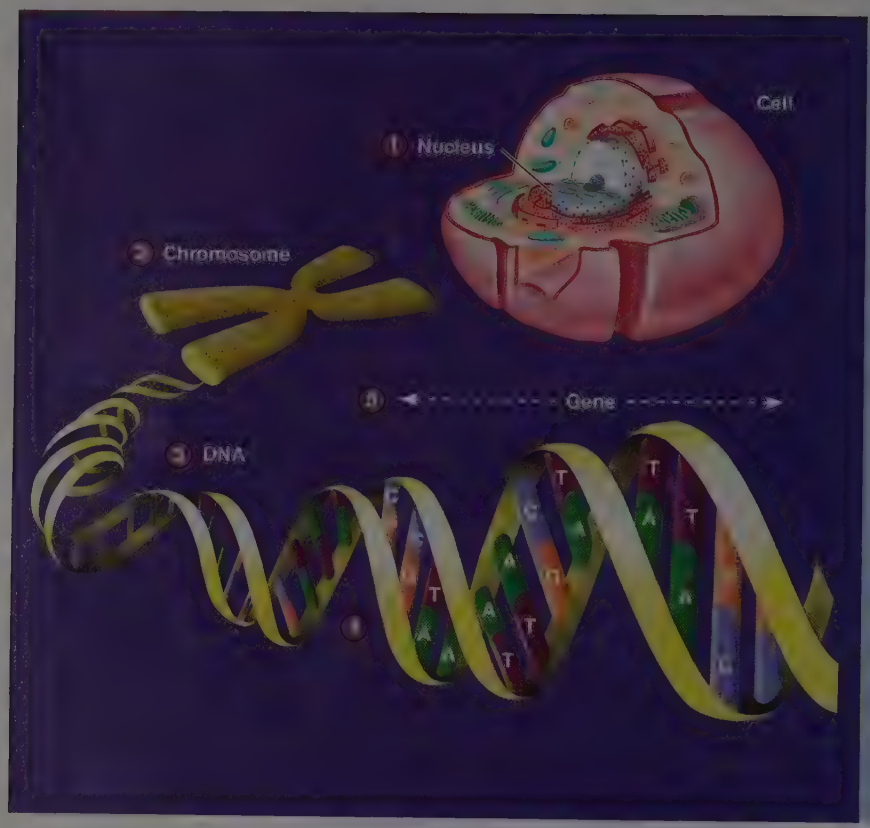
Many nutrients and phytochemicals regulate gene expression and influence health through their involvement in DNA **methylation.**[9] Some, such as folate, silence genes and protect against some cancers by providing methylation.[10] Others, such as a phytochemical found in green tea, activate genes and protect against some cancers by inhibiting methylation activity.[11] Whether silencing or activating a gene is beneficial or harmful depends on what the gene does. Silencing a gene that stimulates cancer growth, for example, would be beneficial, but silencing a gene that suppresses cancer growth would be harmful. Similarly, activating a gene that defends against obesity would be beneficial, but activating a gene that promotes obesity would



© Jirtie and Waterland

Both of these mice have the gene that tends to produce fat, yellow pups, but their mothers had different diets. The mother of the mouse on the right received a dietary supplement, which silenced the gene, resulting in brown pups with normal appetites.

> **FIGURE H6-2 The Human Genome**



1. The human genome is a complete set of genetic material organized into 46 chromosomes, located within the nucleus of a cell.
2. A chromosome is made of DNA and associated proteins.
3. The double helical structure of a DNA molecule is made up of two long chains of nucleotides. Each nucleotide is composed of a phosphate group, a 5-carbon sugar, and a base.
4. The sequence of nucleotide bases (C, G, A, T) determines the amino acid sequence of proteins. These bases are connected by hydrogen bonding to form base pairs—adenine (A) with thymine (T) and guanine (G) with cytosine (C).
5. A gene is a segment of DNA that includes the information needed to synthesize one or more proteins.

© Cengage Learning 2013

SOURCE: Adapted from "A Primer: From DNA to Life," Human Genome Project, US Department of Energy Office of Science, accessed at www.orn.gov/sci/techresources/human_genome/primer-pic.shtml.

be harmful. Figure H6-3 illustrates how nutrient regulation of gene expression can influence a person's health. Much research is under way to determine which nutrients activate or silence which genes. Such knowledge is expected to help researchers reverse the epigenetic changes that lead to cancer.[12] Similarly, researchers exploring how kcalorie-restricted diets influence DNA methylation are gaining new insights on the regulation of appetite and the metabolism of weight loss.[13]

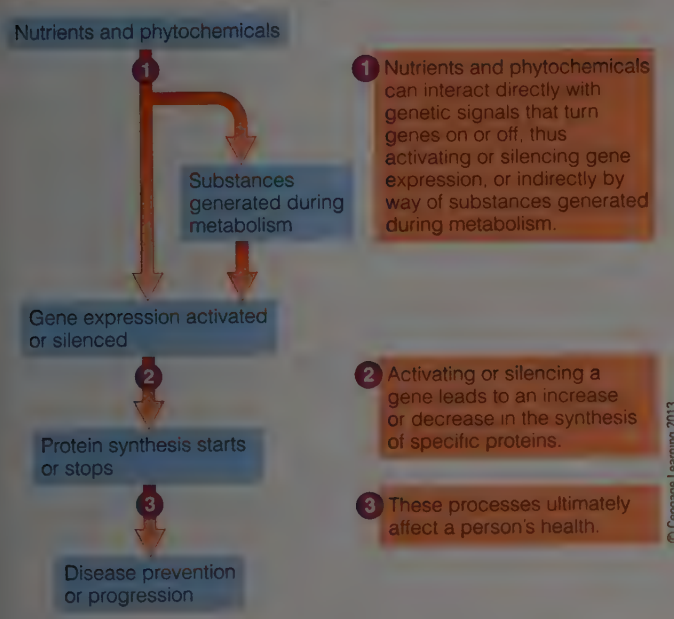
Genetic Variation and Disease

Except for identical twins, no two persons are genetically identical. Even then, a particular gene may become active in one twin and silenced in the other because of epigenetic changes.[14]

The variation in the genomes of any two persons is only about 0.1 percent, a difference of only one nucleotide base in every 1000. Yet it is this incredibly small difference that makes each of us unique and explains why, given the same environmental influences, some of us develop certain diseases and others do not. Similarly, genetic variation explains why some of us respond to interventions such as diet and others do not. For example, following a diet low in saturated fats will significantly lower LDL cholesterol for most people, but the degree of change varies dramatically among individuals, with some people having only a small decrease or even a slight increase. In other words, dietary factors may be more helpful or more harmful depending on a person's particular genetic variations. Such findings help to explain some of the conflicting results from research studies. One of the goals of nutritional genomics is to custom design *specific* recommendations that fit the needs of *each* individual. Such personalized recommendations are expected to provide more effective disease prevention and treatment solutions.

Diseases characterized by a single-gene disorder are genetically predetermined, usually exert their effects early in life, and greatly affect those touched by them; such diseases are relatively rare. The cause and effect of single-gene disorders is clear—those with the genetic defect get the disease and those without it don't. In contrast, the more common diseases, such as heart disease and cancer, are influenced by many genes and typically develop over several decades. These chronic diseases have multiple genetic components that *predispose* the prevention or development of a disease, depending on a variety of environmental factors (such as smoking, diet, and physical activity).[15] Both types of diseases are of interest to researchers studying nutritional genomics.

> **FIGURE H6-3 Nutrient Regulation of Gene Expression**



Single-Gene Disorders

Some disorders are caused by **mutations** in single genes that are inherited at birth. The consequences of a missing or malfunctioning protein can seriously disrupt metabolism and may require significant dietary or medical intervention. A classic example of a diet-related, single-gene disorder is **phenylketonuria,** or **PKU.**

Approximately one in every 15,000 infants in the United States is born with PKU. PKU arises from mutations in the gene that codes for the enzyme that converts the essential amino acid phenylalanine to the amino acid tyrosine. Without this enzyme, phenylalanine and its metabolites accumulate and damage the nervous system, resulting in mental retardation, seizures, and behavior abnormalities. At the same time, the body cannot make tyrosine or compounds made from it (such as the neurotransmitter epinephrine). Consequently, tyrosine becomes an essential amino acid: because the body cannot make it, the diet must supply it.

Although the most debilitating effect is on brain development, other symptoms of PKU become evident if the condition is left untreated. Infants with PKU may have poor appetites and grow slowly. They may be irritable or have tremors or seizures. Their bodies and urine may have a musty odor. Their skin coloring may be unusually pale, and they may develop skin rashes.

The effect of nutrition intervention in PKU is remarkable. In fact, the only current treatment for PKU is a diet that restricts phenylalanine and supplies tyrosine to maintain blood levels of these amino acids within safe ranges. Because all foods containing protein provide phenylalanine, the diet must depend on a special formula to supply a phenylalanine-free source of energy, amino acids, vitamins, and minerals. If the restricted diet is conscientiously followed, the symptoms can be prevented. Because phenylalanine is an essential amino acid, the diet cannot exclude it completely. Children with PKU need phenylalanine to grow, but they cannot handle excesses without detrimental effects. Therefore, their diets must provide enough phenylalanine to support normal growth and health but not enough to cause harm. The diet must also provide tyrosine. To ensure that blood concentrations of phenylalanine and tyrosine are close to normal, children and adults who have PKU must have blood tests periodically and adjust their diets as necessary.

Multigene Disorders

In multigene disorders, several genes can influence the progression of a disease, but no single gene causes the disease on its own.[16] For this reason, genomics researchers must study the expression and interactions of *multiple* genes. Because multigene disorders are often sensitive to interactions with environmental influences, they are not as straightforward as single-gene disorders.

Heart disease provides an example of a chronic disease with multiple gene and environmental influences. Consider that major risk factors for heart disease include elevated blood cholesterol levels, obesity, diabetes, and hypertension. Each of these risk factors has multiple underlying genetic and environmental causes, many of which are not completely understood. Research in nutritional genomics involves coordinating multiple findings on each of these risk factors and explaining the interactions among several genes, biological pathways, and nutrients in relatively little time.[17] Studies have been quite successful in examining the genome and identifying multiple pathways in the development of complex diseases.[18] This information could then guide physicians and dietitians to prescribe the most appropriate medical and dietary interventions from among many possible solutions.[19] Finding the best option for each person is a challenge given the many possible interactions between genes and environmental factors and the millions of possible gene variations in the human genome that make each individual unique.

The results of genomic research are helping to explain findings from previous nutrition research. Consider dietary fat and heart disease, for example. As Highlight 5 explains, epidemiological and clinical studies have found that a diet high in omega-3 polyunsaturated fatty acids benefits heart health. Now genetic studies offer an underlying explanation of this relationship: diets rich in omega-3 polyunsaturated fatty acids alter gene expression of immune cells to suppress inflammation and inhibit plaque build-up.[20] Both actions support a healthy heart.

To learn more about how individuals respond to diet, researchers examine the genetic differences among people. The most common genetic differences involve a change in a single nucleotide base located in a particular region of a DNA strand—thymine replacing cytosine, for example. Such variations are called single nucleotide polymorphisms (SNPs), and they commonly occur throughout the genome. Many SNPs (commonly pronounced "snips") have no effect on cell activity. In fact, SNPs are significant only if they affect the amino acid sequence of a protein in a way that alters its function *and* if that function is critical to the body's well-being. In these cases, SNPs may reveal fascinating answers to previously unexplained findings. Consider that research on a gene that plays a key role in lipid metabolism

reveals differences in a person's response to diet depending on whether the gene has a common SNP. People with the SNP have lower LDL when eating a diet rich in polyunsaturated fatty acids—and higher LDL with a low intake—than those without the SNP.[21] These findings clearly show how diet (in this case, polyunsaturated fat) interacts with a gene (in this case, a fat metabolism gene with a SNP) to influence the development of a disease (changing blood lipids implicated in heart disease).

Clinical Concerns

Because multigene, chronic diseases are common, an understanding of the human genome will have widespread ramifications for health care.[22] This new understanding of the human genome is expected to change health care by:

- Providing knowledge of an individual's genetic predisposition to specific diseases[23]
- Allowing physicians to develop "designer" therapies—prescribing the most effective schedule of screening, behavior changes (including diet), and medical interventions based on each individual's genetic profile
- Enabling manufacturers to create new medications for each genetic variation so that physicians can prescribe the best medicine in the exact dose and frequency to enhance effectiveness and minimize the risks of side effects[24]
- Providing a better understanding of how nutrition influences the biological pathways of diseases[25]

Enthusiasm surrounding genomic research needs to be put into perspective, however, in terms of the present status of clinical medicine as well as people's willingness to make difficult lifestyle choices. Critics have questioned whether genetic markers for disease would be more useful than simple family history and clinical measurements, which reflect both genetic *and* environmental influences. In other words, knowing that a person is genetically predisposed to diabetes is not necessarily more useful than knowing the person's actual risk factors.[26] Furthermore, if a disease has many genetic risk factors, each gene that contributes to susceptibility may have little influence on its own, so the benefits of identifying an individual genetic marker might be small. The long-range possibility is that many genetic markers will eventually be identified, and the hope is that the combined information will be a useful and accurate predictor of disease. Of course, the flood of information may also be overwhelming, offer no benefit, and create anxiety.[27]

Having the knowledge to prevent disease and actually taking action do not always coincide. Despite the abundance of current dietary recommendations, many people are unwilling to make behavior changes known to improve their health—especially when they can simply blame their genes.[28] For example, it has been estimated that heart disease and type 2 diabetes are 90 percent preventable when people adopt an appropriate diet, maintain a healthy body weight, and exercise regularly. Yet these two diseases remain among the leading causes of death. Given the difficulty that many people have with current recommendations, it may be unrealistic to expect that they will enthusiastically adopt an even more detailed list of lifestyle modifications. Then again, compliance may be better when it is supported by information based on a person's own genetic profile and the knowledge that the epigenetic profile can be changed.

The debate over nature versus nurture—whether genes or the environment are more influential—has quieted. The focus has shifted. Scientists acknowledge the important roles of each and understand the real answers lie within the myriad interactions. Current research is sorting through how nutrients and other dietary factors interact with genes to confer health benefits or risks. Answers from genomic research may not become apparent for years to come, but the opportunities and rewards may prove well worth the efforts.

REFERENCES

1. W. G. Feero, A. E. Guttmacher, and F. S. Collins, Genomic medicine: An updated primer, *New England Journal of Medicine* 362 (2010): 2001–2011.
2. Government Accountability Office, *Direct-to-consumer genetic tests: Misleading test results are further complicated by deceptive marketing and other questionable practices*, GAO-10-847T (Washington D.C.: July 22, 2010); J. P. Annes, M. A. Giovanni, and M. F. Murray, Risks of presymptomatic direct-to-consumer genetic testing, *New England Journal of Medicine* 363 (2010): 1100–1101; L. Esserman and V. Kaklamani, Lessons learned from genetic testing, *Journal of the American Medical Association* 304 (2010): 1011–1012; J. P. Evans, D. C. Dale, and C. Fomous, Preparing for a consumer-driven genomic age, *New England Journal of Medicine* 363 (2010): 1099–1103; A. L. McGuire and W. Burke, An unwelcome side effect of direct-to-customer personal genome testing: Raiding the medical commons, *Journal of the American Medical Association* 300 (2008): 2669–2671.
3. P. J. Stover and M. A. Caudill, Genetic and epigenetic contributions to human nutrition and health: Managing genome-diet interactions, *Journal of the American Dietetic Association* 108 (2008): 1480–1487.
4. H. Varmus, Ten years on: The human genome and medicine, *New England Journal of Medicine* 362 (2010): 2028–2029; R. Raqib and A. Cravioto, Nutrition, immunology, and genetics: Future perspectives, *Nutrition Reviews* 67 (2009): S227–S236; A. P. Feinberg, Epigenetics at the epicenter of modern medicine, *Journal of the American Medical Association* 299 (2008): 1345–1350.
5. M. P. Keller and A. D. Attie, Physiological insights gained from gene expression analysis in obesity and diabetes, *Annual Review of Nutrition* 30 (2010): 341–364; M. I. McCarthy, Genomics, type 2 diabetes, and obesity, *New England Journal of Medicine* 363 (2010): 2339–2350.
6. S. W. Choi and S. Friso, Epigenetics: A new bridge between nutrition and health, *Advances in Nutrition* 1 (2010): 8–16; G. P. Kauwell, Epigenetics: What it is and how it can affect dietetics practice, *Journal of the American Dietetic Association* 108 (2008): 1056–1059.
7. M. Esteller, Epigenetics in cancer, *New England Journal of Medicine* 358 (2008): 1148–1159.
8. S. A. Ross and coauthors, Introduction: Diet, epigenetic events and cancer prevention, *Nutrition Reviews* 66 (2008): S1–S6.
9. M. P. Lee and B. K. Dunn, Influence of genetic inheritance on global epigenetic states and cancer risk prediction with DNA methylation signature: Challenges in technology and data analysis, *Nutrition Reviews* 66 (2008): S69–S72.

10. C. M. Ulrich, M. C. Reed, and H. F. Nijhout, Modeling folate, one-carbon metabolism, and DNA methylation, *Nutrition Reviews* 66 (2008): S27–S30.
11. C. S. Yang and coauthors, Reverse of hypermethylation and reactivation of genes by dietary polyphenolic compounds, *Nutrition Reviews* 66 (2008): S18–S20.
12. S. Sharma, T. K. Kelly, and P. A. Jones, Epigenetics in cancer, *Carcinogenesis* 31 (2010): 27–36.
13. L. Bouchard and coauthors, Differential epigenomic and transcriptomic responses in subcutaneous adipose tissue between low and high responders to caloric restriction, *American Journal of Clinical Nutrition* 91 (2010): 309–320; M. den Hoed and coauthors, Postprandial responses in hunger and satiety are associated with the rs9939609 single nucleotide polymorphism in *FTO, American Journal of Clinical Nutrition* 90 (2009): 1426–1432.
14. Z. A. Kaminsky and coauthors, DNA methylation profiles in monozygotic and dizygotic twins, *Nature Genetics* 41 (2009): 240–245.
15. L. R. Ferguson and M. Philpott, Nutrition and mutagenesis, *Annual Review of Nutrition* 28 (2008): 313–329.
16. J. Hardy and A. Singleton, Genomewide association studies and human disease, *New England Journal of Medicine* 360 (2009): 1759–1768.
17. Hardy and Singleton, 2009.
18. T. A. Manolio, Genomewide association studies and assessment of the risk of disease, *New England Journal of Medicine* 363 (2010): 166–176.
19. R. DeBusk, Diet-related disease, nutritional genomics, and food and nutrition professionals, *Journal of the American Dietetic Association* 109 (2009): 410–413.
20. M. Bouwens and coauthors, Fish-oil supplementation induces anti-inflammatory gene expression profiles in human blood mononuclear cells, *American Journal of Clinical Nutrition* 90 (2009): 415–424.
21. E. S. Tai and coauthors, Polyunsaturated fatty acids interact with PPARA–L162V polymorphism to affect plasma triglyceride apolipoprotein C-III concentrations in the Framingham Heart Study, *Journal of Nutrition* 135 (2005): 397–403.
22. M. M. Bergmann, U. Görman, and J. C. Mathers, Bioethical considerations for human nutrigenomics, *Annual Review of Nutrition* 28 (2008): 447–467.
23. R. P. Lifton, Individual genomes on the horizon, *New England Journal of Medicine* 362 (2010): 1235–1236.
24. S. B. Shurin and E. G. Nabel, Pharmacogenomics: Ready for prime time? *New England Journal of Medicine* 358 (2008): 1061–1063.
25. J. N. Hirschhorn, Genomewide association studies: Illuminating biologic pathways, *New England Journal of Medicine* 360 (2009): 1699–1701; G. Panagiotou and J. Nielsen, Nutritional systems biology: Definitions and approaches, *Annual Review of Nutrition* 29 (2009): 329–339.
26. N. P. Paynter and coauthors, Association between a literature-based genetic risk score and cardiovascular events in women, *Journal of the American Medical Association* 303 (2010): 631–637; P. Kraft and D. J. Hunter, Genetic risk prediction: Are we there yet? *New England Journal of Medicine* 360 (2009): 1701–1703; J. B. Meigs and coauthors, Genotype score in addition to common risk factors for prediction of type 2 diabetes, *New England Journal of Medicine* 359 (2008): 2208–2219.
27. R. A. Kane and R. L. Kane, Effect of genetic testing for risk of Alzheimer's disease, *New England Journal of Medicine* 361 (2009): 298–299; P. M. Visscher and G. W. Montgomery, Genome-wide association studies and human disease: From trickle to flood, *Journal of the American Medical Association* 302 (2009): 2028–2029.
28. S. C. O'Neill and coauthors, Preferences for genetic and behavioral health information: The impact of risk factors and disease attributions, *Annals of Behavioral Medicine* 40 (2010): 127–173.



CENGAGE LEARNING'S GLOBAL NUTRITION

Most of the body's metabolic work involves either anabolic or catabolic reactions. Go to Nutrition and Health/Disease → Metabolism to review anabolic and catabolic reactions. In what ways are anabolic and catabolic reactions similar and how do they differ?

7

Energy Metabolism

LEARNING GPS

7.1 Chemical Reactions in the Body 198

LEARN IT Identify the nutrients involved in energy metabolism and the high-energy compound that captures the energy released during their breakdown.

7.2 Breaking Down Nutrients for Energy 201

LEARN IT Summarize the main steps in the energy metabolism of glucose, glycerol, fatty acids, and amino acids.

- **Glucose 203**
- **Glycerol and Fatty Acids 207**
- **Amino Acids 207**
- **The Final Steps of Energy Metabolism 208**

7.3 Feasting and Fasting 213

LEARN IT Explain how an excess of any of the three energy-yielding nutrients contributes to body fat and how an inadequate intake of any of them shifts metabolism.

- **Feasting—Excess Energy 213**
- **The Transition from Feasting to Fasting 215**
- **Fasting—Inadequate Energy 217**
- **Low-Carbohydrate Diets 218**

Highlight 7 Alcohol in the Body 220

LEARN IT Describe how alcohol disrupts metabolism and impairs health.

Nutrition in Your Life

You eat breakfast and hustle off to class. After lunch, you study for tomorrow's exam. Dinner is followed by an evening of dancing. Do you ever think about how the food you eat powers the activities of your life? What happens when you don't eat—or when you eat too much? Learn how the cells of your body transform carbohydrates, fats, and proteins into energy—and what happens when you give your cells too much or too little of any of these nutrients. Discover the metabolic pathways that lead to body fat and those that support physical activity. It's really quite fascinating. In the Nutrition Portfolio at the end of this chapter, you can determine whether your diet provides a healthy balance of the energy nutrients.

Energy makes it possible for people to breathe, ride bicycles, compose music, and do everything else they do. As Chapter 1 explains, *energy* is the capacity to do work. Although every aspect of our lives depends on energy, the concept of energy can be difficult to grasp because it cannot be seen or touched, and it manifests in various forms, including heat, mechanical, electrical, and chemical energy. In the body, heat energy maintains a constant body temperature, mechanical energy moves muscles, and electrical energy sends nerve impulses. Energy is stored in foods and in the body as chemical energy. This chemical energy powers the myriad activities of all cells.

All the energy that sustains human life initially comes from the sun—the ultimate source of energy. During **photosynthesis,** plants make simple sugars from carbon dioxide and capture the sun's light energy in the chemical bonds of those sugars. Then human beings eat either the plants or animals that have eaten the plants. These foods provide energy, but how does the body obtain that energy from foods? This chapter answers that question by following the nutrients that provide the body with **fuel** through a series of reactions that

photosynthesis: the process by which green plants use the sun's energy to make carbohydrates from carbon dioxide and water.

- **photo** = light
- **synthesis** = put together (making)

fuel: compounds that cells can use for energy. The major fuels include glucose, fatty acids, and amino acids; other fuels include ketone bodies, lactate, glycerol, and alcohol.

release energy from their chemical bonds. As the bonds break, they release energy in a controlled version of the same process by which wood burns in a fire. Both wood and food have the potential to provide energy. When wood burns in the presence of oxygen, it generates heat and light (energy), steam (water), and some carbon dioxide and ash (waste). Similarly, during **metabolism,** the body releases energy, water, and carbon dioxide (and other waste products).

By studying metabolism, you will understand how the body uses foods to meet its needs and why some foods meet those needs better than others. Readers who are interested in weight control will discover which foods contribute most to body fat and which to select when trying to gain or lose weight safely. Readers who are physically active will discover which foods best support endurance activities and which to select when trying to build lean body mass.

7.1 Chemical Reactions in the Body

LEARN IT Identify the nutrients involved in energy metabolism and the high-energy compound that captures the energy released during their breakdown.

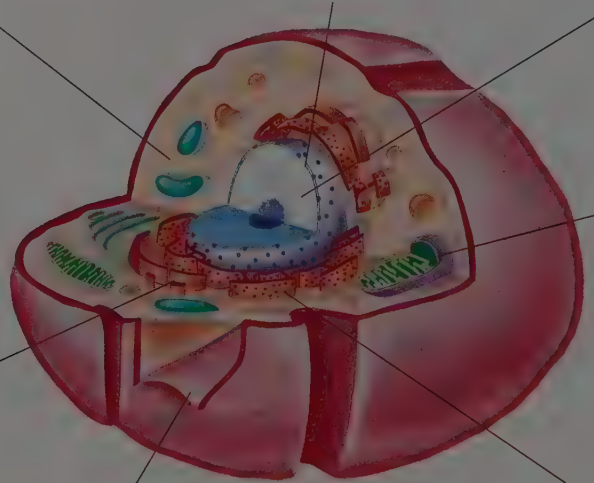
Earlier chapters introduced some of the body's chemical reactions: the making and breaking of the bonds in carbohydrates, fats, and proteins. Metabolism is the sum of these and all the other chemical reactions that go on in living cells; *energy metabolism* includes all the ways the body obtains and uses energy from food.

metabolism: the sum total of all the chemical reactions that go on in living cells. *Energy metabolism* includes all the reactions by which the body obtains and expends the energy from food.

- **metaballein** = change

The Site of Metabolic Reactions—Cells The human body is made up of trillions of cells, and each cell busily conducts its metabolic work all the time. (Appendix A presents a brief summary of the structure and function of the cell.) Figure 7-1 depicts a typical cell and shows where the major reactions of energy metabolism take place. The type and extent of metabolic activities vary depending on the type of cell, but of all the body's cells, the liver cells are the most versatile and metabolically active. Table 7-1 offers insights into the liver's work.

FIGURE 7-1 A Typical Cell (Simplified Diagram)



© Cengage Learning 2013

TABLE 7-1 Metabolic Work of the Liver

The liver is the most active processing center in the body. When nutrients enter the body from the digestive tract, the liver receives them first; then it metabolizes, packages, stores, or ships them out for use by other tissues. When alcohol, drugs, or poisons enter the body, they are also sent directly to the liver; here they are detoxified and their by-products shipped out for excretion. An enthusiastic anatomy and physiology professor once remarked that given the many vital activities of the liver, we should express our feelings for others by saying, "I love you with all my liver" instead of "with all my heart." Granted, this declaration lacks romance, but it makes a valid point. Here are just some of the many jobs performed by the liver. To renew your appreciation for this remarkable organ, review Figure 3-11 (p. 81).

Carbohydrates

- Metabolizes fructose, galactose, and glucose
- Makes and stores glycogen
- Breaks down glycogen and releases glucose
- Breaks down glucose for energy when needed
- Makes glucose from some amino acids and glycerol when needed
- Converts excess glucose and fructose to fatty acids

Lipids

- Builds and breaks down triglycerides, phospholipids, and cholesterol as needed
- Breaks down fatty acids for energy when needed
- Packages lipids in lipoproteins for transport to other body tissues
- Manufactures bile to send to the gallbladder for use in fat digestion
- Makes ketone bodies when necessary

Proteins

- Manufactures nonessential amino acids that are in short supply
- Removes from circulation amino acids that are present in excess of need and converts them to other amino acids or deaminates them and converts them to glucose or fatty acids
- Removes ammonia from the blood and converts it to urea to be sent to the kidneys for excretion
- Makes other nitrogen-containing compounds the body needs (such as bases used in DNA and RNA)
- Makes many proteins

Other

- Detoxifies alcohol, other drugs, and poisons; prepares waste products for excretion
- Helps dismantle old red blood cells and captures the iron for recycling
- Stores most vitamins and many minerals
- Activates vitamin D

© Cengage Learning 2013

The Building Reactions—Anabolism Earlier chapters describe how condensation reactions combine molecules to build body compounds. Glucose molecules may be joined together to make glycogen chains. Glycerol and fatty acids may be assembled into triglycerides. Amino acids may be linked together to make proteins. Each of these reactions starts with small, simple compounds and uses them as building blocks to form larger, more complex structures. Because such reactions involve doing work, they require energy. The building up of body compounds is known as **anabolism.** Anabolic reactions are represented in this book, wherever possible, with "up" arrows in chemical diagrams (such as those shown at the top of Figure 7-2, p. 200).

The Breakdown Reactions—Catabolism The breaking down of body compounds is known as **catabolism;** catabolic reactions release energy and are represented, wherever possible, by "down" arrows in chemical diagrams (as in the bottom of Figure 7-2, p. 200). Earlier chapters describe how hydrolysis reactions break down glycogen to glucose, triglycerides to fatty acids and glycerol, and proteins to amino acids. When the body needs energy, it breaks down any or all of these molecules further.

The Transfer of Energy in Reactions—ATP Some of the energy released during the breakdown of glucose, glycerol, fatty acids, and amino acids is captured in the high-energy compound ATP **(adenosine triphosphate).** ATP, as its name indicates, contains three phosphate groups (see Figure 7-3, p. 200). ♦ The negative charges on the phosphate groups make ATP vulnerable to hydrolysis. When the bonds between the phosphate groups are hydrolyzed, they readily break, splitting off one or two phosphate groups and releasing energy. In this way, ATP provides the energy that powers all the activities of living cells. Figure 7-4 (p. 201) describes how the body captures and releases energy in the bonds of ATP.

Quite often, the hydrolysis of ATP occurs simultaneously with reactions that will use that energy—a metabolic duet known as **coupled reactions.** In essence, the body uses ATP to transfer the energy released during catabolic reactions to power anabolic reactions. The body converts the chemical energy of food to the chemical energy of ATP with about 50 percent efficiency, radiating the rest as

♦ ATP = A–P~P~P.
Each ~ denotes a "high-energy" bond.

anabolism (an-AB-o-lism): reactions in which small molecules are put together to build larger ones. Anabolic reactions require energy.

- **ana** = (build) up

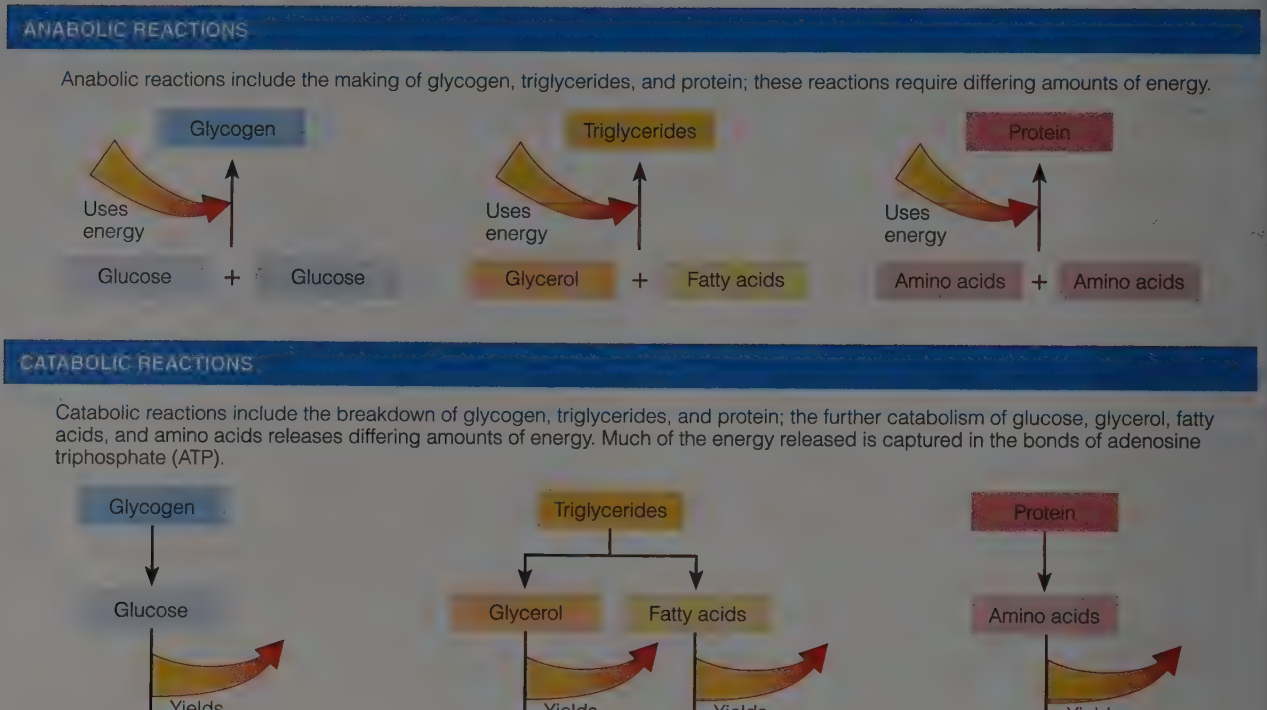
catabolism (ca-TAB-o-lism): reactions in which large molecules are broken down to smaller ones. Catabolic reactions release energy.

- **kata** = (break) down

ATP or **adenosine** (ah-DEN-oh-seen) **triphosphate** (try-FOS-fate): a common high-energy compound composed of a purine (adenine), a sugar (ribose), and three phosphate groups.

coupled reactions: pairs of chemical reactions in which some of the energy released from the breakdown of one compound is used to create a bond in the formation of another compound.

> FIGURE 7-2 Anabolic and Catabolic Reactions Compared

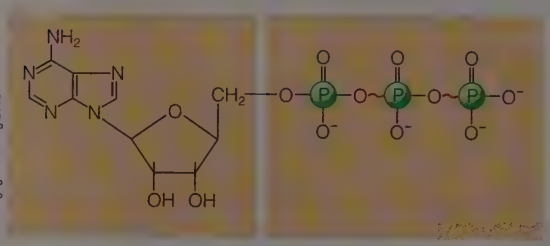


© Cengage Learning 2013

NOTE: You need not memorize a color code to understand the figures in this chapter, but you may find it helpful to know that blue is used for carbohydrates, yellow for fats, and red for proteins.

> FIGURE 7-3 ATP (Adenosine Triphosphate)

Notice that the bonds connecting the three phosphate groups have been drawn as wavy lines, indicating a high-energy bond. When these bonds are broken, energy is released.



© Cengage Learning 2013

heat. Some energy is lost as heat again when the body uses the chemical energy of ATP to do its work—moving muscles, synthesizing compounds, or transporting nutrients, for example.

The Helpers in Metabolic Reactions—Enzymes and Coenzymes Metabolic reactions almost always require **enzymes** to facilitate their action. In many cases, the enzymes need assistants to help them. Enzyme helpers are called **coenzymes.***

Coenzymes are complex organic molecules that associate closely with enzymes but are not proteins themselves. The relationships between various coenzymes and their respective enzymes may differ in detail, but one thing is true of all: without its coenzyme, an enzyme cannot function. Some of the B vitamins serve as coenzymes that participate in the energy metabolism of glucose, glycerol, fatty acids, and amino acids. (Chapter 10 provides more details.)

REVIEW IT Identify the nutrients involved in energy metabolism and the high-energy compound that captures the energy released during their breakdown.

During digestion the energy-yielding nutrients—carbohydrates, fats, and proteins—are broken down to glucose (and other monosaccharides), glycerol, fatty acids, and amino acids. With the help of enzymes and coenzymes, the cells use these molecules to build more complex compounds (anabolism) or break them down further to release energy (catabolism). High-energy compounds such as ATP may capture the energy released during catabolism and provide the energy needed for anabolism.

enzymes: proteins that facilitate chemical reactions without being changed in the process; protein catalysts.

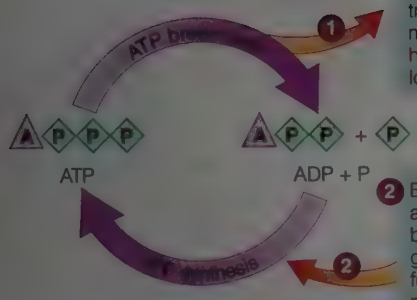
coenzymes: complex organic molecules that work with enzymes to facilitate the enzymes' activity. Many coenzymes have B vitamins as part of their structures. (Figure 10-2 on p. 301 illustrates coenzyme action.)

- **co** = with

*The general term for substances that facilitate enzyme action is *cofactors;* they include both organic coenzymes made from vitamins and inorganic substances such as minerals.

> FIGURE 7-4 The Capture and Release of Energy by ATP

It may help to think of ATP as a rechargeable battery—capturing and releasing energy as it does the body's work.



1 Energy is released when a high-energy phosphate bond in ATP is broken. Just as a battery can be used to provide energy for a variety of uses, the energy from ATP can be used to do most of the body's work—contract muscles, transport compounds, make new molecules, and more. With the loss of a phosphate group, high-energy ATP (charged battery) becomes low-energy ADP (used battery).

2 Energy is required when a phosphate group is attached to ADP, making ATP. Just as a used battery needs energy from an electrical outlet to get recharged, ADP (used battery) needs energy from the breakdown of carbohydrate, fat, and protein to make ATP (recharged battery).

© Cengage Learning 2013

7.2 Breaking Down Nutrients for Energy

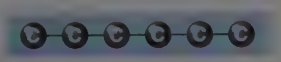
LEARN IT Summarize the main steps in the energy metabolism of glucose, glycerol, fatty acids, and amino acids.

Chapters 4, 5, and 6 provide previews of metabolism; a brief review may be helpful. During digestion, the body breaks down the three energy-yielding nutrients—carbohydrates, fats, and proteins—into smaller molecules that can be absorbed:

- From carbohydrates—glucose (and other monosaccharides)
- From fats (triglycerides)—glycerol and fatty acids
- From proteins—amino acids

Each molecule of glucose, glycerol, fatty acids, and amino acids is composed of atoms—carbons, nitrogens, oxygens, and hydrogens. During catabolism, the bonds between these atoms break, releasing energy. To follow this action, recall how many carbons are in each of these molecules:

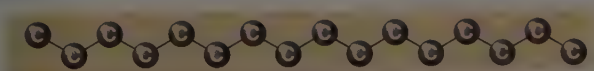
- Glucose has 6 carbons:



- Glycerol has 3 carbons:



- A fatty acid usually has an even number of carbons, commonly 16 or 18 carbons:*



- An amino acid has 2, 3, or more carbons with a nitrogen attached:**



*The figures in this chapter show 16- or 18-carbon fatty acids. Fatty acids may have 4 to 20 or more carbons, with chain lengths of 16 and 18 carbons most prevalent.

**The figures in this chapter usually show amino acids as compounds of 2, 3, or 5 carbons arranged in a straight line, but in reality amino acids may contain other numbers of carbons and assume other structural shapes (see Appendix C).



© Stockbyte/Alamy

All the energy used to keep the heart beating, the brain thinking, and the body moving comes from the carbohydrates, fats, and proteins in foods.

Full chemical structures and reactions appear both in the earlier chapters and in Appendix C; this chapter diagrams the reactions using just the compounds' carbon and nitrogen atoms.

As you will see, each of these molecules—glucose, glycerol, fatty acids, and amino acids—starts down a different path, but they all can end up in the same place. (Similarly, three people entering an interstate highway at three different locations can all travel to the same destination.) Along the way, two new names appear—**pyruvate** (a 3-carbon structure) and **acetyl CoA** (a 2-carbon structure with a coenzyme, **CoA**, attached)—and the rest of the story falls into place around them.* Two major points to notice in the following discussion:

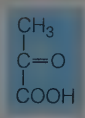
- Pyruvate can be used to make glucose.
- Acetyl CoA cannot be used to make glucose.

Learning which fuels can be converted to glucose and which cannot is a major key to understanding energy metabolism. Amino acids and glycerol can be converted to pyruvate and therefore *can* provide glucose for the body. Fatty acids are converted to acetyl CoA and therefore *cannot* make glucose. Acetyl CoA can readily make fat. Whereas most of the body's cells can use glucose, fat, or both for energy, the body *must* have glucose to fuel the activities of the central nervous system and red blood cells. Without glucose from food, the body will break down its own lean (protein-containing) tissue to get the amino acids needed to make glucose. To protect this protein tissue, the body needs foods that provide glucose—primarily carbohydrate. Eating only fat provides abundant acetyl CoA, but forces the body to break down protein tissue to make glucose. Eating only protein requires the body to convert protein to glucose. Clearly, the best diet ♦ provides ample carbohydrate, adequate protein, and some fat.

Figure 7-5 provides a simplified overview of the energy-yielding pathways. Upcoming sections of the chapter describe how each of the energy-yielding nutrients follows its pathway as it is broken down to acetyl CoA. Their paths merge at acetyl CoA, where the real action begins. Acetyl CoA enters the **TCA cycle**, and energy is harnessed through the **electron transport chain.** The TCA cycle and electron transport chain have central roles in energy metabolism and receive

♦ A healthy diet provides:
- 45–65% kcalories from carbohydrate
- 10–35% kcalories from protein
- 20–35% kcalories from fat

pyruvate (PIE-roo-vate): a 3-carbon compound that plays a key role in energy metabolism.



acetyl CoA (ASS-eh-teel or ah-SEET-il, coh-AY): a 2-carbon compound (acetate or acetic acid) to which a molecule of CoA is attached.

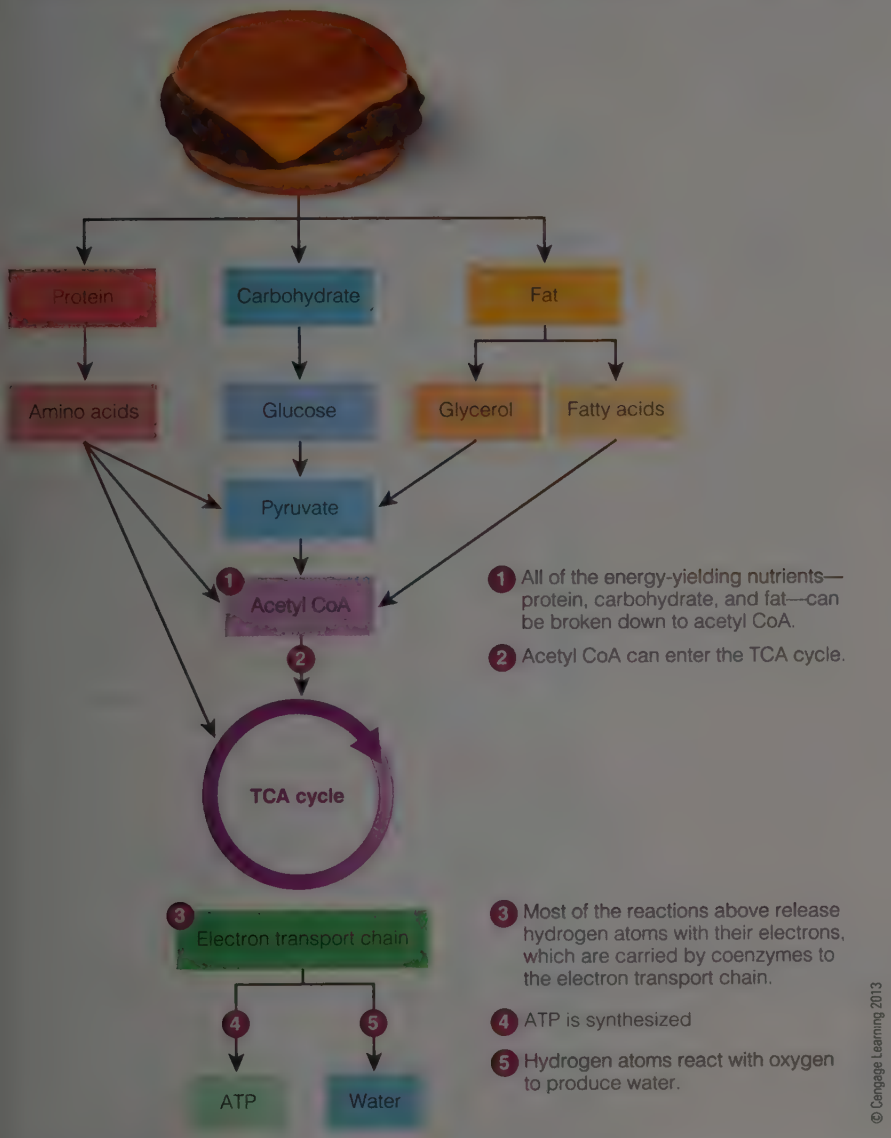
CoA (coh-AY): coenzyme A; the coenzyme derived from the B vitamin pantothenic acid and central to energy metabolism.

TCA cycle or **tricarboxylic** (try-car-box-ILL-ick) **acid cycle:** a series of metabolic reactions that break down molecules of acetyl CoA to carbon dioxide and hydrogen atoms; also called the *citric acid cycle* or the *Kreb's cycle* after the biochemist who elucidated its reactions.

electron transport chain: the final pathway in energy metabolism that transports electrons from hydrogen to oxygen and captures the energy released in the bonds of ATP; also called the *respiratory chain.*

*The term *pyruvate* means a salt of *pyruvic acid.* (Throughout this book, the ending *-ate* is used interchangeably with *-ic acid;* for our purposes they mean the same thing.)

FIGURE 7-5 Simplified Overview of Energy-Yielding Pathways



© Cengage Learning 2013

full attention later in the chapter—after following each of the energy nutrient pathways to acetyl CoA.

Glucose What happens to glucose, glycerol, fatty acids, and amino acids during energy metabolism can best be understood by starting with glucose. This discussion features glucose because of its central role in carbohydrate metabolism and because liver cells can convert the monosaccharides fructose and galactose to compounds that enter the same energy pathways.

Glucose-to-Pyruvate The first pathway glucose takes on its way to yield energy is called **glycolysis** (glucose splitting).* Figure 7-6 (p. 204) shows a simplified drawing of glycolysis. (This pathway actually involves several steps and several enzymes, which are detailed in Appendix C.) In a series of reactions, the 6-carbon glucose is converted to similar 6-carbon compounds before being split in half, forming two 3-carbon compounds. These 3-carbon compounds continue along the pathway until they are converted to pyruvate. Thus the net yield of one glucose molecule is two pyruvate molecules.

glycolysis (gly-COL-uh-sis) the metabolic breakdown of glucose to pyruvate. Glycolysis does not require oxygen (anaerobic).

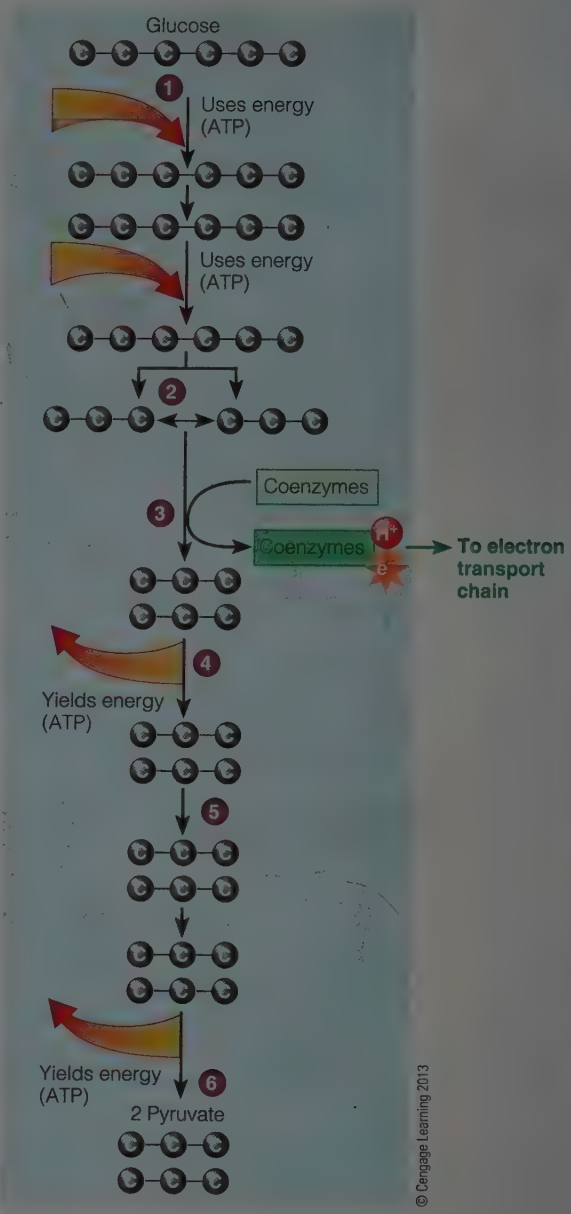
- **glyco** = glucose
- **lysis** = breakdown

*Glycolysis takes place in the cytosol of the cell (see Figure 7-1, p. 198).

> **FIGURE 7-6 Glycolysis: Glucose-to-Pyruvate**

This simplified overview of glycolysis illustrates the steps in the process of converting glucose to pyruvate. (Appendix C provides more details.) Notice that these arrows point down indicating the breakdown of glucose to pyruvate during energy metabolism. (Alternatively, the arrows could point up indicating the making of glucose from pyruvate, but that is not the focus of this discussion.)

1. A little ATP is used to start glycolysis. Galactose and fructose enter glycolysis at different places, but all continue on the same pathway.
2. In a series of reactions, the 6-carbon glucose is converted to other 6-carbon compounds, which eventually split into two interchangeable 3-carbon compounds.
3. Coenzymes carry the hydrogens and their electrons to the electron transport chain.
4. A little ATP is produced.
5. The 3-carbon compounds go through a series of conversions, producing another 3-carbon compound, each slightly different.
6. Eventually, the 3-carbon compounds are converted to pyruvate. Glycolysis of one molecule of glucose produces two molecules of pyruvate.



NOTE: The cell uses a little energy (–2 ATP) to begin the breakdown of glucose to pyruvate, but then it gains a little more energy (4 ATP) for a small net gain (of 2 ATP).

The net yield of energy at this point is small; to start glycolysis, the cell uses a little energy and then produces only a little more than it invested initially.* In addition, as glucose breaks down to pyruvate, hydrogen atoms with their electrons are released and carried to the electron transport chain by coenzymes made from the B vitamin niacin. A later section of the chapter explains how oxygen accepts the electrons and combines with the hydrogens to form water and how the process captures energy in the bonds of ATP.

This discussion focuses primarily on the breakdown of glucose for energy, but if needed, cells in the liver (and to some extent, the kidneys) can make glucose again

*The cell uses two ATP to begin the breakdown of glucose to pyruvate, but it then gains four ATP for a net gain of two ATP.

from pyruvate in a process similar to the reversal of glycolysis. Making glucose requires energy, however, and a few different enzymes. Still, glucose can be made from pyruvate, so the arrows between glucose and pyruvate could point up as well as down. ♦

♦ Glucose may go "down" to make pyruvate, or pyruvate may go "up" to make glucose, depending on the cell's needs.



Pyruvate's Options—Anaerobic or Aerobic Whenever carbohydrates, fats, or proteins are broken down to provide energy, oxygen is always ultimately involved in the process. The role of oxygen in metabolism is worth noticing, for it helps our understanding of physiology and metabolic reactions. Chapter 14 describes the body's use of the energy nutrients to fuel physical activity, but the facts presented here offer a sneak preview.

When the body needs energy quickly—as occurs when you run a quarter mile as fast as you can—pyruvate is converted to lactate. The breakdown of glucose-to-pyruvate-to-lactate proceeds without oxygen—it is **anaerobic.** This anaerobic pathway yields energy quickly, but it cannot be sustained for long—a couple of minutes at most.

When energy expenditure proceeds at a slower pace—as occurs when you jog around the track for an hour—pyruvate breaks down to acetyl CoA in an **aerobic** pathway. Aerobic pathways produce energy more slowly, but because they can be sustained for a long time, their total energy yield is greater. The following paragraphs provide more details.

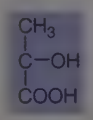
anaerobic (AN-air-ROE-bic): not requiring oxygen.
- **an** = not

aerobic (air-ROE-bic): requiring oxygen.

mitochondria (my-toh-KON-dree-uh): the cellular organelles responsible for producing ATP aerobically; made of membranes (lipid and protein) with enzymes mounted on them. (The singular is *mitochondrion*.)
- **mitos** = thread (referring to their slender shape)
- **chondros** = cartilage (referring to their external appearance)

Pyruvate-to-Lactate (Anaerobic) As mentioned earlier, coenzymes carry the hydrogens from glucose breakdown to the electron transport chain. If the electron transport chain is unable to accept these hydrogens, as may occur when cells lack sufficient **mitochondria** (review Figure 7-1, p. 198) or in the absence of sufficient oxygen, pyruvate can accept the hydrogens. By accepting the hydrogens, pyruvate becomes **lactate,** and the coenzymes are freed to return to glycolysis to pick up more hydrogens (see the left side of Figure 7-7). In this way, glucose can continue providing energy anaerobically for a while.

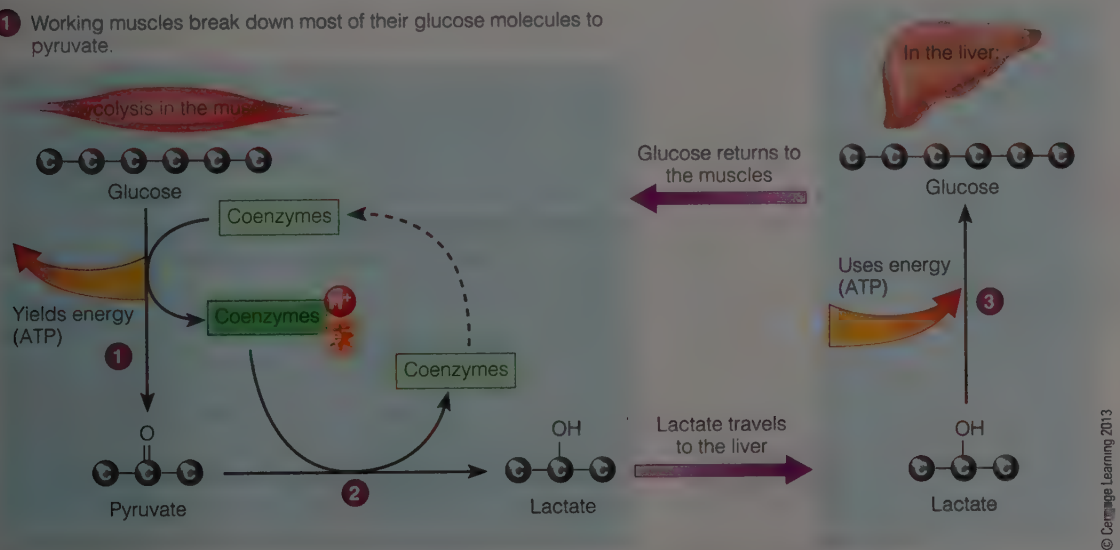
lactate: a 3-carbon compound produced from pyruvate during anaerobic metabolism.



The production of lactate occurs to a limited extent even at rest. During high-intensity exercise, however, the muscles rely heavily on anaerobic glycolysis to produce ATP quickly, and the concentration of lactate increases dramatically. The rapid rate of glycolysis produces abundant pyruvate and releases hydrogen-carrying coenzymes more rapidly than the mitochondria can handle. To enable exercise to

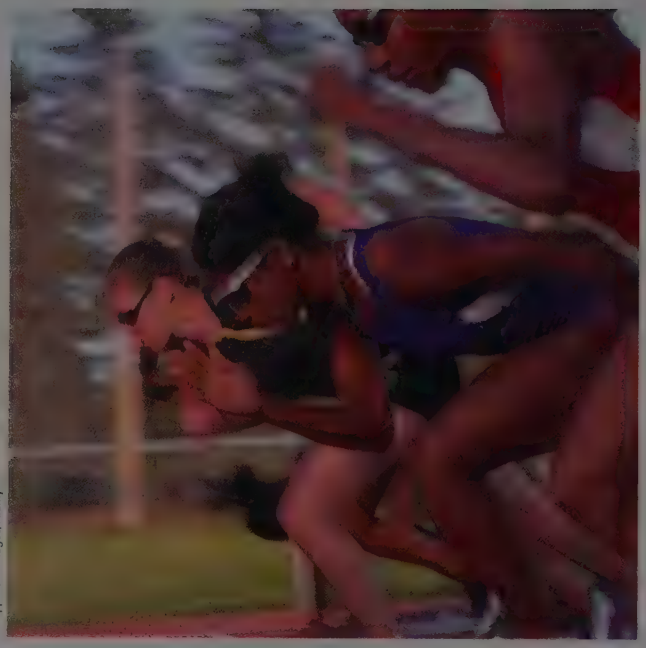
> FIGURE 7-7 Pyruvate-to-Lactate

Because muscle cells lack the enzyme to convert lactate to glucose, lactate must first travel to the liver. The process of converting lactate from the muscles to glucose in the liver that can be returned to the muscles is known as the Cori cycle.



2 If the cells lack sufficient mitochondria or in the absence of sufficient oxygen, pyruvate can accept the hydrogens from glucose breakdown and become lactate. This conversion frees the coenzymes so that glycolysis can continue.

3 Liver enzymes can convert lactate to glucose, but this reaction requires energy.



© UpperCut Images/Alamy

The anaerobic breakdown of glucose-to-pyruvate-to-lactate is the major source of energy for short, intense exercise.

continue at this intensity, pyruvate is converted to lactate and coenzymes are released, which allows glycolysis to continue. The accumulation of lactate in the muscles coincides with—but does not seem to be the cause of—the subsequent drop in blood pH, burning pain, and fatigue that are commonly associated with intense exercise. In fact, making lactate from pyruvate consumes two hydrogen ions, which actually diminishes acidity and improves the performance of tired muscles. A person performing the same exercise following endurance training actually experiences less discomfort—in part because the number of mitochondria in the muscle cells has increased. This adaptation improves the mitochondria's ability to keep pace with the muscles' demand for energy.

One possible fate of lactate is to be transported from the muscles to the liver. There the liver can convert the lactate produced in muscles to glucose, which can then be returned to the muscles. (Muscle cells cannot convert lactate to glucose because they lack the necessary enzyme.) This recycling process is called the **Cori cycle** (see the right side of Figure 7-7, p. 205).

Pyruvate-to-Acetyl CoA (Aerobic) If a cell needs energy and oxygen is available, pyruvate molecules enter the mitochondria of the cell. There a carbon group (COOH) from the 3-carbon pyruvate is removed to produce a 2-carbon compound that bonds with a molecule of CoA, becoming acetyl CoA. The carbon group from pyruvate becomes carbon dioxide (CO_2), which is released into the blood, circulated to the lungs, and breathed out. Figure 7-8 diagrams the pyruvate-to-acetyl CoA reaction.

Figure 7-9 shows that many of the body's metabolic pathways are reversible, but the step from pyruvate to acetyl CoA is not one of them. A cell cannot retrieve the carbons from carbon dioxide to remake pyruvate and then glucose. It is one way only.

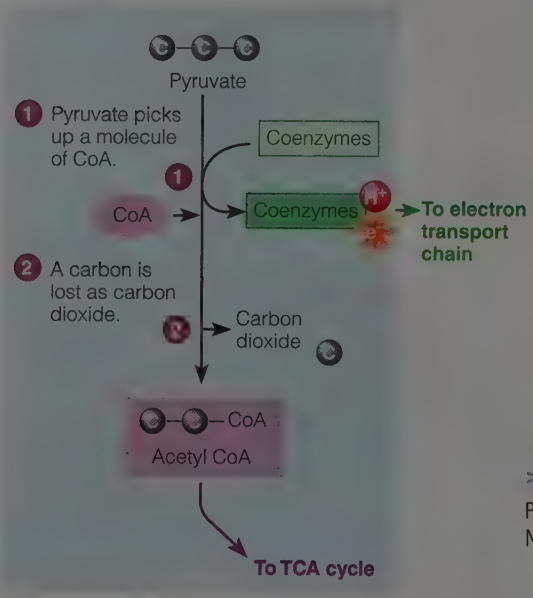
The story of acetyl CoA continues on p. 208 after a discussion of how fat and protein arrive at the same crossroads. For now, know that when acetyl CoA continues on its energy-yielding pathway, much more ATP is produced than during glycolysis.

REVIEW IT

The glucose-to-energy pathway begins with glycolysis—the breakdown of glucose to pyruvate. Pyruvate may be converted to lactate anaerobically or to acetyl CoA aerobically. The pathway from pyruvate to acetyl CoA is irreversible. Once the commitment to acetyl CoA is made, glucose is not retrievable; acetyl CoA cannot go back to glucose. Glucose can be synthesized only from pyruvate or compounds earlier in the pathway. Figure 7-10 summarizes the metabolism of glucose for energy.

FIGURE 7-8 Pyruvate-to-Acetyl CoA

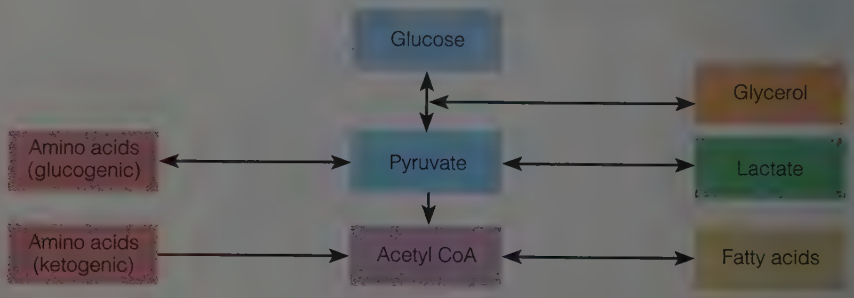
The pyruvate-to-acetyl CoA reaction is not reversible.



© Cengage Learning 2013

FIGURE 7-9 The Paths of Pyruvate and Acetyl CoA

Pyruvate may follow several reversible paths, but the path from pyruvate to acetyl CoA is irreversible. Notice that fatty acids cannot be used to make glucose.



© Cengage Learning 2013

NOTE: Amino acids that can be used to make glucose are called *glucogenic*; amino acids that are converted to acetyl CoA are called *ketogenic*.

Cori cycle: the pathway in which glucose is metabolized to lactate (by anaerobic glycolysis) in the muscle, lactate is converted back to glucose in the liver, and then glucose is returned to the muscle; named after the scientist who elucidated this pathway.

Glycerol and Fatty Acids

Recall that triglycerides can break down to glycerol and fatty acids. They enter energy metabolism via different pathways.

Glycerol-to-Pyruvate Glycerol is a 3-carbon compound like pyruvate but with a different arrangement of H and OH on the C. As such, glycerol can easily be converted to another 3-carbon compound that can go either "up" to glucose or "down" to pyruvate and then to acetyl CoA (review Figure 7-9, p. 206).

Fatty Acids-to-Acetyl CoA Fatty acids are taken apart two carbons at a time in a series of reactions known as **fatty acid oxidation**.* Figure 7-11 (p. 208) illustrates fatty acid oxidation and shows that in the process, each 2-carbon fragment splits off and combines with a molecule of CoA to make acetyl CoA. As each 2-carbon fragment breaks off, hydrogens and their electrons are released and carried to the electron transport chain by coenzymes made from the B vitamins riboflavin and niacin.

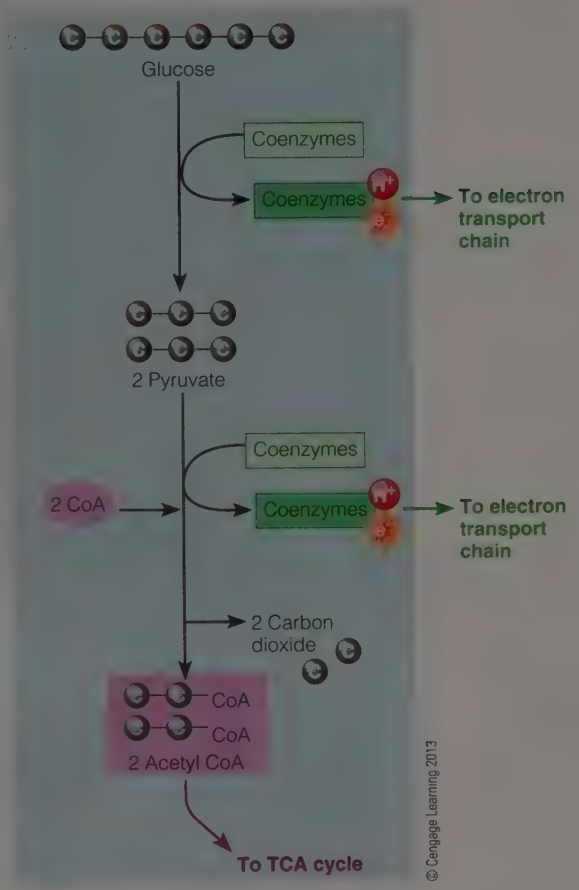
Fatty Acids Cannot Make Glucose As mentioned earlier, red blood cells and the brain and nervous system depend primarily on glucose as fuel. When carbohydrate is unavailable, liver cells can make glucose from pyruvate and other 3-carbon compounds, such as glycerol. Importantly, cells cannot make glucose from the 2-carbon fragments of fatty acids.

Remember that almost all dietary fats are triglycerides and that triglycerides contain only one small molecule of glycerol with three fatty acids. The glycerol can yield glucose, but that represents only 3 of the 50 or so carbons in a triglyceride—about 5 percent of its weight. The other 95 percent cannot be used to make glucose.

REVIEW IT

The body can convert the small glycerol portion of a triglyceride to either pyruvate (and then glucose) or acetyl CoA. The fatty acids of a triglyceride, on the other hand, cannot make glucose, but they can provide abundant acetyl CoA. Acetyl CoA may then enter the TCA cycle to release energy or combine with other molecules of acetyl CoA to make body fat. Figure 7-12 (p. 209) summarizes the metabolism of fats for energy.

> **FIGURE 7-10 Glucose Enters the Energy Pathway**



REVIEW IT

1 glucose yields 2 pyruvate, which yield 2 acetyl CoA.

Amino Acids

The preceding two sections have described how the breakdown of carbohydrate and fat produces acetyl CoA. One energy-yielding nutrient remains: protein or, rather, the amino acids of protein.

Amino Acid Deamination Before entering the metabolic pathways, amino acids are deaminated (that is, they lose their nitrogen-containing amino group). Chapter 6 describes how deamination produces ammonia (NH_3), which provides the nitrogen needed to make nonessential amino acids and other nitrogen-containing compounds. Any remaining ammonia is cleared from the body via urea synthesis in the liver and excretion in the kidneys.

Amino Acid Pathways Amino acids can enter the energy pathways in several ways. Some amino acids can be converted to pyruvate, others are converted to acetyl CoA, and still others enter the TCA cycle directly as compounds other than acetyl CoA.

As you might expect, amino acids that are used to make pyruvate can provide glucose, whereas those used to make acetyl CoA can provide additional energy or make body fat but cannot make glucose. Amino acids entering the TCA cycle directly can continue in the cycle and generate energy; alternatively, they can generate glucose.** Thus protein, unlike fat, is a fairly good source of glucose when carbohydrate is not available.

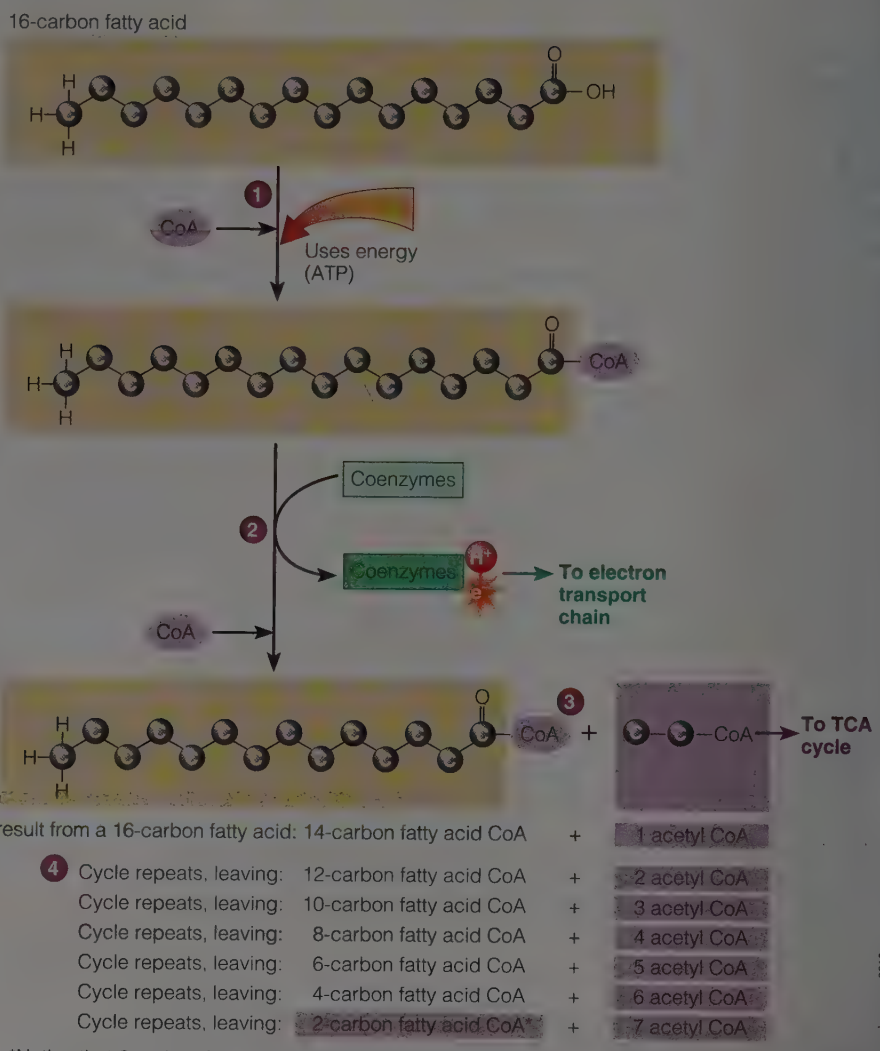
*Oxidation of fatty acids occurs in the mitochondria of the cells (review Figure 7-1, p. 198).

**Amino acids that can make glucose via either pyruvate or TCA cycle intermediates are *glucogenic*; amino acids that are degraded to acetyl CoA are *ketogenic*.

fatty acid oxidation: the metabolic breakdown of fatty acids to acetyl CoA; also called *beta oxidation*.

> FIGURE 7-11 Fatty Acid-to-Acetyl CoA

Fatty acids are broken apart into 2-carbon fragments that combine with CoA to make acetyl CoA.



1. The fatty acid is first activated by coenzyme A.
2. As each carbon-carbon bond is cleaved, hydrogens and their electrons are released, and coenzymes pick them up.
3. Another CoA joins the chain, and the bond at the second carbon (the beta-carbon) weakens. Acetyl CoA splits off, leaving a fatty acid that is two carbons shorter.
4. The shorter fatty acid enters the pathway and the cycle repeats, releasing more hydrogens with their electrons to coenzymes and producing more acetyl CoA. The molecules of acetyl CoA enter the TCA cycle, and the coenzymes carry the hydrogens and their electrons to the electron transport chain.

*Notice that 2-carbon fatty acid CoA = acetyl CoA, so that the final yield from a 16-carbon fatty acid is 8 acetyl CoA.

© Cengage Learning 2013

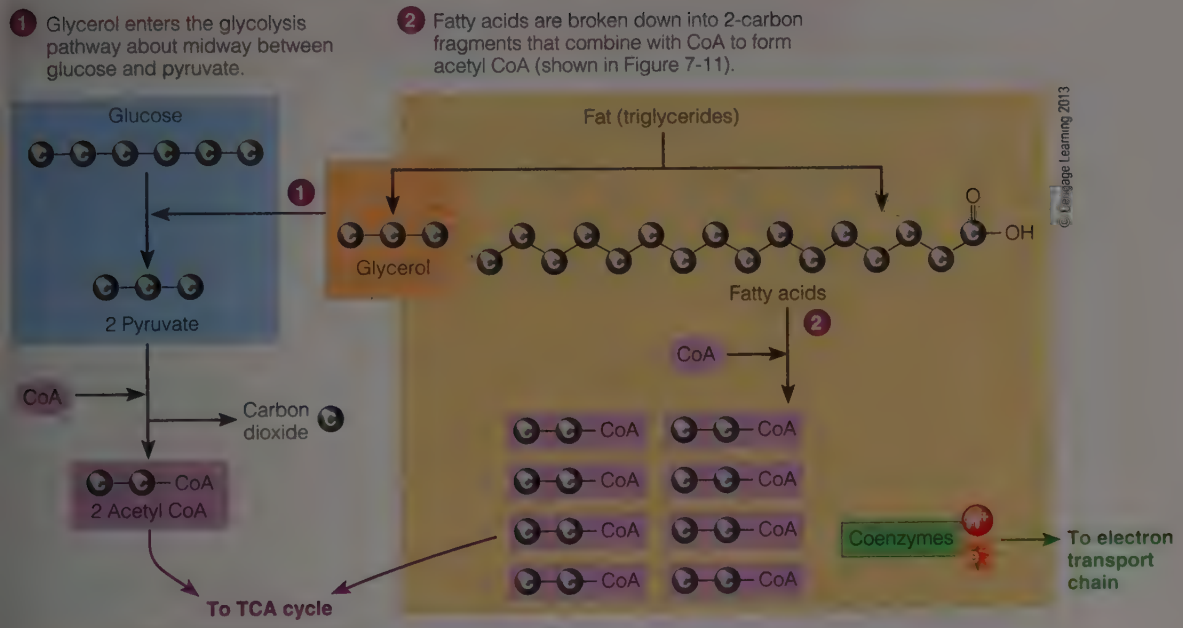
REVIEW IT

The body can use some amino acids to make glucose, whereas others can be used either to provide energy or to make fat. Before an amino acid enters any of these metabolic pathways, its nitrogen-containing amino group must be removed through deamination. Figure 7-13 summarizes the metabolism of amino acids for energy.

Table 7-2 (p. 210) reviews the ways the body can use the energy-yielding nutrients. To obtain energy, the body uses glucose and fatty acids as its primary fuels and amino acids to a lesser extent. To make glucose, the body can use all carbohydrates and most amino acids, but it can convert only 5 percent of fat (the glycerol portion) to glucose. Fatty acids cannot make glucose. To make proteins, the body needs amino acids. It can use glucose and glycerol to make some nonessential amino acids when nitrogen is available; it cannot use fatty acids to make body proteins. Finally, when energy intake exceeds the body's needs, all three energy-yielding nutrients can contribute to body fat stores.

The Final Steps of Energy Metabolism Thus far the discussion has followed each of the energy-yielding nutrients down three different pathways,

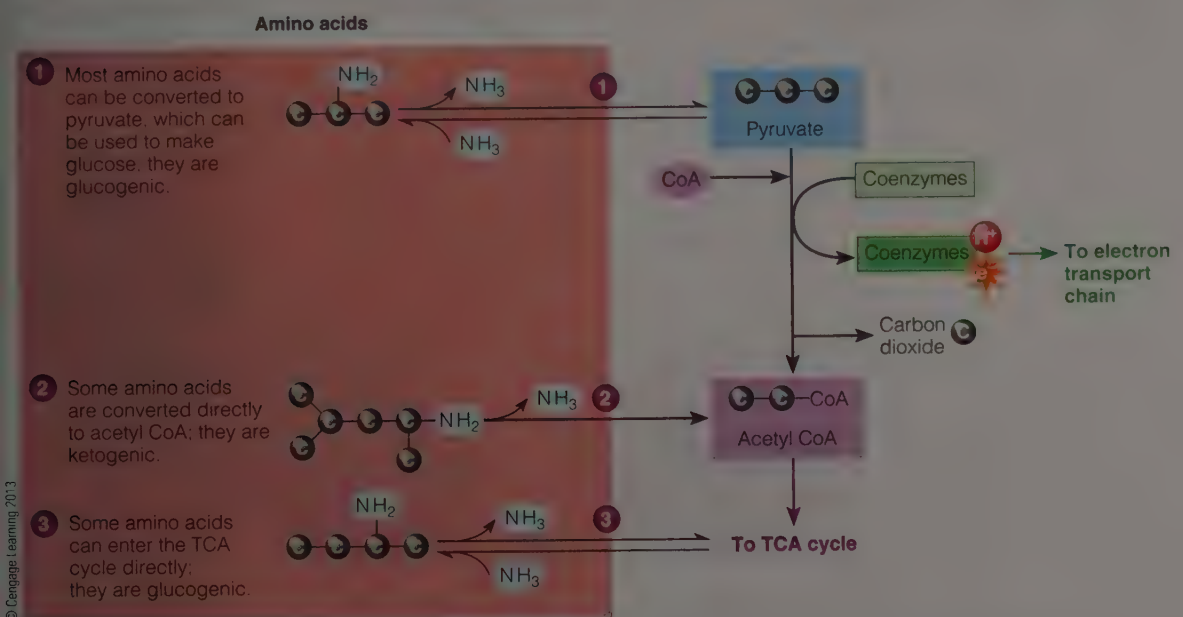
FIGURE 7-12 Fats Enter the Energy Pathway



REVIEW IT 16-carbon fatty acid yields 8 acetyl CoA.

all arriving at acetyl CoA. Acetyl CoA has two main options—it may be used to synthesize fats or to generate the high-energy compound ATP. When ATP is abundant, acetyl CoA makes fat, the most efficient way to store energy for later use when energy may be needed. Thus any molecule that can make acetyl CoA—including glucose, glycerol, fatty acids, and amino acids—can make fat. In reviewing Figure 7-9 (p. 206) notice that acetyl CoA can be used as a building block for

FIGURE 7-13 Amino Acids Enter the Energy Pathway



NOTE: Deamination and the synthesis of urea are discussed and illustrated in Chapter 6, Figure 6-13 (p. 180). The arrows from pyruvate and the TCA cycle to amino acids are possible only for *nonessential* amino acids; remember, the body cannot make essential amino acids.

TABLE 7-2 Review of Energy-Yielding Nutrient Endpoints

Nutrient	Yields energy?	Yields glucose?	Yields amino acids and body proteins?	Yields fat stores?
Carbohydrates (glucose)	Yes	Yes	Yes—when nitrogen is available, can yield *nonessential* amino acids	Yes
Lipids (fatty acids)	Yes	No	No	Yes
Lipids (glycerol)	Yes	Yes—when carbohydrate is unavailable	Yes—when nitrogen is available, can yield *nonessential* amino acids	Yes
Proteins (amino acids)	Yes	Yes—when carbohydrate is unavailable	Yes	Yes

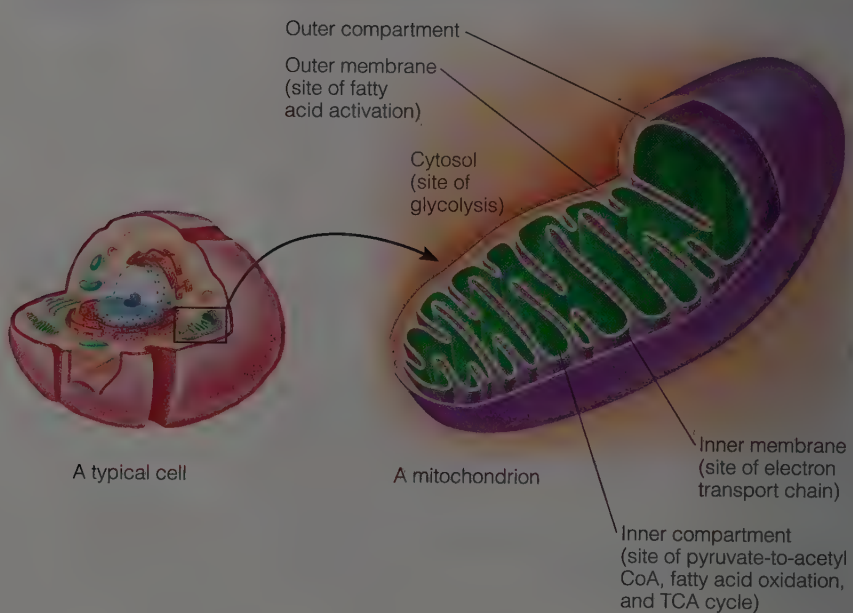
fatty acids, but it cannot be used to make glucose or amino acids. When ATP is low and the cell needs energy, acetyl CoA may proceed through the TCA cycle, releasing hydrogens with their electrons to the electron transport chain.

The TCA Cycle The TCA cycle reactions take place in the inner compartment of the mitochondria. Examine the structure of the mitochondria shown in Figure 7-14. The significance of its structure will become evident as details unfold.

When cells need energy, acetyl CoA enters the TCA cycle, a busy metabolic traffic center. The TCA cycle is a circular path, but that doesn't mean it regenerates acetyl CoA. Acetyl CoA goes one way only—down to two carbon dioxide molecules and a coenzyme (CoA). The TCA cycle is a circular path because a 4-carbon compound known as **oxaloacetate** is needed in the first step and it is synthesized in the last step.

Oxaloacetate's role in replenishing the TCA cycle is critical. When oxaloacetate is insufficient, the TCA cycle slows down, and the cells face an energy crisis. Oxaloacetate is made primarily from pyruvate, although it can also be made from certain amino acids. Importantly, oxaloacetate cannot be made from fat. That oxaloacetate must be available for acetyl CoA to enter the TCA cycle underscores the importance of carbohydrates in the diet. A diet that provides ample carbohydrate

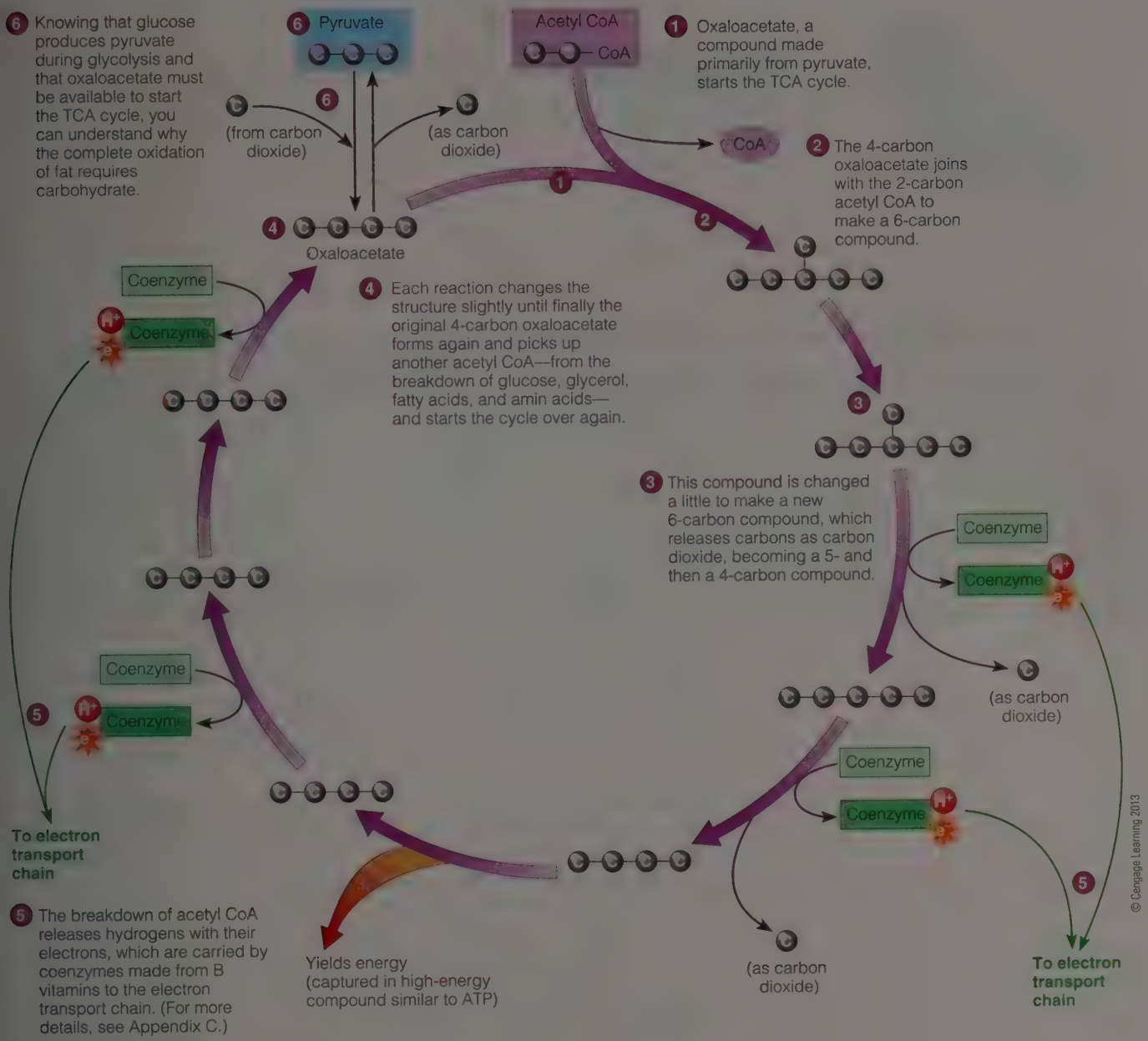
> **FIGURE 7-14 A Mitochondrion**



oxaloacetate (OKS-ah-low-AS-eh-tate): a carbohydrate intermediate of the TCA cycle.

© Cengage Learning 2013

FIGURE 7-15 The TCA Cycle

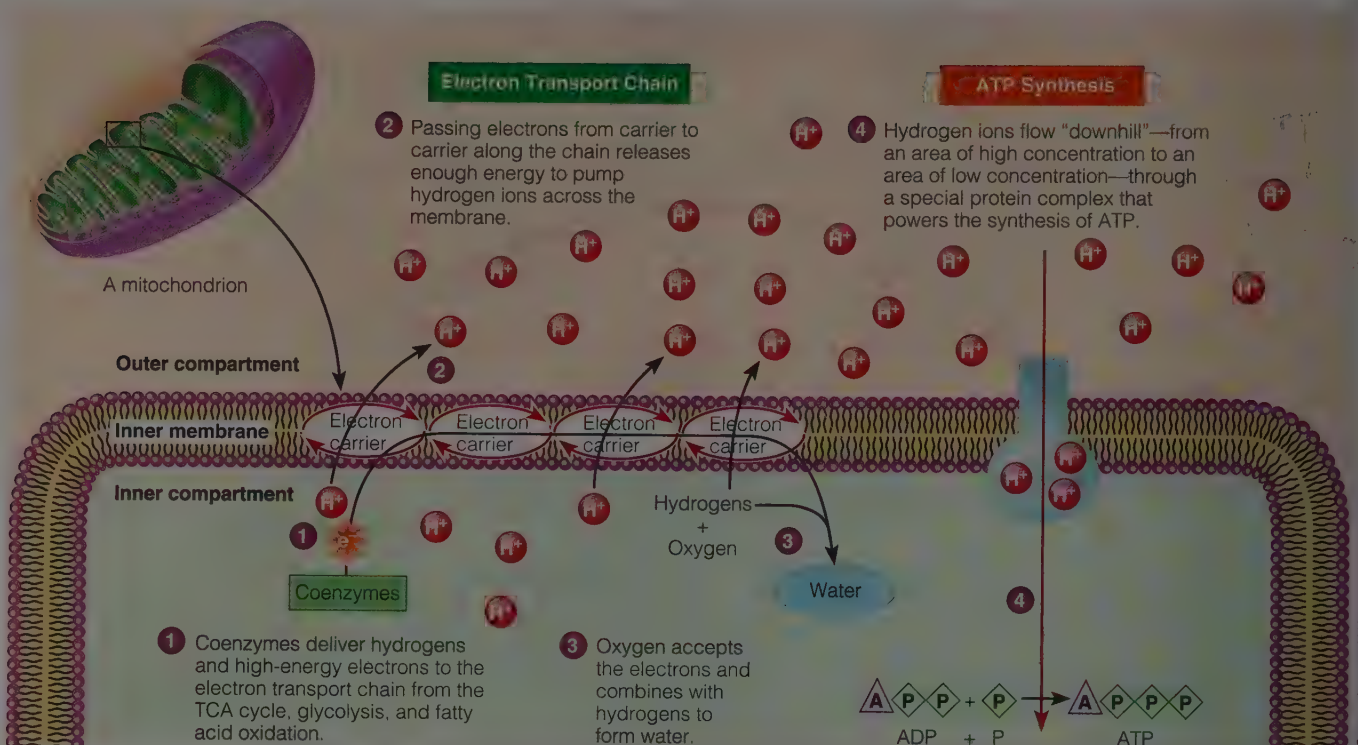


ensures an adequate supply of oxaloacetate—because glucose produces pyruvate during glycolysis. (This chapter closes with a discussion of the consequences of low-carbohydrate diets.)

As Figure 7-15 shows, oxaloacetate is the first 4-carbon compound to enter the TCA cycle. Oxaloacetate picks up acetyl CoA (a 2-carbon compound), drops off one carbon (as carbon dioxide), then another carbon (as carbon dioxide), and returns to pick up another acetyl CoA. As for the acetyl CoA, its carbons go only one way—to carbon dioxide (see Appendix C for additional details).*

*Actually, the carbons that enter the cycle in acetyl CoA may not be the exact ones that are given off as carbon dioxide. In one of the steps of the cycle, a 6-carbon compound of the cycle becomes symmetrical, both ends being identical. Thereafter it loses carbons to carbon dioxide at one end or the other. Thus only half of the carbons from acetyl CoA are given off as carbon dioxide in any one turn of the cycle; the other half become part of the compound that returns to pick up another acetyl CoA. It is true to say, though, that for each acetyl CoA that enters the TCA cycle, two carbons are given off as carbon dioxide. It is also true that with each turn of the cycle, the energy equivalent of one acetyl CoA is released.

> **FIGURE 7-16** **Electron Transport Chain and ATP Synthesis**



As compounds in the TCA cycle lose a carbon to carbon dioxide, hydrogen atoms with their electrons are carried off by coenzymes made from the B vitamins niacin and riboflavin to the electron transport chain—much like a taxicab that picks up passengers in one location and drops them off in another. Each turn of the TCA cycle releases a total of eight electrons.

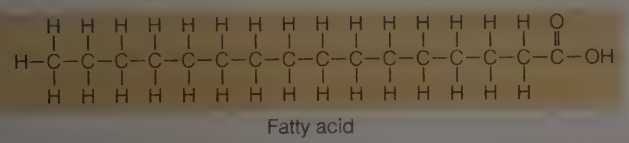
The Electron Transport Chain The electron transport chain captures energy in the high-energy bonds of ATP. The electron transport chain consists of a series of proteins that serve as electron "carriers." These carriers are mounted in sequence on the inner membrane of the mitochondria (shown in Figure 7-14, p. 210). As the coenzymes deliver their electrons from the TCA cycle, glycolysis, and fatty acid oxidation to the electron transport chain, each carrier receives the electrons and passes them on to the next carrier. These electron carriers continue passing the electrons down until they reach oxygen. Oxygen (O) accepts the electrons and combines with hydrogen atoms (H) to form water (H_2O). That oxygen must be available for energy metabolism explains why it is essential to life.

As electrons are passed from carrier to carrier, hydrogen ions are pumped across the membrane to the outer compartment of the mitochondria. The rush of hydrogen ions back into the inner compartment powers the synthesis of ATP. In this way, energy is captured in the bonds of ATP. The ATP leaves the mitochondria and enters the cytoplasm, where it can be used for energy. Figure 7-16 provides a simple diagram of the electron transport chain (see Appendix C for details).

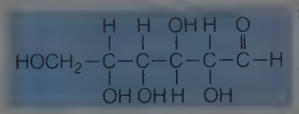
♦ Fat = 9 kcal/g
Carbohydrate = 4 kcal/g
Protein = 4 kcal/g

The kCalories-per-Gram Secret Revealed Of the three energy-yielding nutrients, fat provides the most energy per gram. ♦ The reason may be apparent in Figure 7-17, which compares a fatty acid with a glucose molecule. Notice that nearly all the bonds in the fatty acid are between carbons and hydrogens. Oxygen can be added to all of them—forming carbon dioxide (CO_2) with the carbons and water (H_2O) with the hydrogens. As this happens, hydrogens are released to coenzymes heading for the electron transport chain. In glucose, on the other hand, an oxygen is already bonded to each carbon. Thus there is less potential for oxidation, and fewer hydrogens are released when the remaining bonds are broken.

> **FIGURE 7-17 Chemical Structures of a Fatty Acid and Glucose Compared**
To ease comparison, the structure shown here for glucose is not the ring structure shown in Chapter 4, but an alternative way of drawing its chemical structure.



Fatty acid



Glucose

© Cengage Learning 2013

Because fat contains many carbon-hydrogen bonds that can be readily oxidized, it sends numerous coenzymes with their hydrogens and electrons to the electron transport chain where that energy can be captured in the bonds of ATP. This explains why fat yields more kcalories per gram than carbohydrate or protein. (Remember that each ATP holds energy and that kcalories measure energy; thus the more ATP, the more kcalories.) For example, one glucose molecule will yield 30 to 32 ATP when completely oxidized. In comparison, one 16-carbon fatty acid molecule will yield 129 ATP when completely oxidized. Fat is a more efficient fuel source. Gram for gram, fat can provide much more energy than either of the other two energy-yielding nutrients, making it the body's preferred form of energy storage. (Similarly, you might prefer to fill your car with a fuel that provides 130 miles per gallon versus one that provides 30 miles per gallon.)

REVIEW IT Summarize the main steps in the energy metabolism of glucose, glycerol, fatty acids, and amino acids.

Carbohydrate, fat, and protein take different paths to acetyl CoA, but once there, the final pathways—the TCA cycle and electron transport chain—are shared. All of the pathways, which are shown as a simplified overview in Figure 7-5 (p. 203), are shown again in more detail in Figure 7-18 (p. 214). Instead of dismissing this figure as "too busy," take a few moments to appreciate the busyness of it all. Consider that this figure is merely an overview of energy metabolism, and then imagine how busy a living cell really is during the metabolism of hundreds of compounds, each of which may be involved in several reactions, each requiring an enzyme.

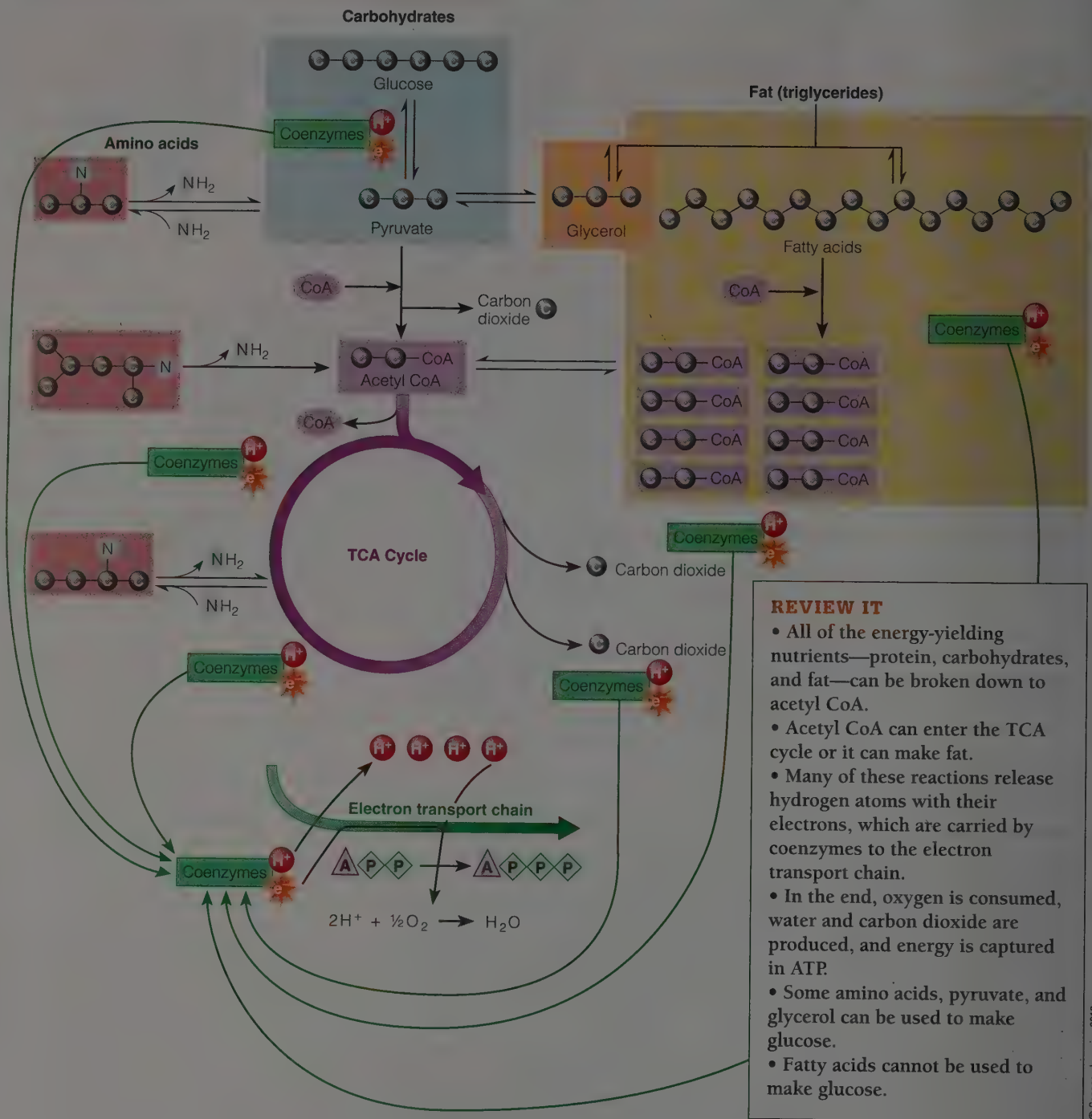
7.3 Feasting and Fasting

LEARN IT Explain how an excess of any of the three energy-yielding nutrients contributes to body fat and how an inadequate intake of any of them shifts metabolism.

Every day, a healthy diet delivers more than a thousand kcalories of energy—from carbohydrate, fat, and protein—to fuel the physical activity and metabolic work of the body. The details of energy metabolism have already been described; this discussion examines what happens when energy intake is excessive or inadequate and how metabolism shifts when the three energy-yielding nutrients are out of balance.

Feasting—Excess Energy When a person eats too much, metabolism favors fat formation. Fat cells enlarge regardless of whether the excess in kcalories derives from protein, carbohydrate, or fat. The pathway from dietary fat to body fat, however, is the most direct (requiring only a few metabolic steps) and the most efficient (costing only a few kcalories). To convert a dietary triglyceride to a triglyceride in adipose tissue, the body removes two of the fatty acids from the glycerol, absorbs the parts, and puts them (and others) together again. By comparison, to convert a molecule of sucrose, the body has to split glucose from fructose, absorb them, dismantle them to pyruvate and acetyl CoA, assemble many acetyl CoA molecules into fatty acid chains, and finally attach fatty acids to a glycerol molecule to make a triglyceride for storage in adipose tissue. Quite simply, the body uses much less energy to convert dietary fat to body fat than it does to convert dietary carbohydrate to body fat. On average, storing excess energy from dietary fat as body fat uses only 5 percent of the ingested energy intake, but storing excess energy from dietary carbohydrate as body fat requires 25 percent of the ingested energy intake.

> **FIGURE 7-18** The Central Pathways of Energy Metabolism



REVIEW IT

- All of the energy-yielding nutrients—protein, carbohydrates, and fat—can be broken down to acetyl CoA.
- Acetyl CoA can enter the TCA cycle or it can make fat.
- Many of these reactions release hydrogen atoms with their electrons, which are carried by coenzymes to the electron transport chain.
- In the end, oxygen is consumed, water and carbon dioxide are produced, and energy is captured in ATP.
- Some amino acids, pyruvate, and glycerol can be used to make glucose.
- Fatty acids cannot be used to make glucose.

© Cengage Learning 2013

The pathways from excess protein and excess carbohydrate to body fat are not only indirect and inefficient, but they are also less preferred by the body (having other priorities for using these nutrients). Before entering fat storage, protein must first tend to its many roles in the body's lean tissues, and carbohydrate must fill the glycogen stores. Simply put, using these two nutrients to make fat is a low priority for the body. Still, if eaten in abundance, any of the energy-yielding nutrients will be converted to fat for storage.

This chapter has described each of the energy-yielding nutrients individually, but cells use a mixture of these fuels. How much of which nutrient is in the fuel

mix depends, in part, on its availability from the diet.[1] (The proportion of each fuel also depends on physical activity, as Chapter 14 explains.) Usually, protein's contribution to the fuel mix is relatively minor and fairly constant, but protein oxidation does increase when protein is eaten in excess. Similarly, carbohydrate eaten in excess significantly enhances carbohydrate oxidation. In contrast, fat oxidation does *not* respond to dietary fat intake. The more protein or carbohydrate in the fuel mix, the less fat contributes to the fuel mix. Instead of being oxidized, fat accumulates in storage. Details follow.

Excess Protein Recall from Chapter 6 that the body cannot store excess amino acids as such; it has to convert them to other compounds. Contrary to popular opinion, a person cannot grow muscle simply by overeating protein. Lean tissue such as muscle develops in response to a stimulus such as hormones or physical activity. When a person overeats protein, the body uses the surplus first by replacing normal daily losses and then by increasing protein oxidation. An increase in protein oxidation uses some protein excess, but it displaces fat in the fuel mix. If excess protein is still available, the amino acids are deaminated and the remaining carbons are used to make fatty acids, which are stored as triglycerides in adipose tissue. Thus a person can grow fat by eating too much protein.

People who eat huge portions of meat and other protein-rich foods may wonder why they have weight problems. Not only does the fat in those foods lead to body fat, but the protein can, too, when energy intake exceeds energy needs. Many fad weight-loss diets encourage high protein intakes based on the false assumption that protein builds only muscle, not fat.

Excess Carbohydrate Compared with protein, the proportion of carbohydrate in the fuel mix changes more dramatically when a person overeats. The body handles abundant carbohydrate by first storing it as glycogen, but glycogen storage areas are limited and fill quickly. Because maintaining glucose balance is critical, the body uses glucose frugally when the diet provides only small amounts and freely when supplies are abundant. In other words, glucose oxidation rapidly adjusts to the dietary intake of carbohydrate.

Like protein, excess glucose can also be converted to fat directly.[2] This pathway is relatively minor, however. As mentioned earlier, converting glucose to fat is energetically expensive and does not occur until after glycogen stores have been filled. Even then, only a little, if any, new fat is made from carbohydrate.

Nevertheless, excess dietary carbohydrate can displace fat in the fuel mix.[3] When this occurs, carbohydrate spares both dietary fat and body fat from oxidation—an effect that may be more pronounced in overweight people than in lean people. The net result: excess carbohydrate contributes to obesity or at least to the maintenance of an overweight body.

Excess Fat Unlike excess protein and carbohydrate, which both increase oxidation, eating too much fat does not promote fat oxidation. Instead, excess dietary fat moves efficiently into the body's fat stores; almost all of the excess is stored.

The Transition from Feasting to Fasting

Figure 7-19 (p. 216) shows the metabolic pathways operating in the body as it shifts from feasting (part A) to fasting (parts B and C). After a meal, glucose, glycerol, and fatty acids from foods are used as needed and then stored. Later, as the body shifts from a fed state to a fasting one, it begins drawing on these stores. Glycogen and fat are released from storage to provide more glucose, glycerol, and fatty acids for energy.

Energy is needed all the time. Even when a person is asleep and totally relaxed, the cells are hard at work. In fact, this work—the cells' work that maintains all life processes without any conscious effort—represents about two-thirds of the total energy a person expends in a day.* The small remainder is the work that a person's muscles perform voluntarily during waking hours.

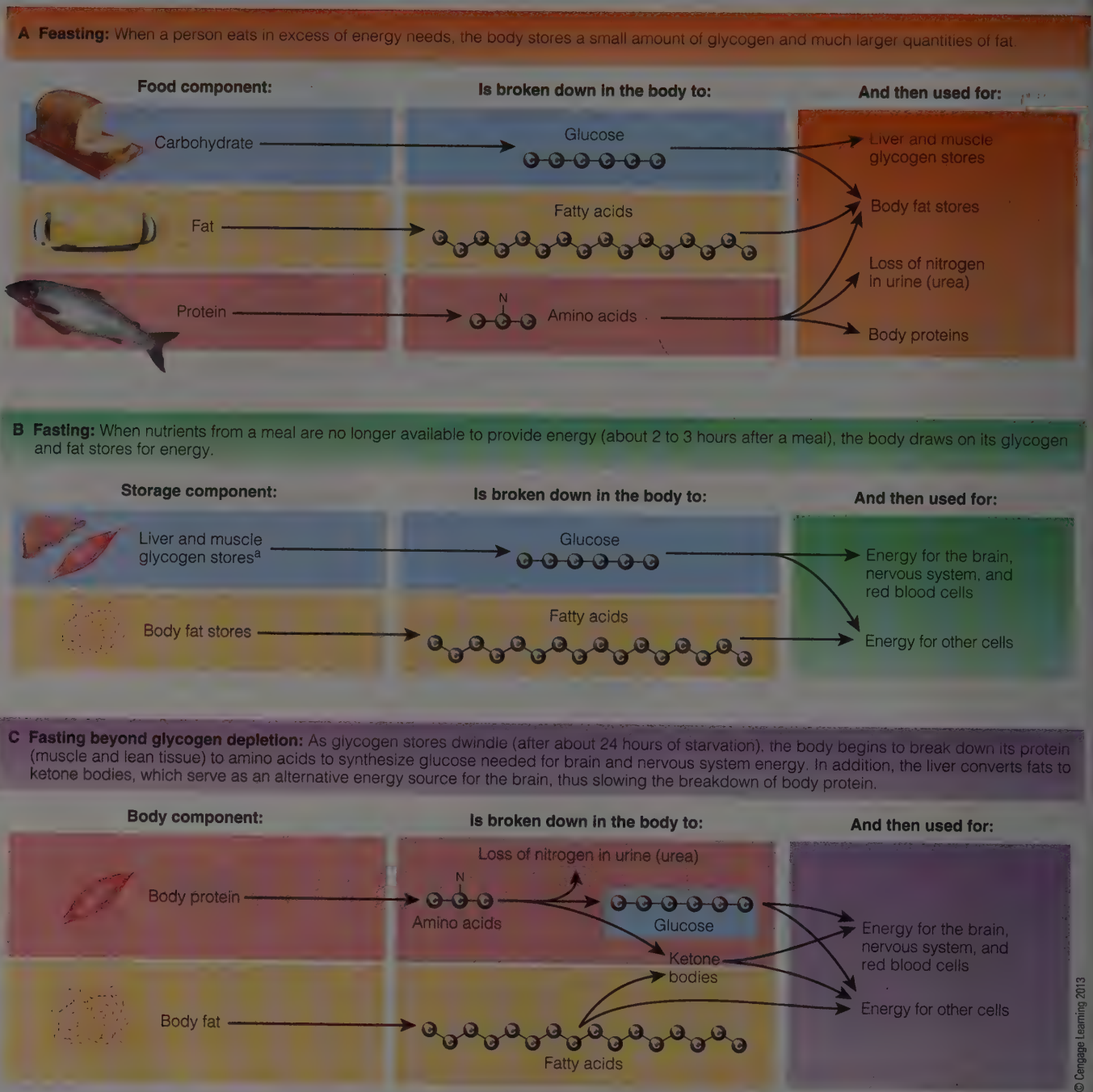


© Pixland/Jupiterimages.com

People can enjoy bountiful meals such as this without storing body fat, provided they expend as much energy as they take in.

*The cells' work that maintains all life processes refers to the body's *basal metabolism*, which is described in Chapter 8.

> **FIGURE 7-19 Feasting and Fasting**



NOTE: Alcohol is not included because it is a toxin and not a nutrient, but it does contribute energy to the body. After detoxifying the alcohol, the body uses the remaining two carbon fragments to build fatty acids and stores them as fat.

[a]The muscles' stored glycogen provides glucose only for the muscle in which the glycogen is stored.

The body's top priority is to meet the cells' needs for energy, and it normally does this by periodic refueling—that is, by eating several times a day. When food is not available, the body turns to its own tissues for fuel. If people choose not to eat, we say they are fasting; if they have no choice, we say they are starving. The body makes no such distinction. In either case, the body must draw on its reserves of carbohydrate and fat and, within a day or so, on its vital protein tissues as well.

Fasting—Inadequate Energy During fasting, carbohydrate, fat, and protein are all eventually used for energy—fuel must be delivered to every cell. As the fast begins, glucose from the liver's stored glycogen and fatty acids from the adipose tissue's stored fat travel to the cells. As described earlier, these molecules are broken down to acetyl CoA, which enters the energy pathways that power the cells' work. Several hours later, however, liver glycogen is depleted and blood glucose begins to fall. The body must adjust its normal metabolism to survive without food. Starvation demands cells to degrade their components for fuel.[4]

Adaptation: Making Glucose At this point, most cells are using fatty acids for their fuel. But, as mentioned earlier, red blood cells and the cells of the nervous system need glucose. Glucose is their primary energy fuel. Normally, the brain and nerve cells—which weigh only about three pounds—consume about half of the total *glucose* used each day (about 500 kcalories' worth). About one-fourth of the *energy* the adult body uses when it is at rest is spent by the brain.

During a fast, the need for glucose poses a major problem. The body can use its stores of fat, which may be quite generous, to furnish most of its cells with energy, but the red blood cells are completely dependent on glucose, and the brain and nerves prefer energy in the form of glucose.* Amino acids that yield pyruvate can be used for **gluconeogenesis**—the making of glucose from noncarbohydrate sources. The liver is the major site of gluconeogenesis, but the kidneys become increasingly involved under certain circumstances, such as starvation.

The glycerol portion of a triglyceride and most amino acids can be used to make glucose (review Figure 7-9, p. 206). To obtain the amino acids, body proteins must be broken down. ♦ For this reason, protein tissues such as muscle and liver always break down to some extent during fasting. The amino acids that cannot be used to make glucose are used as an energy source for other body cells.

The breakdown of body protein is an expensive way to obtain glucose. In the first few days of a fast, body protein provides about 90 percent of the needed glucose; glycerol, about 10 percent. If body protein losses were to continue at this rate, death would follow within three weeks, regardless of the quantity of fat a person had stored. Fortunately, fat breakdown also increases with fasting—in fact, fat breakdown almost doubles, providing energy for other body cells and glycerol for glucose production.

Adaptation: Creating an Alternate Fuel As the fast continues, the body finds a way to use its fat to fuel the brain. It adapts by combining acetyl CoA fragments derived from fatty acids to produce an alternate energy source, **ketone bodies** (see Figure 7-20, p. 218). Normally produced and used only in small quantities, ketone bodies can efficiently provide fuel for brain cells. Ketone body production rises until, after about 10 days of fasting, it is meeting much of the nervous system's energy needs. Still, many areas of the brain rely exclusively on glucose, and to produce it, the body continues to sacrifice protein—albeit at a slower rate than in the early days of fasting.

A ketone body that contains an acid group (COOH) is called a **keto acid.** Small amounts of keto acids are a normal part of the blood chemistry, but when their concentration rises, the pH of the blood drops. This is ketosis, a sign that the body's chemistry is going awry. Acidic blood denatures proteins, leaving them unable to function. Elevated blood ketones (ketonemia) are excreted in the urine (ketonuria). A fruity odor on the breath (known as acetone breath) develops, reflecting the presence of the ketone acetone.

Ketosis induces a loss of appetite. As starvation continues, this loss of appetite becomes an advantage to a person without access to food. When food becomes available again and the person eats, the body shifts out of ketosis and appetite returns.

*Red blood cells contain no mitochondria. Review Figure 7-1 (p. 198) to fully appreciate why red blood cells must depend on glucose for energy.



© David Buffington/PhotoLibrary.com

The brain and nerve cells depend on glucose—either directly from carbohydrates or indirectly from proteins (through gluconeogenesis). Importantly, fatty acids cannot provide glucose.

♦ 1 g protein can make ½ g glucose

gluconeogenesis (gloo-ko-nee-oh-JEN-ih-sis): the making of glucose from a noncarbohydrate source such as amino acids or glycerol.

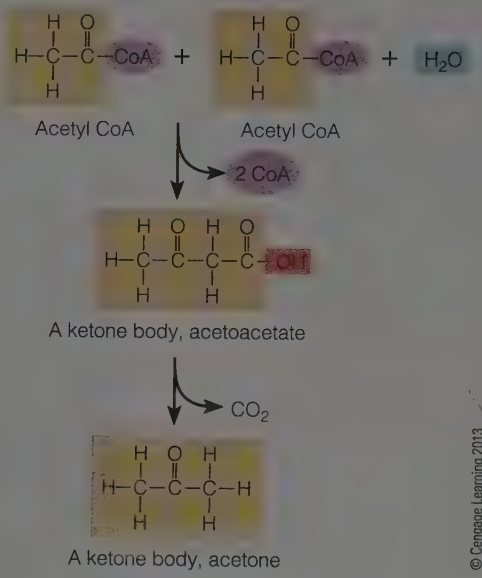
- **gluco** = glucose
- **neo** = new
- **genesis** = making

ketone (KEE-tone) **bodies:** compounds produced during the incomplete breakdown of fat when glucose is not available in the cells.

keto (KEY-toe) **acid:** an organic acid that contains a carbonyl group (C=O).

> **FIGURE 7-20 Ketone Body Formation**

1. The first step in the formation of ketone bodies is the condensation of two molecules of acetyl CoA and the removal of the CoA to form a compound that is converted to the first ketone body, acetoacetate.



2. Acetoacetate may lose a molecule of carbon dioxide to become another ketone body, acetone.

3. Or, acetoacetate may add two hydrogens, becoming another ketone body (beta-hydroxybutyrate). See Appendix C for more details.

© Cengage Learning 2013

Adaptation: Conserving Energy In an effort to conserve body tissues for as long as possible, the hormones of fasting slow metabolism. As the body shifts to the use of ketone bodies, it simultaneously reduces its energy output and conserves both its fat and its lean tissue. Still the lean protein tissues shrink and perform less metabolic work, reducing energy expenditures. As the muscles waste, they can do less work and so demand less energy, reducing expenditures further. Although fasting may promote dramatic *weight* loss, a low-kcalorie diet and physical activity better support *fat* loss while retaining lean tissue.

These adaptations of fasting—slowing of energy output and reduction in fat loss—occur in the starving child, the hungry homeless adult, the fasting religious person, the adolescent with anorexia nervosa, and the malnourished hospital patient. Such adaptations help to prolong their lives and explain the physical symptoms of starvation: wasting; slowed heart rate, respiration, and metabolism; lowered body temperature; impaired vision; organ failure; and reduced resistance to disease. Psychological effects of food deprivation include depression, anxiety, and food-related dreams.

The body's adaptations to fasting are sufficient to maintain life for a long time—up to 2 months. Mental alertness need not be diminished, and even some physical energy may remain unimpaired for a surprisingly long time. These remarkable adaptations, however, should not prevent anyone from recognizing the very real hazards that fasting presents.

Low-Carbohydrate Diets

When a person consumes a low-carbohydrate diet, a metabolism similar to that of fasting prevails. With little dietary carbohydrate coming in, the body uses its glycogen stores to provide glucose for the cells of the brain, nerves, and blood. Once the body depletes its glycogen reserves, it begins making glucose from the amino acids of protein (gluconeogenesis). A low-carbohydrate diet may provide abundant protein from food, but the body still uses some protein from body tissues.

Dieters can know glycogen depletion has occurred and gluconeogenesis has begun by monitoring their urine. Whenever glycogen or protein is broken down, water is released and urine production increases. Low-carbohydrate diets also induce ketosis, and ketones can be detected in the urine. Ketones form whenever glucose is lacking and fat breakdown is incomplete.

Many fad diets regard ketosis as the key to losing weight, but studies comparing weight-loss diets find no relation between ketosis and weight loss. People in ketosis may experience a loss of appetite and a dramatic weight loss within the first few days.[5] They should know that much of this weight loss reflects the loss of glycogen and protein together with large quantities of body fluids and important minerals. They need to appreciate the difference between loss of *fat* and loss of *weight*. Fat losses on ketogenic diets are no greater than on other diets providing the same number of kcalories. Once the dieter returns to well-balanced meals that provide adequate energy, carbohydrate, fat, protein, vitamins, and minerals, the body avidly retains these needed nutrients.



© Matthew Farruggio

Low-carbohydrate meals overemphasize meat, fish, poultry, eggs, and cheeses, and shun breads, pastas, fruits, and starchy vegetables.

The weight will return, quite often to a level higher than the starting point. Table 7-3 lists other consequences of a ketogenic diet.

TABLE 7-3 Adverse Side Effects of Low-Carbohydrate, Ketogenic Diets

- Nausea
- Fatigue (especially if physically active)
- Constipation
- Low blood pressure
- Elevated uric acid (which may exacerbate kidney disease and cause inflammation of the joints in those predisposed to gout)
- Stale, foul taste in the mouth (bad breath)
- In pregnant women, fetal harm and stillbirth

REVIEW IT Explain how an excess of any of the three energy-yielding nutrients contributes to body fat and how an inadequate intake of any of them shifts metabolism.

When energy intake exceeds energy needs, the body makes fat—regardless of whether the excess intake is from protein, carbohydrate, or fat. The only difference is that the body is much more efficient at storing energy when the excess derives from dietary fat.

When fasting, the body makes a number of adaptations: increasing the breakdown of fat to provide energy for most of the cells, using glycerol and amino acids to make glucose for the red blood cells and central nervous system, producing ketones to fuel the brain, suppressing the appetite, and slowing metabolism. All of these measures conserve energy and minimize losses. Low-carbohydrate diets incur similar changes in metabolism.

This chapter has probed the intricate details of metabolism at the level of the cells. Several upcoming chapters and highlights build on this information. The highlight that follows this chapter focuses on how alcohol disrupts metabolism. Chapter 8 describes how a person's intake and expenditure of energy are reflected in body weight and body composition. Chapter 9 examines the consequences of unbalanced energy budgets—overweight and underweight. Chapter 10 shows the vital roles the B vitamins play as coenzymes assisting in all the metabolic pathways described here. And Chapter 14 revisits metabolism to show how it supports the work of physically active people and how athletes can best apply that information in their choices of foods to eat.

Nutrition Portfolio

All day, every day, your cells dismantle carbohydrates, fats, and proteins, with the help of vitamins, minerals, and water, releasing energy to meet your body's immediate needs or storing it as fat for later use. Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Intake vs. Goals report and answer the following questions. Keep in mind that in this report 100 percent means you are meeting your needs perfectly.

- How close were you to 100 percent for: carbohydrates, fats, proteins, vitamins, minerals, and water? In general, which category was lowest? Which category was highest?
- Describe what types of foods best support aerobic and anaerobic activities.
- Consider whether you eat more protein, carbohydrate, or fat than your body needs.
- Explain how a low-carbohydrate diet forces your body into ketosis.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. A. Wise, Transcriptional switches in the control of macronutrient metabolism, *Nutrition Reviews* 66 (2008): 321–325.
2. M. F. Chong and coauthors, Parallel activation of de novo lipogenesis and stearoyl-CoA desaturase activity after 3 d of high-carbohydrate feeding, *American Journal of Clinical Nutrition* 87 (2008): 817–823.
3. R. Roberts and coauthors, Reduced oxidation of dietary fat after a short-term high-carbohydrate diet, *American Journal of Clinical Nutrition* 87 (2008): 824–831.
4. M. H. Stipanuk, Macroautophaghy and its role in nutrient homeostasis, *Nutrition Reviews* 67 (2009): 677–689.
5. A. M. Johnstone and coauthors, Effects of a high-protein ketogenic diet on hunger, appetite, and weight loss in obese men feeding ad libitum, *American Journal of Clinical Nutrition* 87 (2008): 44–55.

LEARN IT Describe how alcohol disrupts metabolism and impairs health.



Alcohol in the Body

With the understanding of metabolism gained from Chapter 7, you are in a position to understand how the body handles alcohol, how alcohol interferes with metabolism, and how alcohol impairs health and nutrition. Before examining alcohol's damaging effects, it may be appropriate to mention that drinking alcohol in *moderation* may have some health benefits, including reduced risks of heart disease, diabetes, and osteoporosis.[1] Moderate alcohol consumption may lower mortality from all causes, but only in adults aged 35 and older.[2] No health benefits are evident before middle age. Similarly, health benefits begin to disappear in older age, as metabolism changes and organs become more sensitive to toxic substances.[3] Importantly, any benefits of moderate alcohol use must be weighed against the many harmful effects of excessive alcohol use described in this highlight, as well as the possibility of alcohol abuse.[4]

Alcohol in Beverages

To the chemist, **alcohol** refers to a class of organic compounds containing hydroxyl (OH) groups (the accompanying glossary defines *alcohol* and related terms). The glycerol to which fatty acids are attached in triglycerides is an example of an alcohol to a chemist. To most people, though, *alcohol* refers to the intoxicating ingredient in **beer, wine,** and **liquor (distilled spirits).** The chemist's name for this particular alcohol is *ethyl alcohol,* or **ethanol.** Glycerol has three carbons with three hydroxyl groups attached; ethanol has only two carbons and one hydroxyl group (see Figure H7-1). The remainder of this highlight talks about the particular alcohol ethanol but refers to it simply as *alcohol.*

Alcohols affect living things profoundly, partly because they act as lipid solvents. Their ability to dissolve lipids out of cell membranes allows alcohols to penetrate rapidly into cells,

GLOSSARY

acetaldehyde (ass-et-AL-duh-hide): an intermediate in alcohol metabolism.

alcohol: a class of organic compounds containing hydroxyl (OH) groups.

- **ol** = alcohol

alcohol abuse: a pattern of drinking that includes failure to fulfill work, school, or home responsibilities; drinking in situations that are physically dangerous (as in driving while intoxicated); recurring alcohol-related legal problems (as in aggravated assault charges); or continued drinking despite ongoing social problems that are caused by or worsened by alcohol.

alcohol dehydrogenase (dee-high-DROJ-eh-nayz): an enzyme active in the stomach and the liver that converts ethanol to acetaldehyde.

alcoholism: a pattern of drinking that includes a strong craving for alcohol, a loss of control and an inability to stop drinking once begun, withdrawal symptoms (nausea, sweating, shakiness, and anxiety) after heavy drinking, and the need for increasing amounts of alcohol to feel "high."

antidiuretic hormone (ADH): a hormone produced by the pituitary gland in response to dehydration (or a high sodium concentration in the blood) that stimulates the kidneys to reabsorb more water and therefore to excrete less. In addition to its antidiuretic effect, ADH elevates blood pressure and so is also called *vasopressin* (VAS-oh-PRES-in).

beer: an alcoholic beverage traditionally brewed by fermenting malted barley and adding hops for flavor.

binge drinking: pattern of drinking that raises blood alcohol concentration to 0.08 percent or higher, usually corresponds to four or more drinks for women and five or more drinks for men on a single occasion, generally within a couple of hours.

cirrhosis (seer-OH-sis): advanced liver disease in which liver cells turn orange, die, and harden, permanently losing their function; often associated with alcoholism.

- **cirrhos** = an orange

drink: a dose of any alcoholic beverage that delivers ½ ounce of pure ethanol:

- 5 ounces of wine
- 10 ounces of wine cooler
- 12 ounces of beer
- 1½ ounces of liquor (80 proof whiskey, scotch, rum, or vodka)

drug: a substance that can modify one or more of the body's functions.

ethanol: a particular type of alcohol found in beer, wine, and liquor; also called *ethyl alcohol* (see Figure H7-1). Ethanol is the most widely used—and abused—drug in our society. It is also the only legal, nonprescription drug that produces euphoria.

excessive drinking: heavy drinking, binge drinking, or both.

fatty liver: an early stage of liver deterioration seen in several diseases, including kwashiorkor and alcoholic liver disease. Fatty liver is characterized by an accumulation of fat in the liver cells.

fibrosis (fye-BROH-sis): an intermediate stage of liver deterioration seen in several diseases, including viral hepatitis and alcoholic liver disease. In fibrosis, the liver cells lose their function and assume the characteristics of connective tissue cells (fibers).

heavy drinking: consuming an average of more than one drink per day for women and more than two drinks per day for men.

liquor or **distilled spirits:** an alcoholic beverage traditionally made by fermenting and distilling a carbohydrate source such as molasses, potatoes, rye, beets, barley, or corn.

MEOS or **microsomal** (my-krow-SO-mal) **ethanol-oxidizing system:** a system of enzymes in the liver that oxidize not only alcohol but also several classes of drugs.

moderation: up to one drink per day for women with no more than three drinks on any single day and up to two drinks per day for men with no more than four drinks on any single day.

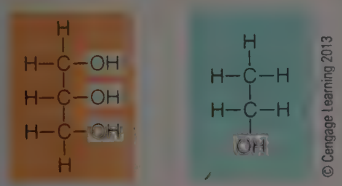
narcotic (nar-KOT-ic): a drug that dulls the senses, induces sleep, and becomes addictive with prolonged use.

proof: a way of stating the percentage of alcohol in distilled liquor. Liquor that is 100 proof is 50 percent alcohol; 90 proof is 45 percent, and so forth.

Wernicke-Korsakoff (VER-nee-key KORE-sah-kof) **syndrome:** a neurological disorder typically associated with chronic alcoholism and caused by a deficiency of the B vitamin thiamin; also called *alcohol-related dementia.*

wine: an alcoholic beverage traditionally made by fermenting a sugar source such as grape juice.

> **FIGURE H7-1 Two Alcohols: Glycerol and Ethanol**



Glycerol is the alcohol used to make triglycerides.

Ethanol is the alcohol in beer, wine, and liquor.

destroying cell structures and thereby killing the cells. For this reason, most alcohols are toxic in relatively small amounts; by the same token, because they kill microbial cells, they are useful as skin disinfectants.

Ethanol is less toxic than the other alcohols. Sufficiently diluted and taken in small enough doses, its action in the brain produces an effect that people seek—not with zero risk, but with a low enough risk (if the doses are low enough) to be tolerable. Used in this way, alcohol is a **drug**—that is, a substance that modifies body functions. Like all drugs, alcohol both offers benefits and poses hazards. The *Dietary Guidelines for Americans* advise "if alcohol is consumed, it should be consumed in moderation."



> DIETARY GUIDELINES FOR AMERICANS 2010

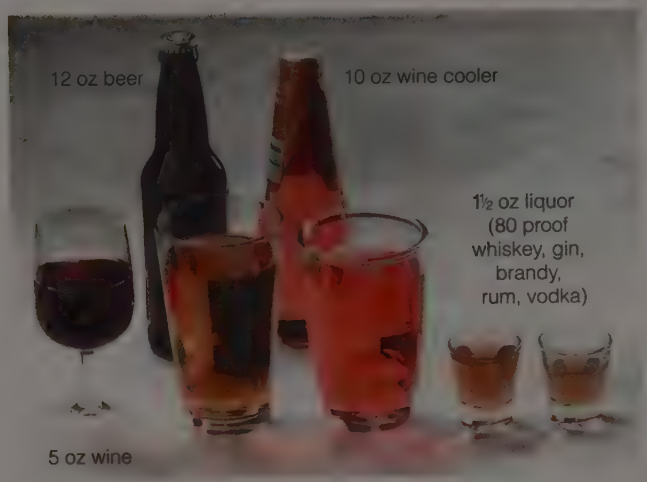
- If alcohol is consumed, it should be consumed in moderation—up to one drink per day for women and two drinks per day for men—and only by adults of legal drinking age.
- Alcoholic beverages should not be consumed by some individuals, including those who cannot restrict their alcohol intake to moderate levels, women of childbearing age who may become pregnant, pregnant and lactating women, children and adolescents, individuals taking medications that can interact with alcohol, and those with specific medical conditions.
- Alcoholic beverages should not be consumed by individuals engaging in activities that require attention, skill, or coordination, such as driving or swimming.

The term **moderation** is important when describing alcohol use. How many drinks constitute moderate use, and how much is "a drink"? First, a **drink** is any alcoholic beverage that delivers ½ ounce of *pure ethanol:*

- 5 ounces of wine
- 10 ounces of wine cooler
- 12 ounces of beer
- 1½ ounces of liquor (80 proof whiskey, scotch, rum, or vodka)

As a practical tip, prevent overpouring by measuring liquids and using tall, narrow glasses.

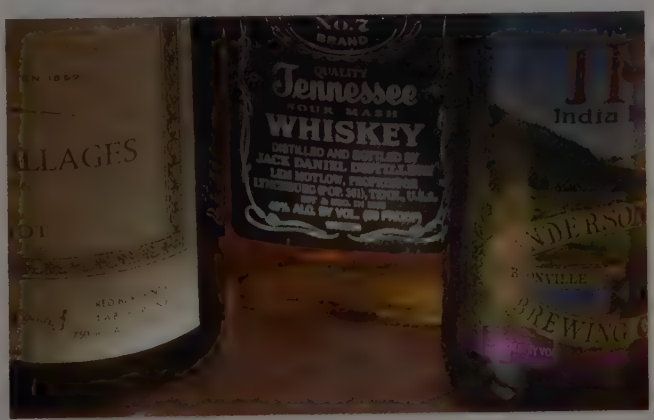
Beer, wine, and liquor deliver different amounts of alcohol. The amount of alcohol in liquor is stated as **proof:** 100 proof liquor is 50 percent alcohol, 80 proof is 40 percent alcohol, and so forth. Wine and



Each of these servings equals one drink. Moderation is up to one drink per day for women and two drinks per day for men.

beer have less alcohol than liquor, although some fortified wines and beers have more alcohol than the regular varieties (see photo caption below).

Second, because people have different tolerances for alcohol, it is impossible to name an exact daily amount of alcohol that is appropriate for everyone. Authorities have attempted to identify amounts that are acceptable for most healthy people. An accepted definition of *moderation* is up to two drinks per day for men and up to one drink per day for women. (Pregnant women are advised to abstain from alcohol, as Highlight 15 explains.) Notice that this advice is stated as a maximum, not as an average; seven drinks one night a week would not be considered moderate, even though one a day would be. Doubtless,



Wines contain 7 to 24 percent alcohol by volume; those containing 14 percent or more must state their alcohol content on the label, whereas those with less than 14 percent may simply state "table wine" or "light wine." Beers typically contain less than 5 percent alcohol by volume and malt liquors, 5 to 8 percent; regulations vary, with some states requiring beer labels to show the alcohol content and others prohibiting such statements.

some people could consume slightly more; others could not handle nearly so much without risk. The amount a person can drink safely is highly individual, depending on genetics, health, gender, body composition, age, and family history.

Alcohol's Influence

From the moment an alcoholic beverage enters the body, alcohol is treated as if it has special privileges. Its influence is most apparent in the GI tract, the liver, and the brain.

In the GI Tract

Unlike foods, which require time for digestion, alcohol needs no digestion and is quickly absorbed across the walls of an empty stomach, reaching the brain within a few minutes. Consequently, a person can immediately feel euphoric when drinking, especially on an empty stomach.

When the stomach is full of food, alcohol has less chance of touching the walls and diffusing through, so its influence on the brain is slightly delayed. This information leads to another practical tip: eat snacks when drinking alcoholic beverages. Carbohydrate snacks slow alcohol absorption and high-fat snacks slow peristalsis, keeping the alcohol in the stomach longer. Salty snacks make a person thirsty; to quench thirst, drink water instead of more alcohol.

The stomach begins to break down alcohol with its **alcohol dehydrogenase** enzyme. Women produce less of this stomach enzyme than men; consequently, more alcohol reaches the intestine for absorption into the bloodstream. As a result, women absorb more alcohol than men of the same size who drink the same amount of alcohol. Consequently, they are more likely to become more intoxicated on less alcohol than men. Such differences between men and women help explain why women have a lower alcohol tolerance and a lower guideline for moderate intake.

In the small intestine, alcohol is rapidly absorbed. From this point on, alcohol receives priority treatment: it gets absorbed and metabolized before most nutrients. Alcohol's priority status helps to ensure a speedy disposal and reflects two facts: alcohol cannot be stored in the body, and it is potentially toxic.

In the Liver

As Chapter 3 explains, the capillaries of the digestive tract merge into veins that carry blood first to the liver. These veins branch and rebranch into a capillary network that touches every liver cell. Consequently, liver cells are the first to receive alcohol-laden blood. Liver cells are also the only other cells in the body that can make enough of the alcohol dehydrogenase enzyme to oxidize alcohol at an appreciable rate. The routing of blood through the liver cells gives them the chance to dispose of some alcohol before it moves on.

Alcohol affects every organ of the body, but the most dramatic evidence of its disruptive behavior appears in the liver. If liver cells could talk, they would describe alcohol as demanding, egocentric, and disruptive of the liver's efficient way of running its business. For example, liver cells normally prefer fatty acids as their fuel, and they like to package excess fatty acids into triglycerides and ship them out to other tissues. When alcohol is present, however, the liver cells metabolize alcohol first and let the fatty acids accumulate, sometimes in huge stockpiles. Alcohol metabolism can also permanently change liver cell structure, impairing the liver's ability to metabolize fats. As a result, heavy drinkers develop fatty livers.

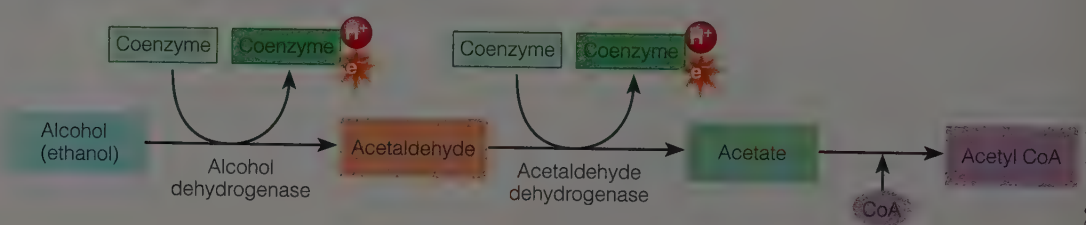
The liver is the primary site of alcohol metabolism. It can process about ½ ounce of *ethanol* per hour (the amount defined as a drink), depending on the person's body size, previous drinking experience, food intake, and general health. This maximum rate of alcohol breakdown is determined by the amount of alcohol dehydrogenase available. If more alcohol arrives at the liver than the enzymes can handle, the extra alcohol travels around the body, circulating again and again until liver enzymes are finally available to process it. Another practical tip derives from this information: drink slowly enough to allow the liver to keep up—no more than one drink per hour.

The amount of alcohol dehydrogenase enzyme present in the liver varies with individuals, depending on the genes they have inherited and on how recently they have eaten. Fasting for as little as a day prompts the body to degrade its proteins, including the alcohol-processing enzymes, and this can slow the rate of alcohol metabolism by half. Drinking after not eating all day thus causes the drinker to feel the effects more promptly for two reasons: rapid absorption and slowed breakdown.

Figure H7-2 provides a simplified diagram of alcohol metabolism; Appendix C provides the chemical details. The alcohol dehydrogenase enzyme breaks down alcohol by removing hydrogens in two steps. In the first step, alcohol dehydrogenase oxidizes alcohol to

> FIGURE H7-2 Alcohol Metabolism

The conversion of alcohol to acetyl CoA requires the B vitamin niacin in its role as a coenzyme. When the enzymes oxidize alcohol, they remove H atoms and attach them to the niacin coenzyme.



© Cengage Learning 2013

acetaldehyde—a highly reactive and toxic compound. High concentrations of acetaldehyde in the brain and other tissues are responsible for many of the damaging effects of **alcohol abuse.**

In the second step, a related enzyme, acetaldehyde dehydrogenase, converts acetaldehyde to acetate, which is then converted to either carbon dioxide (CO_2) or acetyl CoA—the compound that plays such a central role in energy metabolism, as described in Chapter 7. The reactions from alcohol to acetaldehyde to acetate produce hydrogens (H^+) and electrons. The B vitamin niacin, in its role as a coenzyme, helpfully picks up these hydrogens and electrons and escorts them to the electron transport chain. (Chapter 10 presents information on the coenzyme roles of the B vitamins.)

During alcohol metabolism, the multitude of other metabolic processes for which the niacin coenzyme is required, including glycolysis, the TCA cycle, and the electron transport chain, falter. Its presence is sorely missed in these energy pathways because it is the chief carrier of the hydrogens that travel with their electrons along the electron transport chain. Without adequate coenzymes, these energy pathways cannot function. Traffic either backs up or an alternate route is taken.

Such changes in the normal flow of energy pathways have striking metabolic consequences. For one, the accumulation of hydrogen ions during alcohol metabolism shifts the body's acid-base balance toward acid. For another, alcohol's interference with energy metabolism promotes the making of lactate from pyruvate. The conversion of pyruvate to lactate uses some of the excess hydrogens, but a lactate build-up has serious consequences of its own—it adds still further to the body's acid burden and interferes with the excretion of another acid, uric acid, causing inflammation of the joints.

Alcohol alters both amino acid and protein metabolism. Synthesis of proteins important in the immune system slows down, weakening the body's defenses against infections. Evidence of protein deficiency becomes apparent, both from a diminished synthesis of proteins and from a poor diet. Normally, the cells would at least use the amino acids from the protein foods a person eats, but the drinker's liver deaminates the amino acids and uses the carbon fragments primarily to make fat or ketone bodies. Eating well does not protect the drinker from protein depletion; a person has to stop drinking alcohol.

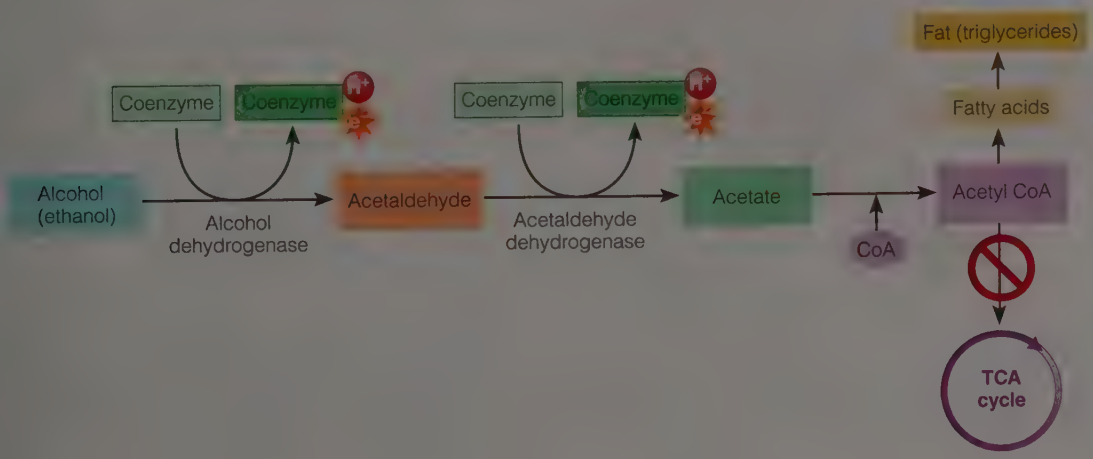
The accumulation of coenzymes with their hydrogens and electrons slows the TCA cycle, so pyruvate and acetyl CoA build up. Excess acetyl CoA then takes the pathway to fatty acid synthesis (as Figure H7-3 illustrates), and fat clogs the liver. As you might expect, a liver overburdened with fat cannot function properly. Liver cells become less efficient at performing a number of tasks. Much of this inefficiency impairs a person's nutritional health in ways that cannot be corrected by diet alone. For example, the liver has difficulty activating vitamin D, as well as producing and releasing bile. The fatty liver has difficulty making glucose from protein. Without gluconeogenesis, blood glucose can plummet, leading to irreversible damage to the central nervous system. The lack of glucose together with the overabundance of acetyl CoA sets the stage for ketosis. The body uses excess acetyl CoA to make ketone bodies; their acidity pushes the acid-base balance further toward acid and suppresses nervous system activity. To overcome such problems, a person needs to stop drinking alcohol.

The synthesis of fatty acids accelerates with exposure to alcohol. Fat accumulation can be seen in the liver after a single night of heavy drinking. **Fatty liver,** the first stage of liver deterioration seen in heavy drinkers, interferes with the distribution of nutrients and oxygen to the liver cells. Fatty liver is reversible with abstinence from alcohol. If fatty liver lasts long enough, however, the liver cells will die and form fibrous scar tissue. This second stage of liver deterioration is called **fibrosis.** Some liver cells can regenerate with good nutrition and abstinence from alcohol, but in the most advanced stage, **cirrhosis,** damage is the least reversible.

The liver's priority treatment of alcohol affects its handling of drugs as well as nutrients. In addition to the dehydrogenase enzyme already described, the liver possesses an enzyme system that metabolizes *both* alcohol and several other types of drugs. Called the **MEOS (microsomal ethanol-oxidizing system),** this system handles

> FIGURE H7-3 Alternate Route for Acetyl CoA: To Fat

Acetyl CoA molecules are blocked from getting into the TCA cycle by the low level of coenzymes. Instead of being used for energy, the acetyl CoA molecules become building blocks for fatty acids.



about one-fifth of the total alcohol a person consumes. At high blood concentrations or with repeated exposures, alcohol stimulates the synthesis of enzymes in the MEOS. The result is a more efficient metabolism of alcohol and tolerance to its effects.

As a person's blood alcohol rises, alcohol competes with—and wins out over—other drugs whose metabolism also relies on the MEOS. If a person drinks and uses another drug at the same time, the MEOS will dispose of alcohol first and metabolize the drug more slowly. While the drug waits to be handled later, the dose may build up so that its effects are greatly amplified—sometimes to the point of being fatal. Many drug labels provide warnings to avoid alcohol while taking the drug.

In contrast, once a heavy drinker stops drinking and alcohol is no longer competing with other drugs, the enhanced MEOS metabolizes drugs much faster than before. As a result, determining the correct dosages of medications can be challenging.

This discussion has emphasized the major way that the blood is cleared of alcohol—metabolism by the liver—but there is another way. About 10 percent of the alcohol leaves the body through the breath and in the urine. This is the basis for the breath and urine tests for drunkenness. The amounts of alcohol in the breath and in the urine are in proportion to the amount still in the bloodstream and brain. In nearly all states, legal drunkenness is set at 0.10 percent or less, reflecting the relationship between alcohol use and traffic and other accidents.

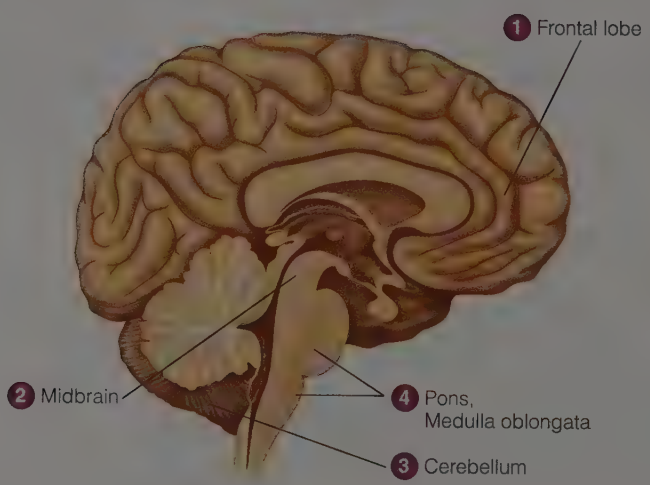
In the Brain

Figure H7-4 describes alcohol's effects on the brain. Alcohol is a **narcotic.** People used it for centuries as an anesthetic because it can deaden pain. But alcohol was a poor anesthetic because one could never be sure how much a person would need and how much would be a fatal dose. Today's anesthetics provide a more predictable response. Alcohol continues to be used socially to help people relax or to relieve anxiety. People think that alcohol is a stimulant because it seems to relieve inhibitions. Actually, though, it accomplishes this by sedating *inhibitory* nerves, which are more numerous than excitatory nerves. Ultimately, alcohol acts as a depressant and affects all the nerve cells.

It is lucky that the brain centers respond to a rising blood alcohol concentration in the order described in Figure H7-4 because a person usually passes out before managing to drink a lethal dose. It is possible, though, to drink so fast that the effects of alcohol continue to accelerate after the person has passed out. Occasionally, a person drinks so much as to stop breathing and die. Table H7-1 shows the blood alcohol levels that correspond to progressively greater intoxication, and Table H7-2 shows the brain responses that occur at these blood levels.

Like liver cells, brain cells die with excessive exposure to alcohol. Liver cells may be replaced, but not all brain cells can regenerate.

> **FIGURE H7-4 Alcohol's Effects on the Brain**



1. Judgment and reasoning centers are most sensitive to alcohol. When alcohol flows to the brain, it first sedates the frontal lobe, the center of all conscious activity. As alcohol diffuses into the cells of these lobes, it interferes with reasoning and judgment.

2. Speech and vision centers in the midbrain are affected next. If the drinker drinks faster than the rate at which the liver can oxidize the alcohol, blood alcohol concentrations rise: the speech becomes challenging and vision becomes blurry.

3. Voluntary muscular control is then affected. At still higher concentrations, the cells in the cerebellum responsible for coordination of voluntary muscles are affected, including those used in speech, eye-hand coordination, and limb movements. At this point people under the influence stagger or weave when they try to walk, or they may slur their speech.

4. Respiration and heart action are the last to be affected. Finally, the conscious brain is completely subdued, and the person passes out. Now the person can drink no more; this is fortunate because higher doses would anesthetize the deepest brain centers that control breathing and heartbeat, causing death.

© Cengage Learning 2013

TABLE H7-1 Alcohol Doses and Approximate Blood Level Percentages for Men and Women

Drinks[a]	Body Weight in Pounds—Men								
	100	120	140	160	180	200	220	240	
1	.04	.03	.03	.02	.02	.02	.02	.02	IMPAIRMENT BEGINS
2	.08	.06	.05	.05	.04	.04	.03	.03	
3	.11	.09	.08	.07	.06	.06	.05	.05	DRIVING SKILLS SIGNIFICANTLY AFFECTED
4	.15	.12	.11	.09	.08	.08	.07	.06	
5	.19	.16	.13	.12	.11	.09	.09	.08	
6	.23	.19	.16	.14	.13	.11	.10	.09	
7	.26	.22	.19	.16	.15	.13	.12	.11	LEGALLY INTOXICATED
8	.30	.25	.21	.19	.17	.15	.14	.13	
9	.34	.28	.24	.21	.19	.17	.15	.14	
10	.38	.31	.27	.23	.21	.19	.17	.16	

Drinks[a]	Body Weight in Pounds—Women								
	90	100	120	140	160	180	200	220	240
1	.05	.05	.04	.03	.03	.03	.02	.02	.02	IMPAIRMENT BEGINS
2	.10	.09	.08	.07	.06	.05	.05	.04	.04	
3	.15	.14	.11	.10	.09	.08	.07	.06	.06	DRIVING SKILLS SIGNIFICANTLY AFFECTED
4	.20	.18	.15	.13	.11	.10	.09	.08	.08	
5	.25	.23	.19	.16	.14	.13	.11	.10	.09	
6	.30	.27	.23	.19	.17	.15	.14	.12	.11	
7	.35	.32	.27	.23	.20	.18	.16	.14	.13	LEGALLY INTOXICATED
8	.40	.36	.30	.26	.23	.20	.18	.17	.15	
9	.45	.41	.34	.29	.26	.23	.20	.19	.17	
10	.51	.45	.38	.32	.28	.25	.23	.21	.19	

ONLY SAFE DRIVING LIMIT

© Cengage Learning 2013

NOTE Driving under the influence is proved when an adult's blood contains 0.08 percent alcohol. Many states have adopted a "zero tolerance" policy for drivers under age 21, using 0.00 to 0.02 percent as the limit.

[a]Taken within an hour or so; each drink equivalent to ½ ounce pure ethanol

SOURCE: National Clearinghouse for Alcohol and Drug Information

Thus some heavy drinkers suffer permanent brain damage. Whether alcohol impairs cognition in moderate drinkers is unclear.

Alcohol's Damage

As alcohol busily disrupts cellular activities, the physical consequences become apparent. People become dehydrated and malnourished; their alcohol use brings both short- and long-term effects.

Dehydration

People who drink alcoholic beverages may notice that they urinate more, but they may be unaware of the vicious cycle that results. Alcohol depresses production of **antidiuretic hormone (ADH)**, a hormone produced by the pituitary gland that retains water—consequently, with less ADH, more water is lost. Loss of body water leads to thirst, and thirst leads to more drinking. Water will relieve dehydration, but the thirsty drinker may drink alcohol instead, which only worsens the problem. Such information provides another practical tip: drink water when thirsty and before each alcoholic drink. Drink an extra glass or two before going to bed. This strategy will help lessen the effects of a hangover.

Water loss is accompanied by the loss of important minerals. As Chapters 12 and 13 explain, these minerals are vital to the body's fluid balance and to many chemical reactions in the cells; including muscle action. Detoxification treatment includes restoration of mineral balance as quickly as possible.

Malnutrition

For some light-to-moderate drinkers, alcohol may suppress food intake and prevent weight gains.[5] For others, however, alcohol may actually stimulate appetite. Moderate drinkers usually consume alcohol as *added* energy—on top of their normal food intake. In addition, alcohol in moderate doses is efficiently metabolized. Consequently, alcohol can contribute to body fat and weight gain—either by inhibiting oxidation or by being converted to fat. Metabolically, alcohol is almost as efficient as fat in promoting obesity; each ounce of alcohol represents about a half-ounce of fat. Alcohol's contribution to body fat is most evident in the central obesity that commonly accompanies alcohol consumption, popularly known as the "beer belly."[6]

Alcohol in heavy doses, though, is not efficiently metabolized, generating more heat than fat. Heavy drinkers usually consume alcohol

TABLE H7-2 Alcohol Blood Levels and Brain Responses

Blood Alcohol Concentration	Effect on Brain
0.05	Impaired judgment, relaxed inhibitions, altered mood, increased heart rate
0.10	Impaired coordination, delayed reaction time, exaggerated emotions, impaired peripheral vision, impaired ability to operate a vehicle
0.15	Slurred speech, blurred vision, staggered walk, seriously impaired coordination and judgment
0.20	Double vision, inability to walk
0.30	Uninhibited behavior, stupor, confusion, inability to comprehend
0.40 to 0.60	Unconsciousness, shock, coma, death (cardiac or respiratory failure)

© Cengage Learning 2013

NOTE: Blood alcohol concentration depends on a number of factors, including alcohol in the beverage, the rate of consumption, the person's gender, and body weight. For example, a 100-pound female can become legally drunk (≥0.10 concentration) by drinking three beers in an hour, whereas a 220-pound male consuming that amount at the same rate would have a 0.05 blood alcohol concentration.

as *substituted* energy—instead of their normal food intake. Diet quality declines as alcohol consumption increases.[7] Consequently, many heavy drinkers suffer malnutrition.

Alcohol is rich in energy (7 kcalories per gram), but as with pure sugar or fat, the kcalories are empty of nutrients. The more alcohol people drink, the less likely that they will eat enough food to obtain adequate nutrients. The more kcalories used for alcohol, the fewer kcalories available to use from nutritious foods. Table H7-3 shows the kcalorie amounts of typical alcoholic beverages.

Chronic alcohol abuse not only displaces nutrients from the diet, but it also interferes with the body's metabolism of nutrients. Most dramatic is alcohol's effect on the B vitamin folate. The liver loses its ability to retain folate, and the kidneys increase their excretion of it. Alcohol abuse creates a folate deficiency that devastates digestive system function. The small intestine normally releases and retrieves folate continuously, but it becomes damaged by folate deficiency and alcohol toxicity, so it fails to retrieve its own folate and misses any that may trickle in from food as well. Alcohol also interferes with the action of folate in converting the amino acid homocysteine to methionine. The result is an excess of homocysteine, which has been linked to heart disease, and an inadequate supply of methionine, which slows the production of new cells, especially the rapidly dividing cells of the intestine and the blood. The combination of poor folate status and alcohol consumption has also been implicated in promoting colorectal cancer.

The inadequate food intake and impaired nutrient absorption that accompany chronic alcohol abuse frequently lead to a deficiency of another B vitamin—thiamin. In fact, the cluster of thiamin-deficiency symptoms commonly seen in chronic **alcoholism** has its own name—**Wernicke-Korsakoff syndrome.**[8] This syndrome is characterized by paralysis of the eye muscles, poor muscle coordination, impaired memory, and damaged nerves; it and other alcohol-related memory problems may respond to thiamin supplements.

Acetaldehyde, an intermediate in alcohol metabolism (review Figure H7-2), interferes with nutrient use, too. For example, acetaldehyde dislodges vitamin B_6 from its protective binding protein so that it is destroyed, causing a vitamin B_6 deficiency and, thereby, lowered production of red blood cells.

Malnutrition occurs not only because of lack of intake and altered metabolism but because of direct toxic effects as well. Alcohol causes stomach cells to oversecrete both gastric acid and histamine, an immune system agent that produces inflammation. Beer in particular stimulates gastric acid secretion, irritating the linings of the stomach and esophagus and making them vulnerable to ulcer formation.

Overall, nutrient deficiencies are virtually inevitable in alcohol abuse, not only because alcohol displaces food but also because alcohol directly interferes with the body's use of nutrients, making them ineffective even if they are present. Intestinal cells fail to absorb B vitamins, notably, thiamin, folate, and vitamin B_{12}. Liver cells lose efficiency in activating vitamin D. Cells in the retina of the eye, which normally process the alcohol form of vitamin A (retinol) to the aldehyde form needed in vision (retinal), find themselves processing ethanol to acetaldehyde instead. Likewise, the liver cannot convert the aldehyde form of vitamin A to its acid form (retinoic acid), which is needed to support the growth of its (and all) cells. Regardless of dietary intake,

TABLE H7-3 kCalories in Alcoholic Beverages and Mixers

Beverage	Amount (oz)	Energy (kcal)	Alcohol (g)
Beer			
Regular	12	153	14
Light	12	103	11
Nonalcoholic	12	32	0
Cocktails			
Daiquiri, canned	6.8	259	20
Daiquiri, from recipe	4.5	223	28
Piña colada, canned	6.8	526	20
Piña colada, from recipe	4.5	245	14
Tequila sunrise, canned	6.8	232	20
Whiskey sour, canned	6.8	249	20
Liquor (gin, rum, vodka, whiskey)			
80 proof	1.5	97	14
86 proof	1.5	105	15
90 proof	1.5	110	16
94 proof	1.5	116	17
100 proof	1.5	124	18
Sake	1.5	58	7
Liqueurs			
Coffee and cream liqueur, 34 proof	1.5	154	7
Coffee liqueur, 53 proof	1.5	170	11
Coffee liqueur, 63 proof	1.5	160	14
Crème de menthe, 72 proof	1.5	186	15
Mixers			
Club soda	12	0	0
Cola	12	136	0
Cranberry juice cocktail	4	72	0
Ginger ale or tonic water	12	124	0
Grapefruit juice	4	48	0
Orange juice	4	56	0
Tomato or vegetable juice	4	21	0
Wine			
Champagne	5	105	13
Cooking	5	72	5
Dessert, dry	5	224	23
Dessert, sweet	5	236	23
Red or rosé	5	125	16
White	5	121	15
Wine cooler	10	150	11

© Cengage Learning 2013

excessive drinking over a lifetime creates deficits of all the nutrients mentioned in this discussion and more. No diet can compensate for the damage caused by heavy alcohol consumption.

Short-Term Effects

The effects of abusing alcohol may be apparent immediately, or they may not become evident for years to come. Among the immediate consequences, all of the following involve alcohol use:[9]

- 20 percent of all boating fatalities
- 23 percent of all suicides
- 39 percent of all traffic fatalities
- 40 percent of all residential fire fatalities
- 47 percent of all homicides
- 65 percent of all domestic violence incidents

These statistics are sobering. The consequences of heavy drinking touch all races and all segments of society—men and women, young and old, rich and poor. One group particularly hard hit by heavy drinking is college students—not because they are prone to alcoholism, but because they live in an environment and are in a developmental stage of life in which risk-taking behaviors are common and heavy drinking is acceptable.

Excessive drinking—including both **heavy drinking** and **binge drinking**—is widespread on college campuses and poses serious health and social consequences to drinkers and nondrinkers alike. In fact, binge drinking can kill: the respiratory center of the brain becomes anesthetized, and breathing stops. It can also cause coronary artery spasms, leading to a heart attack and death.[10]

Binge drinking is especially common among college students, especially males.[11] Compared with nondrinkers or moderate drinkers, people who frequently binge drink (at least three times within two weeks) are more likely to engage in unprotected sex, have multiple sex partners, damage property, and assault others. On average, *every day* alcohol is involved in the:

- Death of 5 college students
- Sexual assault of 266 college students
- Injury of 1641 college students
- Assault of 1907 college students

Binge drinkers skew the statistics on college students' alcohol use. The median number of drinks consumed by college students is 1.5 per week, but for binge drinkers, it is 14.5. Nationally, only 20 percent of all students are frequent binge drinkers; yet they account for two-thirds of all the alcohol students report consuming and most of the alcohol-related problems.

The dangers of binge drinking have been amplified by the use of beverages that contain caffeine as an additive. The caffeine seems to mask the sensory cues that an individual normally relies on to determine intoxication. Consequently, individuals drinking these beverages typically consume more alcohol and become more intoxicated than they realize. The Food and Drug Administration (FDA) has warned manufacturers of packaged caffeinated alcoholic beverages to stop sales. The combination of alcohol and added caffeine has not been approved because these products are associated with risky behaviors that may lead to hazardous and life-threatening situations.[12] For the same reasons, individuals should not mix alcohol with high-energy drinks.

Binge drinking is not limited to college campuses, of course, but it is most common among 18 to 24 year olds.[13] That age group and campus environment seem most accepting of such behavior despite its problems. Social acceptance may make it difficult for binge drinkers to recognize themselves as problem drinkers. For this reason, interventions must focus both on educating individuals and on changing the campus social environment. The damage alcohol causes becomes worse if the pattern is not broken. Alcohol abuse sets in much more quickly in young people than in adults. Those who start drinking at an early age more often suffer from alcoholism than others. Table H7-4 lists the key signs of alcoholism.

Long-Term Effects

The most devastating long-term effect of alcohol is the damage done to a child whose mother abused alcohol during pregnancy. The effects of alcohol on the unborn and the message that pregnant women should not drink alcohol are presented in Highlight 15.

For nonpregnant adults, a drink or two sets in motion many destructive processes in the body, but the next day's abstinence reverses them. As long as the doses are moderate, the time between them is ample, and nutrition is adequate, recovery is probably complete.

If the doses of alcohol are heavy and the time between them short, complete recovery cannot take place. Repeated onslaughts of alcohol gradually take a toll on all parts of the body and increase the risks of several chronic diseases (see Table H7-5, p. 228).[14] Compared with nondrinkers and moderate drinkers, heavy drinkers have significantly greater risks of dying from all causes. Excessive alcohol consumption is the third leading preventable cause of death in the United States.

TABLE H7-4 Signs of Alcoholism

- Tolerance: the person needs higher and higher intakes of alcohol to achieve intoxication.
- Withdrawal: the person who stops drinking experiences anxiety, agitation, increased blood pressure, or seizures, or seeks alcohol to relieve these symptoms.
- Impaired control: the person intends to have 1 or 2 drinks, but has 9 or 10 instead, or the person tries to control or quit drinking, but fails.
- Disinterest: the person neglects important social, family, job, or school activities because of drinking.
- Time: the person spends a great deal of time obtaining and drinking alcohol or recovering from excessive drinking.
- Impaired ability: the person's intoxication or withdrawal symptoms interfere with work, school, or home.
- Problems: the person continues drinking despite physical hazards or medical, legal, psychological, family, employment, or school problems.

The presence of three or more of these conditions is required to make a diagnosis.

SOURCE: Adapted from *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed. (Washington, D.C.: American Psychiatric Association, 1994).

© Cengage Learning 2013

TABLE H7-5 Health Effects of Heavy Alcohol Consumption

Health Problem	Effects of Alcohol
Arthritis	Increases the risk of inflamed joints.
Cancer	Increases the risk of cancer of the liver, breast, mouth, pharynx, larynx, esophagus, colon, and rectum.
Fetal alcohol syndrome	Causes physical and behavioral abnormalities in the fetus (see Highlight 15).
Heart disease	In heavy drinkers, raises blood pressure, blood lipids, and the risk of stroke and heart disease; when compared with those who abstain, heart disease risk is generally lower in light-to-moderate drinkers.
Hyperglycemia	Raises blood glucose.
Hypoglycemia	Lowers blood glucose, especially in people with diabetes.
Infertility	Increases the risks of menstrual disorders and spontaneous abortions (in women); suppresses luteinizing hormone (in women) and testosterone (in men).
Kidney disease	Enlarges the kidneys, alters hormone functions, and increases the risk of kidney failure.
Liver disease	Causes fatty liver, alcoholic hepatitis, and cirrhosis.
Malnutrition	Increases the risk of malnutrition; low intakes of protein, calcium, iron, vitamin A, vitamin C, thiamin, vitamin B_6, and riboflavin; and impaired absorption of calcium, phosphorus, vitamin D, and zinc.
Nerve disorders	Causes neuropathy and dementia; impairs balance and memory.
Obesity	Increases energy intake, but is not a primary cause of obesity.
Psychological disturbances	Causes depression, anxiety, and insomnia.

NOTE: This list is by no means all-inclusive. Alcohol has direct toxic effects on all body systems.

© Cengage Learning 2013

Personal Strategies

One obvious option available to people attending social gatherings is to enjoy the conversation, eat the food, and drink nonalcoholic beverages. Several nonalcoholic beverages are available that mimic the look and taste of their alcoholic counterparts. For those who enjoy champagne or beer, sparkling ciders and beers without alcohol are available. Instead of drinking a cocktail, a person can sip tomato juice with a slice of lime and a stalk of celery or just a plain cola beverage. The person who chooses to drink alcohol should sip each drink slowly accompanied by food and water.

If you want to help sober up a friend who has had too much to drink, don't bother walking arm in arm around the block. Walking muscles have to work harder, but muscle cells don't have the enzymes to metabolize alcohol; only liver cells can clear alcohol from the blood. Remember that each person has a limited amount of the alcohol dehydrogenase enzyme, which clears the blood at a steady rate. Time alone will do the job. Nor will it help to give your friend a cup of coffee. Caffeine is a stimulant, but it won't speed up alcohol metabolism. Table H7-6 presents other alcohol myths.

People who have passed out from drinking need 24 hours to sober up completely. Let them sleep, but watch over them. Encourage them to lie on their sides, instead of their backs. That way, if they vomit, they won't choke.

TABLE H7-6 Myths and Truths Concerning Alcohol

Myth:	Liquors such as rum, vodka, and tequila are more harmful than wine and beer.
Truth:	The damage caused by alcohol depends largely on the *amount* consumed. Compared with liquor, beer and wine have relatively low percentages of alcohol, but they are often consumed in larger quantities.
Myth:	Consuming alcohol with raw seafood diminishes the likelihood of getting hepatitis.
Truth:	People have eaten contaminated oysters while drinking alcoholic beverages and not gotten as sick as those who were not drinking. But do not be misled: hepatitis is too serious an illness for anyone to depend on alcohol for protection.
Myth:	Alcohol stimulates the appetite.
Truth:	For some people, alcohol may stimulate appetite, but it seems to have the opposite effect in heavy drinkers. Heavy drinkers tend to eat poorly and suffer malnutrition.
Myth:	Drinking alcohol is healthy.
Truth:	Moderate alcohol consumption is associated with a lower risk for heart disease. Higher intakes, however, raise the risks for high blood pressure, stroke, heart disease, some cancers, accidents, violence, suicide, birth defects, and deaths in general. Furthermore, excessive alcohol consumption damages the liver, pancreas, brain, and heart. No authority recommends that nondrinkers begin drinking alcoholic beverages to obtain health benefits.
Myth:	Wine increases the body's absorption of minerals.
Truth:	Wine may increase the body's absorption of potassium, calcium, phosphorus, magnesium, and zinc, but the alcohol in wine also promotes the body's excretion of these minerals, so no benefit is gained.
Myth:	Alcohol is legal and, therefore, not a drug.
Truth:	Alcohol is legal for adults 21 years old and older, but it is also a drug—a substance that alters one or more of the body's functions.
Myth:	A shot of alcohol warms you up.
Truth:	Alcohol diverts blood flow to the skin making you *feel* warmer, but it actually cools the body.
Myth:	Wine and beer are mild; they do not lead to alcoholism.
Truth:	Alcoholism is not related to the kind of beverage, but rather to the quantity and frequency of consumption.
Myth:	Mixing different types of drinks gives you a hangover.
Truth:	Too much alcohol in any form produces a hangover.
Myth:	Alcohol is a stimulant.
Truth:	People think alcohol is a stimulant because it seems to relieve inhibitions, but it does so by depressing the activity of the brain. Alcohol is medically defined as a depressant drug.
Myth:	Beer is a great source of carbohydrate, vitamins, minerals, and fluids.
Truth:	Beer does provide some carbohydrate, but most of its kcalories come from alcohol. The few vitamins and minerals in beer cannot compete with rich food sources. And the diuretic effect of alcohol causes the body to lose more fluid in urine than is provided by the beer.

© Cengage Learning 2013

Don't drive too soon after drinking. The lack of glucose for the brain to function and the length of time to clear the blood of alcohol make alcohol's adverse effects linger long after its blood concentration has fallen. Driving coordination is still impaired the morning *after* a night of drinking, even if the drinking was moderate. Responsible aircraft pilots know that they must allow 24 hours for their bodies to clear alcohol completely, and they do not fly any sooner. The Federal Aviation Administration and major airlines enforce this rule.

Look again at the drawing of the brain in Figure H7-4 (p. 224), and note that when someone drinks, judgment fails first. Judgment might tell a person to limit alcohol consumption to two drinks at a party, but if the first drink takes judgment away, many more drinks may follow. The failure to stop drinking as planned, on repeated occasions, is a warning sign that the person should not drink at all.

Ethanol interferes with a multitude of metabolic reactions in the body—many more than have been enumerated here. With heavy alcohol consumption, the potential for harm is great. If you drink alcoholic beverages, do so with care, and in moderation.

REFERENCES

1. U. Benedetto and coauthors, Alcohol intake and outcomes following coronary artery bypass grafting, *Circulation* 122 (2010): A14440; D. A. Boggs and coauthors, Coffee, tea, and alcohol intake in relation to risk of type 2 diabetes in African American women, *American Journal of Clinical Nutrition* 92 (2010): 960–966; M. M. Joosten and coauthors, Combined effect of alcohol consumption and lifestyle behaviors on risk of type 2 diabetes, *American Journal of Clinical Nutrition* 91 (2010): 1777–1783; D. O. Baliunas and coauthors, Alcohol as a risk factor for type 2 diabetes: A systematic review and meta-analysis, *Diabetes Care* 32 (2009): 2123–2132; K. L. Tucker and coauthors, Effects of beer, wine, and liquor intakes on bone mineral density in older men and women, *American Journal of Clinical Nutrition* 89 (2009): 1188–1196.
2. M. P. Ferreira and D. Willoughby, Alcohol consumption: The good, the bad, and the indifferent, *Applied Physiology, Nutrition, and Metabolism* 33 (2008): 12–20.
3. A. J. Barnes and coauthors, Prevalence and correlates of at-risk drinking among older adults: The project SHARE study, *Journal of General Internal Medicine* 25 (2010): 840–846; P. Meier and H. K. Seitz, Age, alcohol metabolism and liver disease, *Current Opinion in Clinical Nutrition and Metabolic Care* 11 (2008): 21–26.
4. K. J. Mukamal, A 42-year-old man considering whether to drink alcohol for his health, *Journal of the American Medical Association* 303 (2010): 2065–2073.
5. C. Sayon-Orea, M. A. Martinez-Gonzalez, and M. Bes-Rastrollo, Alcohol consumption and body weight: A systematic review, *Nutrition Reviews* 69 (2011): 419–431; L. Wang and coauthors, Alcohol consumption, weight gain, and risk of becoming overweight in middle-aged and older women, *Archives of Internal Medicine* 170 (2010): 453–461.
6. M. Schütze and coauthors, Beer consumption and the "beer belly": Scientific basis or common belief? *European Journal of Clinical Nutrition* 63 (2009): 1143–1149.
7. R. A. Breslow and coauthors, Alcoholic beverage consumption, nutrient intakes, and diet quality in the US adult population, 1999-2006, *Journal of the American Dietetic Association* 110 (2010): 551–562.
8. A. D. Thomson and coauthors, Wernicke's encephalopathy: "Plus ça change, plus c'est la mème chose," *Alcohol and Alcoholism* 43 (2008): 180–186.
9. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control (NCIPC), www.cdc.gov, accessed June 23, 2008.
10. M. Roerecke and J. Rehm, Irregular heavy drinking occasions and risk of ischemic heart disease: A systematic review and meta-analysis, *American Journal of Epidemiology* 171 (2010): 633–644.
11. R. W. Hingson, Z. Wenxing, and E. R. Weitzman, Magnitude of and trends in alcohol-related mortality and morbidity among US college students ages 18–24, 1998-2005, *Journal of Studies on Alcohol and Drugs* Supplement No. 16 (2009): 12–20.
12. *Questions and Answers: Caffeinated Alcoholic Beverages*, www.fda.gov/Food/FoodIngredientsPackaging/ucm233726.htm, accessed November 17, 2010.
13. Centers for Disease Control and Prevention, Vital signs: Binge drinking among high school students and adults—United States, 2009, *Morbidity and Mortality Weekly Report* 59 (2010): 1274–1279.
14. A. Z. Fan and coauthors, Patterns of alcohol consumption and the metabolic syndrome, *Journal of Clinical Endocrinology and Metabolism* 93 (2008): 3833–3838.



CENGAGE LEARNING'S GLOBAL NUTRITION GLOBAL NUTRITION RESOURCE CENTER

Body mass index is a measure of a person's weight relative to height. Go to Weight Management/Diets → BMI to review the calculation and how to interpret the data. When would it be appropriate to use BMI in research and when would it be best to use another measure of body composition?

8

Energy Balance and Body Composition

Nutrition in Your Life

It's a simple equation: energy in + energy out = energy balance. The reality, of course, is much more complex. One day you may devour a dozen doughnuts at midnight and sleep through your morning workout—tipping the scales toward weight gain. Another day you may snack on veggies and train for this weekend's 10k race—shifting the balance toward weight loss. Your body weight—especially as it relates to your body fat—and your level of fitness have consequences for your health. So, how are you doing? In the Nutrition Portfolio at the end of this chapter, you can see how your "energy in" and "energy out" balance and whether your body weight and fat measures are consistent with good health.

As Chapter 7 explains, the body's remarkable metabolism can cope with variations in the diet. When the diet delivers too little energy, carbohydrate, or protein, the body uses its fat to meet energy needs and degrades its lean tissue to meet glucose and protein needs. When the diet delivers too much energy—whether from excess carbohydrate, excess protein, or excess fat—the body stores fat.

Both excessive and deficient body fat result from an energy imbalance. The simple picture is as follows. People who consume more food energy than they expend store the surplus as body fat. To reduce body fat, they need to expend more energy than they take in from food. In contrast, people who consume too little food energy to support their bodies' activities must rely on their bodies' fat stores and possibly some of their lean tissues as well. To gain weight, these people need to take in more food energy than they expend. As you will see, though, the details of energy balance and weight regulation are quite complex.[1] This chapter describes energy balance and body composition and examines the health problems associated with having too much or too little body fat. The next chapter presents strategies toward resolving these problems.

LEARNING GPS

8.1 Energy Balance 232
LEARN IT Describe energy balance and the consequences of not being in balance.

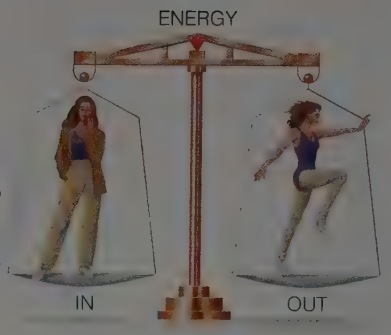
8.2 Energy In: The kCalories Foods Provide 232
LEARN IT Discuss some of the physical, emotional, and environmental influences on food intake.
- Food Composition 232
- Food Intake 233

8.3 Energy Out: The kCalories the Body Expends 236
LEARN IT List the components of energy expenditure and factors that might influence each.
- Components of Energy Expenditure 236
- Estimating Energy Requirements 239

8.4 Body Weight and Body Composition 241
LEARN IT Distinguish between body weight and body composition, including methods to assess each.
- Defining Healthy Body Weight 241
- Body Fat and Its Distribution 243

8.5 Health Risks Associated with Body Weight and Body Fat 246
LEARN IT Identify relationships between body weight and chronic diseases.
- Health Risks of Underweight 247
- Health Risks of Overweight 247
- Fit and Fat versus Sedentary and Slim 249

Highlight 8 Eating Disorders 252
LEARN IT Compare and contrast the diagnoses, characteristics, and treatments of the different eating disorders.

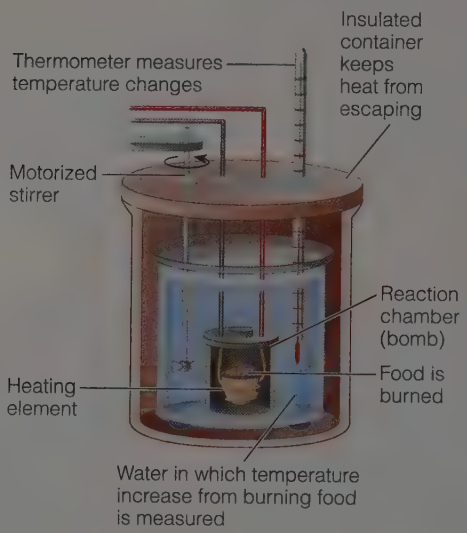


© Cengage Learning 2013

When energy in balances with energy out, a person's body weight is stable.

FIGURE 8-1 Bomb Calorimeter

When food is burned, energy is released in the form of heat. Heat energy is measured in kcalories.



© Cengage Learning 2013

♦ Food energy values can be determined by:

- *Direct calorimetry,* which measures the amount of heat released.
- *Indirect calorimetry,* which measures the amount of oxygen consumed.

energy balance: the energy (kcalories) consumed from foods and beverages compared with the energy expended through metabolic processes and physical activities.

bomb calorimeter (KAL-oh-RIM-eh-ter): an instrument that measures the heat energy released when foods are burned, thus providing an estimate of the potential energy of the foods.

- **calor** = heat
- **metron** = measure

physiological fuel value: the number of kcalories that the body derives from a food, in contrast to the number of kcalories determined by calorimetry.

8.1 Energy Balance

LEARN IT Describe energy balance and the consequences of not being in balance.

People expend energy continuously and eat periodically to refuel. Ideally, their energy intakes cover their energy expenditures with little, or no, excess. Excess energy is stored as fat, and stored fat is used for energy between meals. The fat stores of even a healthy-weight adult represent an ample reserve of energy—50,000 to 200,000 kcalories.

The amount of body fat a person deposits in, or withdraws from, storage on any given day depends on the **energy balance** for that day—the amount consumed (energy in) versus the amount expended (energy out). When a person is maintaining weight, energy in equals energy out. When the balance shifts, weight changes. For each 3500 kcalories eaten in excess, a pound of body fat is stored; similarly, a pound of fat is lost for each 3500 kcalories expended beyond those consumed.*

Quick changes in body weight are not simple changes in fat stores. Weight gained or lost rapidly includes some fat, large amounts of fluid, and some lean tissues such as muscle proteins and bone minerals. Because water constitutes about 60 percent of an adult's body weight, retention or loss of water can greatly influence body weight. Even over the long term, the composition of weight gained or lost is normally about 75 percent fat and 25 percent lean. During starvation, losses of fat and lean are about equal. (Recall from Chapter 7 that without adequate carbohydrate, protein-rich lean tissues break down to provide glucose.) Invariably, though, *fat* gains and losses are gradual. The next two sections examine the two sides of the energy-balance equation—energy in and energy out. As you read, keep in mind that changes on one side usually affect the other.[2]

REVIEW IT Describe energy balance and the consequences of not being in balance.
When energy consumed equals energy expended, a person is in energy balance and body weight is stable. If more energy is taken in than is expended, a person gains weight. If more energy is expended than is taken in, a person loses weight.

8.2 Energy In: The kCalories Foods Provide

LEARN IT Discuss some of the physical, emotional, and environmental influences on food intake.

Foods and beverages provide the "energy in" part of the energy-balance equation. How much energy a person receives depends on the composition of the foods and beverages and on the amount the person eats and drinks.

Food Composition To find out how many kcalories a food provides, a scientist can burn the food in a **bomb calorimeter** (see Figure 8-1). When the food burns, energy is released in the form of heat. The amount of heat given off provides a *direct* measure of the food's energy value (remember that kcalories are units of heat energy).** In addition to releasing heat, these reactions generate carbon dioxide and water—just as the body's cells do when they metabolize the energy-yielding nutrients from foods. Details of the chemical reactions in a calorimeter and in the body differ, but the overall process is similar: when the food burns and the chemical bonds break, the carbons (C) and hydrogens (H) combine with oxygens (O) to form carbon dioxide (CO_2) and water (H_2O). The amount of oxygen consumed gives an *indirect* measure ♦ of the amount of energy released.

A bomb calorimeter measures the available energy in foods but overstates the **physiological fuel value**—the amount of energy that the human body derives from foods. The body is less efficient than a calorimeter and cannot metabolize all of the energy-yielding nutrients in a food completely. Researchers can correct

*Body fat, or adipose tissue, is composed of a mixture of mostly fat, some protein, and water. A pound of body fat (454 g) is approximately 87 percent fat, or (454 x 0.87) 395 g, and 395 g x 9 kcal/g = 3555 kcal.

**As Chapter 1 mentions, many scientists measure food energy in *kilojoules* (a measure of work energy). Conversion factors for these and other measures can be found in Appendix K.

for this discrepancy mathematically to create useful tables of the energy values of foods (such as Appendix H). These values provide reasonable estimates, but they do not reflect the *precise* amount of energy a person will derive from the foods consumed.

The energy values of foods can also be computed from the amounts of carbohydrate, fat, and protein (and alcohol, if present) in the foods.* For example, a food ♦ containing 12 grams of carbohydrate, 5 grams of fat, and 8 grams of protein will provide 48 carbohydrate kcalories, 45 fat kcalories, and 32 protein kcalories, for a total of 125 kcalories. (To review how to calculate the energy foods provide, turn to p. 9.)

♦ Energy values:
- 1 g carbohydrate = 4 kcal
- 1 g fat = 9 kcal
- 1 g protein = 4 kcal
- 1 g alcohol = 7 kcal

Food Intake To achieve energy balance, the body must meet its needs without taking in too much or too little energy. **Appetite** prompts a person to eat—or not to eat. Somehow the body decides how much and how often to eat—when to start eating and when to stop. As you will see, many signals—from both the environment and genetics—initiate or delay eating.[3]

Hunger People eat for a variety of reasons, most obviously (although not necessarily most commonly) because they are hungry. Most people recognize **hunger** as an irritating feeling that prompts thoughts of food and motivates them to start eating. In the body, hunger is the physiological response to a need for food triggered by nerve signals and chemical messengers originating and acting in the brain, primarily in the **hypothalamus**. Hunger can be influenced by the presence or absence of nutrients in the bloodstream, the size and composition of the preceding meal, customary eating patterns, climate (heat reduces food intake; cold increases it), physical activity, hormones, and illnesses. Hunger determines what to eat, when to eat, and how much to eat.

The stomach is ideally designed to handle periodic batches of food, and people typically eat meals at roughly 4-hour intervals. Four hours after a meal, most, if not all, of the food has left the stomach. Most people do not feel like eating again until the stomach is either empty or almost so. Even then, a person may not feel hungry for quite a while.

Satiation During the course of a meal, as food enters the GI tract and hunger diminishes, **satiation** occurs. As receptors in the stomach stretch and hormones such as cholecystokinin become active, the person begins to feel full. The response: satiation, which prompts the person to stop eating.

Satiety After a meal, the feeling of **satiety** continues to suppress hunger and allows a person to not eat again for a while. Whereas *satiation* tells us to "stop eating," *satiety* reminds us to "not start eating again." Figure 8-2 (p. 234) summarizes the relationships among hunger, satiation, and satiety. Of course, people can override these signals, especially when presented with stressful situations or favorite foods.

Overriding Hunger and Satiety Not surprisingly, eating can be triggered by signals other than hunger, even when the body does not need food. Some people experience food cravings when they are bored or anxious. In fact, they may eat in response to any kind of stress, negative or positive. ("What do I do when I'm grieving? Eat. What do I do when I'm celebrating? Eat!") Not too surprisingly, repeatedly eating to relieve chronic stress can lead to overeating and weight gain.

Many people respond to external cues such as the time of day ("It's time to eat") or the availability, sight, and taste of food ("I'd love a piece of chocolate even though I'm full"). Environmental influences such as large portion sizes, favorite foods, or an abundance or variety of foods stimulate eating and increase energy intake. Cognitive influences—such as perceptions, memories, intellect, and social interactions—can easily lead to weight gain. Those who are overweight or obese may be especially susceptible to external cues that trigger hunger and the desire to eat.[4]

appetite: the integrated response to the sight, smell, thought, or taste of food that initiates or delays eating.

hunger: the painful sensation caused by a lack of food that initiates food-seeking behavior.

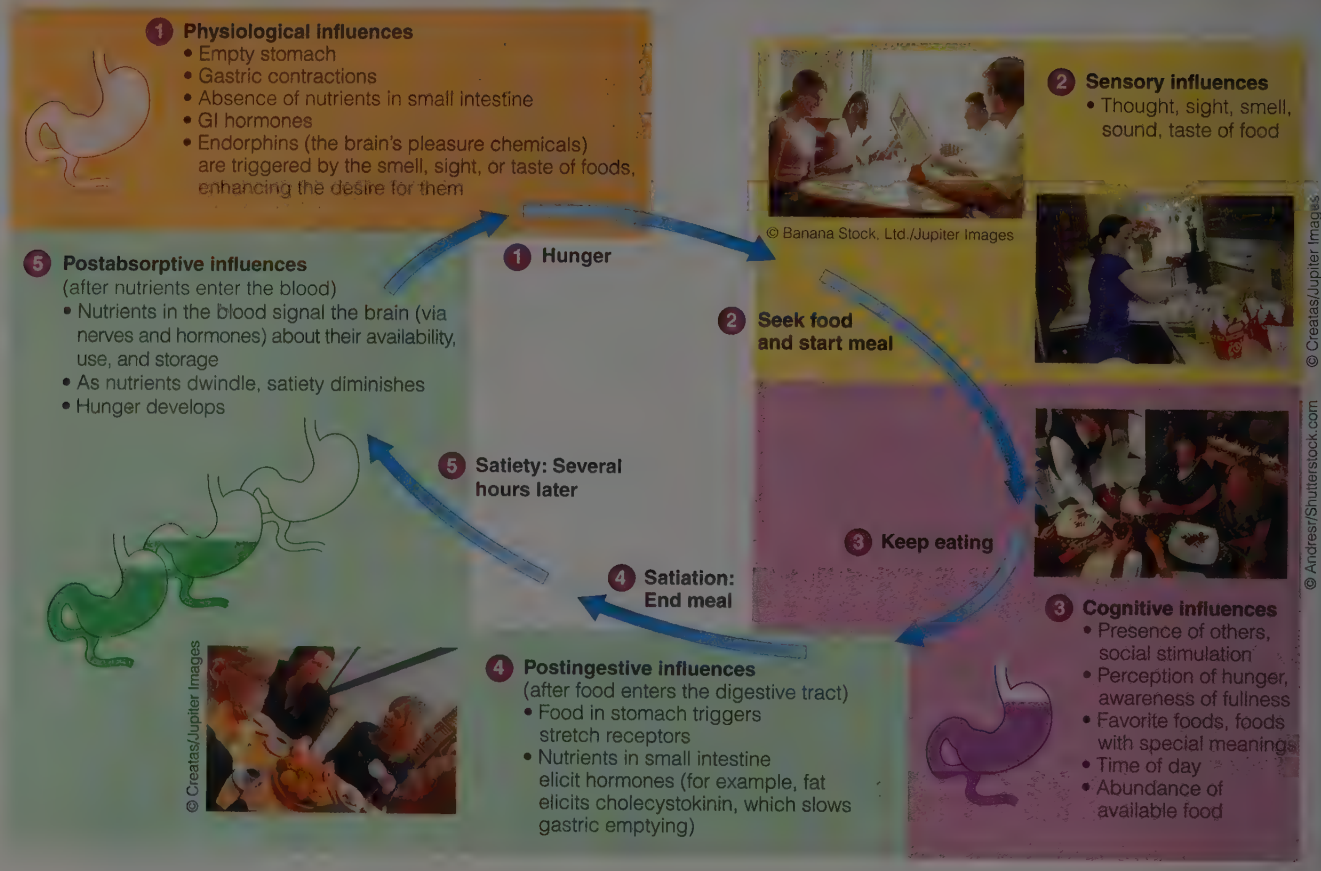
hypothalamus (high-po-THAL-ah-mus): a brain center that controls activities such as maintenance of water balance, regulation of body temperature, and control of appetite.

satiation (say-she-AY-shun): the feeling of satisfaction and fullness that occurs during a meal and halts eating. Satiation determines how much food is consumed during a meal.

satiety: the feeling of fullness and satisfaction that occurs after a meal and inhibits eating until the next meal. Satiety determines how much time passes between meals.

*Some of the food energy values in the table of food composition in Appendix H were derived by bomb calorimetry, and many were calculated from their energy-yielding nutrient contents.

FIGURE 8-2 Hunger, Satiation, and Satiety



Eating can also be suppressed by signals other than satiety, even when a person is hungry. People with the eating disorder anorexia nervosa, for example, use tremendous discipline to ignore the pangs of hunger. Some people simply cannot eat during times of stress, negative or positive. ("I'm too sad to eat." "I'm too excited to eat!") Why some people overeat in response to stress and others cannot eat at


© Jupiterimages/Getty Images

Regardless of hunger, people typically overeat when offered the abundance and variety of a buffet. To limit unhealthy weight gains, listen to hunger and satiety signals.

all remains a bit of a mystery, although researchers are beginning to understand the connections between stress hormones, brain activity, and "comfort foods." Factors that appear to be involved include how the person perceives the stress and whether usual eating behaviors are restrained. (Highlight 8 features anorexia nervosa and other eating disorders.)

Sustaining Satiation and Satiety The extent to which foods produce satiation and sustain satiety depends in part on the nutrient composition of a meal. Of the three energy-yielding nutrients, protein is considered the most **satiating**.[5] In fact, too little protein in the diet can leave a person feeling hungry. Including some protein—such as drinking milk—provides satiety and decreases energy intake at the next meal.[6] In contrast, fructose in a sugary fruit drink seems to stimulate appetite and increase food intake.[7]

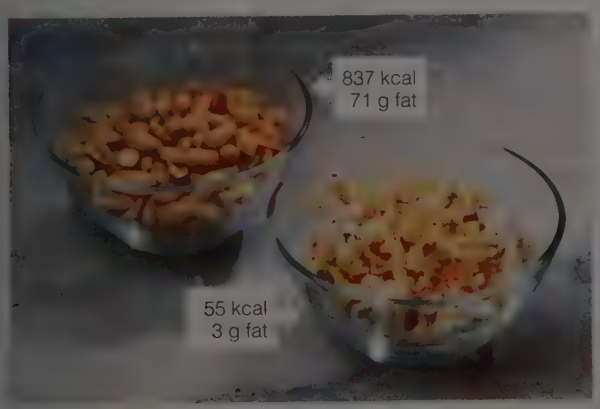
Chapter 1 explains that energy density is a measure of the energy a food provides relative to the amount of food (kcalories per gram). Foods with a high energy density provide more kcalories, and those with low energy density provide fewer kcalories, for the same amount of food. Foods low in energy density are also more satiating. High-fiber foods effectively provide satiation by filling the stomach and delaying the absorption of nutrients. For this reason, eating a large salad as a first course helps a person eat less during the meal. In contrast, fat has a weak effect on satiation; consequently, eating high-fat foods may lead to passive overconsumption. High-fat foods are flavorful, which stimulates the appetite and entices people to eat more. High-fat foods are also energy dense; consequently, they deliver more kcalories per bite. (Chapter 1 introduces the concept of energy density, and Chapter 9 describes how considering a food's energy density can help with weight management.) Although fat provides little satiation during a meal, it produces strong satiety signals once it enters the intestine. Fat in the intestine triggers the release of cholecystokinin—a hormone that signals satiety and inhibits food intake.

Eating high-fat foods while trying to limit energy intake requires small portion sizes, which can leave a person feeling unsatisfied. Portion size correlates directly with a food's satiety. Instead of eating small portions of high-fat foods and feeling deprived, a person can feel satisfied by eating large portions of low-fat, high-fiber, and low energy density foods. Figure 8-3 illustrates how fat influences portion size.

Message Central—The Hypothalamus As you can see, eating is a complex behavior controlled by a variety of psychological, social, metabolic, and physiological factors. The hypothalamus appears to be the control center, integrating messages

satiating having the power to suppress hunger and inhibit eating.

FIGURE 8-3 How Fat Influences Portion Sizes



For the same size portion, peanuts deliver more than 15 times the kcalories and 20 times the fat of popcorn.



© Polara Studios Inc. (both)

For the same number of kcalories, a person can have a few high-fat peanuts or almost 2 cups of high-fiber popcorn. (This comparison used oil-based popcorn; using air-popped popcorn would double the amount of popcorn in this example.)

about energy intake, expenditure, and storage from other parts of the brain and from the mouth, GI tract, and liver. Some of these messages influence satiation, which helps control the size of a meal; others influence satiety, which helps determine the frequency of meals.

Dozens of gastrointestinal hormones ♦ influence appetite control and energy balance.[8] By understanding the action of these hormones, researchers may one day be able to develop anti-obesity treatments. The greatest challenge now is to sort out the many actions of these brain chemicals. For example, one of these chemicals, **neuropeptide Y,** causes carbohydrate cravings, initiates eating, decreases energy expenditure, and increases fat storage—all factors favoring a positive energy balance and weight gain.

♦ Gastrointestinal hormones that regulate food intake:
- Amylin
- Cholecystokinin (CCK)
- Enterostatin
- Ghrelin
- Glucagon-like peptide-1 (GLP-1)
- Oxyntomodulin
- Pancreatic polypeptide (PP)
- Peptide YY (PYY)

REVIEW IT Discuss some of the physical, emotional, and environmental influences on food intake.

A mixture of signals governs a person's eating behaviors. Hunger and appetite initiate eating, whereas satiation and satiety stop and delay eating, respectively. Each responds to messages from the nervous and hormonal systems. Superimposed on these signals are complex factors involving emotions, habits, and other aspects of human behavior.

8.3 Energy Out: The kCalories the Body Expends

LEARN IT List the components of energy expenditure and factors that might influence each.

Chapter 7 explains that heat is released whenever the body breaks down carbohydrate, fat, or protein for energy and again when that energy is used to do work. The generation of heat, known as **thermogenesis,** can be measured to determine the amount of energy expended. ♦ The total energy a body expends reflects three main categories of thermogenesis:

- Energy expended for basal metabolism
- Energy expended for physical activity
- Energy expended for food consumption

A fourth category is sometimes involved:

- Energy expended for adaptation

♦ Energy expenditure, like food energy, can be determined by:
- *Direct calorimetry,* which measures the amount of heat released
- *Indirect calorimetry,* which measures the amount of oxygen consumed and carbon dioxide expelled

♦ Quick and easy estimates for basal energy needs:
- Men: Slightly >1 kcal/min (1.1 to 1.3 kcal/min) or 24 kcal/kg/day
- Women: Slightly <1 kcal/min (0.8 to 1.0 kcal/min) or 23 kcal/kg/day

For perspective, a burning candle or a 75-watt light bulb releases about 1 kcal/min.

♦ BMR equations use actual weight in kilograms, height in centimeters, and age in years:
- Men: $(10 \times wt) + (6.25 \times ht) - (5 \times age) + 5$
- Women: $(10 \times wt) + (6.25 \times ht) - (5 \times age) - 161$

Components of Energy Expenditure

People expend energy when they are physically active, of course, but they also expend energy when they are resting quietly. In fact, quiet metabolic activities account for the largest share of most people's energy expenditures, as Figure 8-4 shows.

Basal Metabolism

About two-thirds of the energy the average person expends in a day supports the body's **basal metabolism.** Metabolic activities include the lungs inhaling and exhaling air, the bone marrow making new red blood cells, the heart beating 100,000 times a day, and the kidneys filtering wastes—in short, they support all the basic processes of life.

The **basal metabolic rate (BMR)** is the rate at which the body expends energy for these life-sustaining activities. ♦ The rate may vary from person to person and may vary for the same individual with a change in circumstance or physical condition. The rate is slowest when a person is sleeping undisturbed, but it is usually measured in a room with a comfortable temperature when the person is awake, but lying still, after a restful sleep and an overnight (12 to 14 hour) fast. A similar measure of energy output—called the **resting metabolic rate (RMR)**—is slightly higher than the BMR because its criteria for recent food intake and physical activity are not as strict. When energy needs cannot be measured, equations ♦ can provide reasonably accurate estimates.

In general, the more a person weighs, the more *total* energy is expended on basal metabolism, but the amount of energy *per pound* of body weight may be lower. For example, an adult's BMR might be 1500 kcalories per day and an

neuropeptide Y: a chemical produced in the brain that stimulates appetite, diminishes energy expenditure, and increases fat storage.

thermogenesis: the generation of heat; used in physiology and nutrition studies as an index of how much energy the body is expending.

basal metabolism: the energy needed to maintain life when a body is at complete digestive, physical, and emotional rest.

basal metabolic rate (BMR): the rate of energy use for metabolism under specified conditions: after a 12-hour fast and restful sleep, without any physical activity or emotional excitement, and in a comfortable setting. It is usually expressed as kcalories per kilogram body weight per hour.

resting metabolic rate (RMR): similar to the basal metabolic rate (BMR), a measure of energy use for a person at rest in a comfortable setting, but with less stringent criteria for recent food intake and physical activity. Consequently, the RMR is slightly higher than the BMR.

infant's only 500, but compared to body weight, the infant's BMR is more than twice as fast. Similarly, a normal-weight adult may have a metabolic rate one and a half times that of an obese adult when compared to body weight because lean tissue is metabolically more active than body fat.

Table 8-1 summarizes the factors that raise and lower the BMR. For the most part, the BMR is highest in people who are growing (children, adolescents, and pregnant women) and in those with considerable **lean body mass** (physically fit people and males). One way to increase the BMR, then, is to participate in endurance and strength-training activities regularly to maximize lean body mass. The BMR is also high in people with fever or under stress and in people with highly active thyroid glands. The BMR slows down with a loss of lean body mass and during fasting and malnutrition.

Physical Activity The second component of a person's energy output is physical activity: voluntary movement of the skeletal muscles and support systems. Physical activity is the most variable—and the most changeable—component of energy expenditure. Consequently, its influence on both weight gain and weight loss can be significant.

During physical activity, the muscles need extra energy to move, and the heart and lungs need extra energy to deliver nutrients and oxygen and dispose of wastes. The amount of energy needed for any activity, whether playing tennis or studying for an exam, depends on three factors: muscle mass, body weight, and activity. The larger the muscle mass and the heavier the weight of the body part being moved, the more energy is expended. Table 8-2 (p. 238) gives average energy expenditures for various activities. The activity's duration, frequency, and intensity also influence energy expenditure: the longer, the more frequent, and the more intense the activity, the more kcalories expended. (Chapter 14 describes how an activity's duration, frequency, and intensity also influence the body's use of the energy-yielding nutrients.)

TABLE 8-1 Factors that Affect the BMR

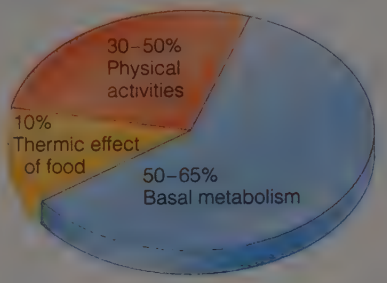
Factor	Effect on BMR
Age	Lean body mass diminishes with age, slowing the BMR.[a]
Height	In tall, thin people, the BMR is higher.[b]
Growth	In children, adolescents, and pregnant women, the BMR is higher.
Body composition (gender)	The more lean tissue, the higher the BMR (which is why males usually have a higher BMR than females). The more fat tissue, the lower the BMR.
Fever	Fever raises the BMR.[c]
Stresses	Stresses (including many diseases and certain drugs) raise the BMR.
Environmental temperature	Both heat and cold raise the BMR.
Fasting/starvation	Fasting/starvation lowers the BMR.[d]
Malnutrition	Malnutrition lowers the BMR.
Hormones (gender)	The thyroid hormone thyroxin, for example, can speed up or slow down the BMR.[e] Premenstrual hormones slightly raise the BMR.
Smoking	Nicotine increases energy expenditure.
Caffeine	Caffeine increases energy expenditure.
Sleep	BMR is lowest when sleeping.

[a]The BMR begins to decrease in early adulthood (after growth and development cease) at a rate of about 2 percent/decade. A reduction in voluntary activity as well brings the total decline in energy expenditure to about 5 percent/decade.
[b]If two people weigh the same, the taller, thinner person will have the faster metabolic rate, reflecting the greater skin surface, through which heat is lost by radiation, in proportion to the body's volume (see Figure 8-5, p. 239).
[c]Fever raises the BMR by 7 percent for each degree Fahrenheit.
[d]Prolonged starvation reduces the total amount of metabolically active lean tissue in the body, although the decline occurs sooner and to a greater extent than body losses alone can explain. More likely, the neural and hormonal changes that accompany fasting are responsible for changes in the BMR.
[e]The thyroid gland releases hormones that travel to the cells and influence cellular metabolism. Thyroid hormone activity can speed up or slow down the rate of metabolism by as much as 50 percent.

© Cengage Learning 2013

> FIGURE 8-4 Components of Energy Expenditure

The amount of energy expended in voluntary physical activities has the greatest variability, depending on a person's activity patterns. For a sedentary person, physical activities may account for less than half as much energy as basal metabolism, whereas an extremely active person may expend as much on activity as for basal metabolism.



© Cengage Learning 2013

The amount of energy expended in a day differs for each individual, but in general, basal metabolism is the largest component of energy expenditure and thermic effect of food is the smallest.

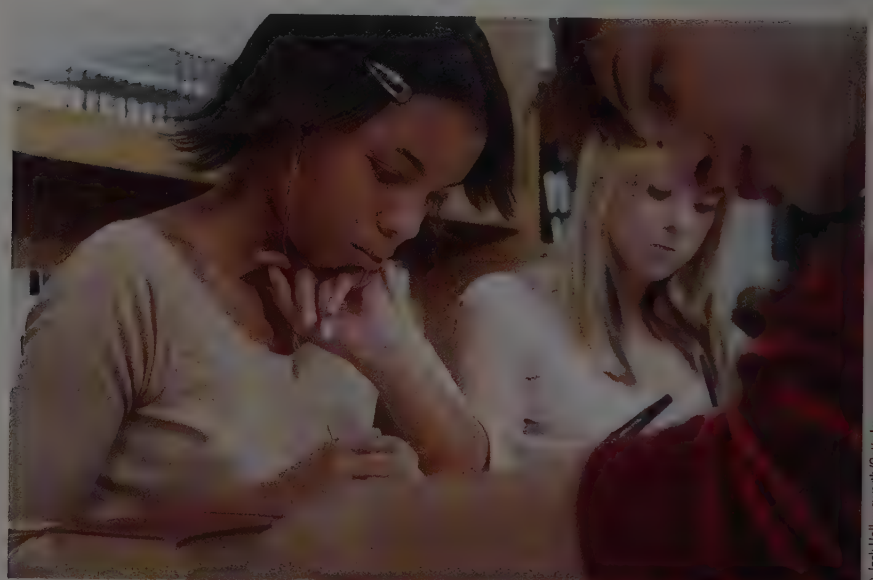
lean body mass: the body minus its fat.

TABLE 8-2 Energy Expended on Various Activities

The values listed in this table reflect both the energy expended in physical activity *and* the amount used for BMR. To calculate kcalories spent per minute of activity for your own body weight, multiply kcal/lb/min (or kcal/kg/min) by your exact weight and then multiply that number by the number of minutes spent in the activity. For example, if you weigh 142 pounds, and you want to know how many kcalories you spent doing 30 minutes of vigorous aerobic dance: 0.062 × 142 = 8.8 kcalories per minute; 8.8 × 30 minutes = 264 total kcalories spent.

Activity	kCal/lb min	kCal/kg min	Activity	kCal/lb min	kCal/kg min	Activity	kCal/lb min	kCal/kg min
Aerobic dance (vigorous)	.062	.136	Handball	.078	.172	Table tennis (skilled)	.045	.099
Basketball (vigorous, full court)	.097	.213	Horseback riding (trot)	.052	.114	Tennis (beginner)	.032	.070
Bicycling			Rowing (vigorous)	.097	.213	Vacuuming and other household tasks	.030	.066
13 mph	.045	.099	Running			Walking (brisk pace)		
15 mph	.049	.108	5 mph	.061	.134	3.5 mph	.035	.077
17 mph	.057	.125	6 mph	.074	.163	4.5 mph	.048	.106
19 mph	.076	.167	7.5 mph	.094	.207	Weight lifting		
21 mph	.090	.198	9 mph	.103	.227	light-to-moderate	.024	.053
23 mph	.109	.240	10 mph	.114	.251	vigorous	.048	.106
25 mph	.139	.306	11 mph	.131	.288	Wheelchair basketball	.084	.185
Canoeing, flat water, moderate pace	.045	.099	Soccer (vigorous)	.097	.213	Wheeling self in wheelchair	.030	.066
Cross-country skiing 8 mph.	.104	.229	Studying	.011	.024	Wii games		
Gardening	.045	.099	Swimming			bowling	.021	.046
Golf (carrying clubs)	.045	.099	20 yd/min	.032	.070	boxing	.021	.047
			45 yd/min	.058	.128	tennis	.022	.048
			50 yd/min	.070	.154			

Thermic Effect of Food When a person eats, the GI tract muscles speed up their rhythmic contractions, the cells that manufacture and secrete digestive juices become active, and some nutrients require energy to be absorbed. This acceleration of activity requires energy and produces heat; it is known as the **thermic effect of food (TEF).**



It feels like work and it may make you tired, but studying requires only one or two kcalories per minute.

thermic effect of food (TEF): an estimation of the energy required to process food (digest, absorb, transport, metabolize, and store ingested nutrients); also called the *specific dynamic effect (SDE)* of food or the *specific dynamic activity (SDA)* of food. The sum of the TEF and any increase in the metabolic rate due to overeating is known as *diet-induced thermogenesis (DIT).*

The thermic effect of food is proportional to the food energy taken in and is usually estimated at 10 percent of energy intake. Thus a person who ingests 2000 kcalories probably expends about 200 kcalories on the thermic effect of food. The proportions vary for different foods, however, and are also influenced by factors such as meal size and frequency. In general, the thermic effect of food is greater for high-protein foods than for high-fat foods ♦ and for a meal eaten all at once rather than spread out over a couple of hours. For most purposes, however, the thermic effect of food can be ignored when estimating energy expenditure because its contribution to total energy output is smaller than the probable errors involved in estimating overall energy intake and output.

♦ Thermic effect of foods:
- Carbohydrate: 5–10%
- Fat: 0–5%
- Protein: 20–30%
- Alcohol: 15–20%

Percentages are calculated by dividing the energy expended during digestion and absorption (above basal) by the energy content of the food.

Adaptive Thermogenesis Additional energy is expended when circumstances in the body are dramatically changed. A body challenged to physical conditioning, extreme cold, overfeeding, starvation, trauma, or other types of stress must adapt; it has extra work to do and uses extra energy to build the tissues and produce the enzymes and hormones necessary to cope with the demand. This energy is known as **adaptive thermogenesis**, and in some circumstances, it makes a considerable difference in the total energy expended. Because this component of energy expenditure is so variable and specific to individuals, it is not included when calculating energy requirements.

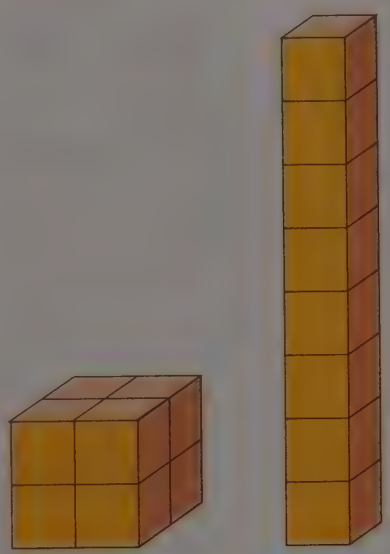
Estimating Energy Requirements

In estimating energy requirements, the DRI Committee developed equations based on research measuring total daily energy expenditure. These equations consider how the following factors influence BMR and consequently energy expenditure:

- *Gender.* In general, women have a lower BMR than men, in large part because men typically have more lean body mass. Two sets of energy equations—one for men and one for women—were developed to accommodate the influence of gender on energy expenditure (provided on the next page).
- *Growth.* The BMR is high in people who are growing. For this reason, pregnant and lactating women, infants, children, and adolescents have their own sets of energy equations (provided in Appendix F).
- *Age.* The BMR declines during adulthood as lean body mass diminishes. This change in body composition occurs, in part, because some hormones that influence appetite, body weight, and metabolism become more, or less, active with age. Physical activities tend to decline as well, bringing the average reduction in energy expenditure to about 5 percent per decade. The decline in BMR that occurs when a person becomes less active reflects the loss of lean body mass and may be minimized with ongoing physical activity. Because age influences energy expenditure, it is also factored into the energy equations.
- *Physical activity.* Using individual values for various physical activities (as in Table 8-2) is time-consuming and impractical for estimating the energy needs of a population. Instead, various activities are clustered according to the typical intensity of a day's efforts. Energy equations include a physical activity factor for various levels of intensity for each gender.
- *Body composition and body size.* The BMR is high in people who are tall and so have a large surface area, as illustrated in Figure 8-5. Similarly, the more a person weighs, the more energy is expended on basal metabolism. For these reasons, energy equations include a factor for both height and weight.

As just explained, energy needs vary between individuals depending on such factors as gender, growth, age, physical activity, and body size and composition. Even when two people are similarly matched, however, their energy needs still differ because of genetic differences. Perhaps one day genetic research will reveal how to estimate requirements for each individual. For now, the "How To" feature on p. 240 provides instructions on calculating your estimated energy requirements using the DRI equations and physical activity factors. Appendix F presents DRI tables

> **FIGURE 8-5 How Body Size Influences BMR**



Each of these structures is made of eight blocks. They weigh the same, but they are arranged differently. The short, wide structure has 24 sides exposed and the tall, thin one has 34. Because the tall, thin structure has a greater surface area, it will lose more heat (expend more energy) than the short, wide one. Similarly, two people of different heights might weigh the same, but the taller, thin one will have a higher BMR (expending more energy) because of the greater skin surface.

adaptive thermogenesis: adjustments in energy expenditure related to changes in environment such as extreme cold and to physiological events such as overfeeding, trauma, and changes in hormone status.

♦ For *most* people, the actual energy requirement falls within these ranges:
- For men, EER ± 200 kcal
- For women, EER ± 160 kcal

For *almost all* people, the actual energy requirement falls within these ranges:
- For men, EER ± 400 kcal
- For women, EER ± 320 kcal

>How To

Estimate Energy Requirements

To determine your estimated energy requirement (EER), use the appropriate equation, inserting your age in years, weight (wt) in kilograms, height (ht) in meters, and physical activity (PA) factor from the accompanying table. (To convert pounds to kilograms, divide by 2.2; to convert inches to meters, divide by 39.37.)

- For men 19 years and older:
  $EER = [662 - (9.53 \times age)] + PA \times [(15.91 \times wt) + (539.6 \times ht)]$
- For women 19 years and older:
  $EER = [354 - (6.91 \times age)] + PA \times [(9.36 \times wt) + (726 \times ht)]$

For example, consider an active 30-year-old male who is 5 feet 11 inches tall and weighs 178 pounds. First, he converts his weight from pounds to kilograms and his height from inches to meters, if necessary:

$$178 \text{ lb} \div 2.2 = 80.9 \text{ kg}$$
$$71 \text{ in} \div 39.37 = 1.8 \text{ m}$$

Next, he considers his level of daily physical activity and selects the appropriate PA factor from the accompanying table. (In this example, 1.25 for an active male.) Then, he inserts his age, PA factor, weight, and height into the appropriate equation:

$$EER = [662 - (9.53 \times 30)] + 1.25 \times [(15.91 \times 80.9) + (539.6 \times 1.8)]$$

(A reminder: Do calculations within the parentheses first.) He calculates:

$$EER = [662 - 286] + 1.25 \times [1287 + 971]$$

(Another reminder: Do calculations within the brackets next.)

$$EER = 376 + 1.25 \times 2258$$

(One more reminder: Do multiplication before addition.)

$$EER = 376 + 2823$$
$$EER = 3199$$

The estimated energy requirement for an active 30-year-old male who is 5 feet 11 inches tall and weighs 178 pounds is about 3200 kcalories/day. His actual requirement probably falls within a range ♦ of 200 kcalories above and below this estimate.

NOTE: Appendix F provides tables of energy expenditure for adults at various levels of activity and various heights and weights. It also includes ERR equations for infants, children, adolescents, and pregnant women.

Physical Activity (PA) Factors for EER Equations

	Men	Women	Physical Activity
Sedentary	1.0	1.0	Typical daily living activities
Low active	1.11	1.12	plus 30–60 min moderate activity
Active	1.25	1.27	plus ≥ 60 min moderate activity
Very active	1.48	1.45	plus ≥ 60 min moderate activity and 60 min vigorous or 120 min moderate activity

NOTE: Moderate activity is equivalent to walking at 3 to 4½ mph.

TRY IT Estimate your energy requirement based on your current age, weight, height, and activity level.

that provide a shortcut to estimating total energy expenditure and instructions to help you determine the appropriate physical activity factor to use in the equation.

REVIEW IT List the components of energy expenditure and factors that might influence each.

A person in energy balance takes in energy from food and expends much of it on basal metabolic activities, some of it on physical activities, and a little on the thermic effect of food. Energy requirements vary from person to person, depending on such factors as gender, age, weight, and height as well as the intensity and duration of physical activity. All of these factors must be considered when estimating energy requirements.

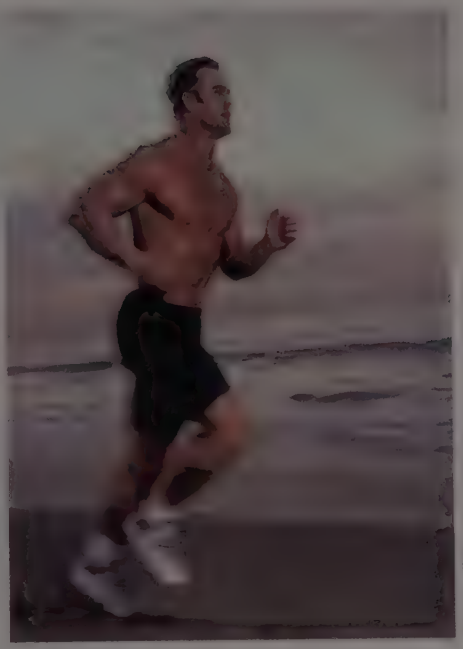
8.4 Body Weight and Body Composition

LEARN IT Distinguish between body weight and body composition, including methods to assess each.

A person 5 feet 10 inches tall who weighs 150 pounds may carry only about 30 of those pounds as fat.* The rest is mostly water and lean tissues—muscles, organs such as the heart and liver, and the bones of the skeleton. Direct measures of **body composition** are impossible in living human beings; instead, researchers assess body composition indirectly based on the following assumption:

Body weight = fat + lean tissue (including water)

Weight gains and losses tell us nothing about how the body's composition may have changed, yet weight is the measure most people use to judge their "fatness." For many people, overweight is overfat, but this is not always the case. Athletes with dense bones and well-developed muscles may be overweight by some standards but have little body fat. Conversely, inactive people may seem to have acceptable weights, when, in fact, they may have too much body fat.



© Rick Schaff

At 6 feet 4 inches tall and 250 pounds (1.93 meters and 113 kilograms), this runner would be considered over*weight* by most standards. Yet he is clearly not over*fat*.

Defining Healthy Body Weight

How much should a person weigh? How can a person know if her weight is appropriate for her height? How can a person know if his weight is jeopardizing his health? Such questions seem so simple, yet the answers can be complex—and quite different depending on whom you ask.

The Criterion of Fashion

In asking what is ideal, people often mistakenly turn to friends and fashion for the answer and judge body weight by appearances. No doubt our society sets unrealistic ideals for body weight, especially for women. Magazines, movies, and television all convey the message that to be thin is to be beautiful and happy. As a result, the media have a great influence on the weight concerns and dieting patterns of people of all ages, but most tragically on young, impressionable children and adolescents.[9]

Importantly, perceived body image may have little to do with actual body weight or size. People of all shapes, sizes, and ages—including extremely thin fashion models with anorexia nervosa and fitness instructors with ideal body composition—have learned to be unhappy with their "overweight" bodies. Such dissatisfaction can lead to damaging behaviors, such as starvation diets, diet pill abuse, and health-care avoidance. The first step toward making healthy changes may be self-acceptance. Keep in mind that fashion is fickle; the body shapes valued by our society change with time. Furthermore, body shapes valued by one society differ from those of other societies. The standards defining "ideal" are subjective and may have little in common with health. Table 8-3 offers some tips for adopting health as an ideal.

body composition the proportions of muscle, bone, fat, and other tissue that make up a person's total body weight.

TABLE 8-3 Tips for Accepting a Healthy Body Weight

- Value yourself and others for human attributes other than body weight. Realize that prejudging people by weight is as harmful as prejudging them by race, religion, or gender.
- Use positive, nonjudgmental descriptions of your body.
- Accept positive comments from others.
- Focus on your whole self including your intelligence, social grace, and professional and scholastic achievements.
- Accept that no magic diet exists.
- Stop dieting to lose weight. Adopt a lifestyle of healthy eating and physical activity permanently.
- Follow the USDA Food Patterns Never restrict food intake below the minimum levels that meet nutrient needs.
- Become physically active, not because it will help you get thin but because it will make you feel good and improve your health.
- Seek support from loved ones. Tell them of your plan for a healthy life in the body you have been given.
- Seek professional counseling, *not* from a weight-loss counselor, but from someone who can help you make gains in self-esteem without weight as the primary focus.
- Appreciate body weight for its influence on health, not appearance.

© Cengage Learning 2013

*In metric terms, a person 1.78 meters tall who weights 68 kilograms may carry only about 14 of those kilograms as fat.



© Randy M. Ury/CORBIS

A healthy body contains enough lean tissue to support health and the right amount of fat to meet body needs.

The Criterion of Health Even if our society were to accept fat as beautiful, obesity is still a major risk factor for several life-threatening diseases, including heart disease, type 2 diabetes, and some cancers.[10] For this reason, the most important criterion for determining how much a person should weigh and how much body fat a person needs is not appearance but good health and longevity. Ideally, a person has enough fat to meet basic needs ♦ but not so much as to incur health risks. This range of healthy body weights has been identified using a common measure of weight and height—the body mass index.

Body Mass Index The **body mass index (BMI)** describes relative weight for height: ♦

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2} \text{ or } \frac{\text{weight (lb)}}{\text{height (in)}^2} \times 703$$

♦ Fat in the body:
- Provides energy
- Insulates against temperature extremes
- Protects against physical shock
- Forms cell membranes
- Makes compounds such as hormones, vitamin D, and bile

♦ To convert pounds to kilograms:
lb ÷ 2.2 lb/kg = kg
To convert inches to meters:
in ÷ 39.37 in/m = m

Weight classifications based on BMI are presented in Table 8-4. Notice that healthy weight falls between a BMI of 18.5 and 24.9, with **underweight** below 18.5, **overweight** above 25, and **obese** above 30. Figure 8-6 shows examples of body shapes with different BMI. More than two-thirds of adults in the United States have a BMI greater than 25, as Figure 8-7 shows.[11]

Obesity-related diseases become evident beyond a BMI of 25. For this reason, a BMI of 25 for adults represents a healthy goal for overweight people and an upper limit for others. The lower end of the healthy range may be a reasonable target for severely underweight people. BMI values slightly below the healthy range may be compatible with good health if food intake is adequate, but signs of illness, reduced work capacity, and poor reproductive function

body mass index (BMI): a measure of a person's weight relative to height; determined by dividing the weight (in kilograms) by the square of the height (in meters).

underweight: body weight lower than the weight range that is considered healthy; BMI less than 18.5.

overweight: body weight greater than the weight range that is considered healthy; BMI 25 to 29.9.

obese: too much body fat with adverse health effects; BMI 30 or more.

> **FIGURE 8-6 BMI and Body Shapes**

Standard silhouette figures such as those shown below are commonly used in research studies (without the BMI numbers) to determine how accurately people perceive their body size.



© Cengage Learning 2013

Source: A. J. Stunkard, T. Sorensen, and F. Schulsinger, Use of the Danish Adoption Register for the study of obesity and thinness, *Research Publications. Association for Research in Nervous and Mental Disorders* 60 (1983): 115–120

TABLE 8-4 Body Mass Index (BMI)

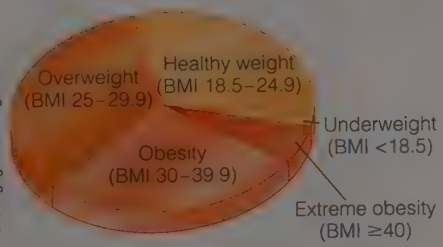
	Underweight (<18.5)			Healthy Weight (18.5–24.9)				Overweight (25–29.9)					Obese (≥30)									
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Height	Body weight (pounds)																						
4'10"	86	91	96	100	105	110	115	119	124	129	134	138	143	148	153	158	162	167	172	177	181	186	191
4'11"	89	94	99	104	109	114	119	124	128	133	138	143	148	153	158	163	168	173	178	183	188	193	198
5'0"	92	97	102	107	112	118	123	128	133	138	143	148	153	158	163	168	174	179	184	189	194	199	204
5'1"	95	100	106	111	116	122	127	132	137	143	148	153	158	164	169	174	180	185	190	195	201	206	211
5'2"	98	104	109	115	120	126	131	136	142	147	153	158	164	169	175	180	186	191	196	202	207	213	218
5'3"	102	107	113	118	124	130	135	141	146	152	158	163	169	175	180	186	191	197	203	208	214	220	225
5'4"	105	110	116	122	128	134	140	145	151	157	163	169	174	180	186	192	197	204	209	215	221	227	232
5'5"	108	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210	216	222	228	234	240
5'6"	112	118	124	130	136	142	148	155	161	167	173	179	186	192	198	204	210	216	223	229	235	241	247
5'7"	115	121	127	134	140	146	153	159	166	172	178	185	191	198	204	211	217	223	230	236	242	249	255
5'8"	118	125	131	138	144	151	158	164	171	177	184	190	197	203	210	216	223	230	236	243	249	256	262
5'9"	122	128	135	142	149	155	162	169	176	182	189	196	203	209	216	223	230	236	243	250	257	263	270
5'10"	126	132	139	146	153	160	167	174	181	188	195	202	209	216	222	229	236	243	250	257	264	271	278
5'11"	129	136	143	150	157	165	172	179	186	193	200	208	215	222	229	236	243	250	257	265	272	279	286
6'0"	132	140	147	154	162	169	177	184	191	199	206	213	221	228	235	242	250	258	265	272	279	287	294
6'1"	136	144	151	159	166	174	182	189	197	204	212	219	227	235	242	250	257	265	272	280	288	295	302
6'2"	141	148	155	163	171	179	186	194	202	210	218	225	233	241	249	256	264	272	280	287	295	303	311
6'3"	144	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	279	287	295	303	311	319
6'4"	148	156	164	172	180	189	197	205	213	221	230	238	246	254	263	271	279	287	295	304	312	320	328
6'5"	151	160	168	176	185	193	202	210	218	227	235	244	252	261	269	277	286	294	303	311	319	328	336
6'6"	155	164	172	181	190	198	207	216	224	233	241	250	259	267	276	284	293	302	310	319	328	336	345

© Cengage Learning 2013

become apparent when BMI is below 17. The "How To" feature on p. 244 describes how to determine your BMI and how to find a goal weight based on a desired BMI.

Keep in mind that BMI reflects height and weight measures and not body composition. Consequently, muscular athletes may be classified as over*weight* by BMI standards and not be over*fat*. At the peak of his bodybuilding career, Arnold Schwarzenegger won the Mr. Olympia competition with a BMI of 31; the runner on p. 241 also has a BMI greater than 30. Yet neither would be considered obese. Striking differences in body composition are also apparent among people of different ages and various ethnic and racial groups, making standard BMI guidelines inappropriate for some populations.[12] For example, blacks tend to have a greater bone density and protein content than whites; consequently, using BMI as the standard may overestimate the prevalence of overweight and obesity among blacks.

FIGURE 8-7 Distribution of Body Weights in US Adults



© Cengage Learning 2013

Body Fat and Its Distribution

Although weight measures are inexpensive, easy to take, and highly accurate, they fail to reveal two valuable pieces of information in assessing disease risk: how much of the weight is fat and where the fat is located. The ideal amount of body fat depends partly on the person. Table 8-5 (p. 244) compares percent body fat values of healthy weight, average fitness individuals with averages from national surveys.

Some People Need Less Body Fat

For many athletes, a lower percentage of body fat may be ideal—just enough fat to provide fuel, insulate and protect the body, assist in nerve impulse transmissions, and support normal hormone activity, but not so much as to burden the body with excess bulk. Percent body fat for athletes, then, might be 7 to 16 percent for young men and 15 to 22 percent for young

TABLE 8-5 Percent Body Fat

Age (yr)	Ideal (Healthy weight, average fitness)	Actual (US average)
Male		
20–39	18–21	26
40–59	22–25	29
60+	24–27	31
Female		
20–39	23–26	38
40–59	28–32	41
60+	31–34	42

SOURCE: L. G. Borrud and coauthors, Body composition data for individuals 8 years of age and older: US population, 1999–2004, *Vital and Health Statistics* 11 (2010): 1–87; *ACSM's Health-Related Physical Fitness Assessment Manual*, 2nd ed. (Baltimore, M.D.: Lippincott Williams & Wilkins, 2008), p. 59.

© Cengage Learning 2013

>How To

Determine BMI

To calculate your body mass index (BMI), use one of the following equations:

$$\text{BMI} = \frac{\text{weight (lb)}}{\text{height (in)}^2} \times 703$$

or

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$$

Consider, for example, a person who is 5'5" (1.65 m) tall and weighs 174 lb (79 kg):

$$\text{BMI} = \frac{174 \text{ lb}}{65 \text{ in}^2} \times 703 = 29$$

or

$$\text{BMI} = \frac{79 \text{ kg}}{1.65 \text{ m}^2} = 29$$

This person has a BMI of 29 and is considered overweight.

You could also use Table 8-4 to determine your BMI. Locate your height in the first column (in this example, 5'5"). Then look across the row until you find the number that is closest to your weight (in this example, 174). The number at the top of that column identifies your BMI (in this example, 29).

A reasonable initial target for most overweight people is a BMI 2 units below their current one. To determine a goal weight based on a desired BMI, locate your height in the first column and then look across the row until you reach the column with the desired BMI at the top. In this example, to reach a BMI of 27, this person's goal weight is 162 pounds, which represents a 12-pound weight loss. Such a determination can help a person set realistic weight goals using health risk as a guide.

TRY IT Calculate your BMI and determine whether you are underweight, healthy weight, overweight, or obese. If your BMI is less than 18.5 or greater than 25, identify a weight that takes your BMI 2 units closer to the healthy weight range.

women.[13] (Review the photo on p. 241 to appreciate what 8 percent body fat looks like—even with a BMI greater than 30.)

Some People Need More Body Fat For an Alaska fisherman, a higher percentage of body fat is probably beneficial because fat provides an insulating blanket to prevent excessive loss of body heat in cold climates. A woman starting a pregnancy needs sufficient body fat to support conception and fetal growth. Below a certain threshold for body fat, hormone synthesis falters, and individuals may become infertile, develop depression, experience abnormal hunger regulation, or become unable to keep warm. These thresholds differ for each function and for each individual; much remains to be learned about them.

Fat Distribution The location of fat on the body may influence health as much, or more than, total fat alone. **Visceral fat** that is stored around the organs of the abdomen is referred to as **central obesity** or upper-body fat (see Figure 8-8). Much research supports the widely held belief that central obesity—significantly and independently of BMI—contributes to heart disease and related deaths.[14] Some research, however, casts doubt and suggests that *all* types of obesity are linked to heart disease; central obesity is no riskier than other shapes.[15]

Visceral fat is most common in men and to a lesser extent in women past menopause. Even when total body fat is similar, men have more visceral fat than women. **Subcutaneous fat** around the hips and thighs, sometimes referred to as lower-body fat, is most common in women during their reproductive years. Figure 8-9 compares the body shapes of people with upper-body fat and lower-body fat.

Waist Circumference A person's **waist circumference** is a good indicator of central obesity. In general, women with a waist circumference of greater than 35 inches (88 centimeters) and men with a waist circumference of greater than 40 inches (102 centimeters) have a high risk of central obesity–related

visceral fat: fat stored within the abdominal cavity in association with the internal abdominal organs; also called *intra-abdominal fat.*

central obesity: excess fat around the trunk of the body; also called *abdominal fat* or *upper-body fat.*

subcutaneous fat: fat stored directly under the skin.

- **sub** = beneath
- **cutaneous** = skin

waist circumference: an anthropometric measurement used to assess a person's abdominal fat.

FIGURE 8-8 Abdominal Fat



© Cengage Learning 2013

In healthy-weight people, some fat is stored around the organs of the abdomen.

In overweight people, excess abdominal fat increases the risks of diseases.

health problems. As waist circumference increases, disease risks increase. Appendix E includes instructions for measuring waist circumference and assessing abdominal fat.

Some researchers use the waist-to-hip ratio as an indicator of disease risks. The ratio requires another step or two (measuring the hips and comparing that measurement to the waist measurement), but it does not provide any additional information. Therefore, waist circumference alone is the preferred method for assessing abdominal fat in a clinical setting.*

Other Measures of Body Composition Health-care professionals commonly use BMI and waist circumference measurements because they are relatively easy and inexpensive. Together, these two measurements prove most valuable in assessing a person's health risks and monitoring changes over time.[16] Researchers needing more precise measures of body composition may choose any of several other techniques to estimate body fat and its distribution (see Figure 8-10). Mastering these techniques requires proper instruction and practice to ensure reliability. In addition to the methods shown in Figure 8-10, researchers sometimes estimate body composition using these methods: total body water, radioactive potassium count, near-infrared spectrophotometry, ultrasound, computed tomography, and magnetic resonance imaging. Each method has advantages and disadvantages with respect to cost, technical difficulty, and precision of estimating body fat. Appendix E provides additional details and includes many of the tables and charts routinely used in assessment procedures.

*The National Heart, Lung, and Blood Institute recommends using the waist circumference instead of the waist-to-hip ratio to assess obesity health risks.

FIGURE 8-9 "Apple" and "Pear" Body Shapes Compared

Popular articles sometimes call bodies with upper-body fat "apples" and those with lower-body fat, "pears." Researchers sometimes refer to upper-body fat as "android" (manlike) obesity and to lower-body fat as "gynoid" (womanlike) obesity.



© Cengage Learning 2013

Upper-body fat is more common in men than in women and may be more closely associated with chronic diseases.

Lower-body fat is more common in women than in men and is not usually associated with chronic diseases.

SOURCE: R.E.C. Wildman and D. M. Medeiros, *Advanced Human Nutrition* (Boca Raton, FL: CRC Press, 2000), pp. 321–323. Copyright © 2000 Taylor and Francis Books LLC. Reprinted with permission.

> FIGURE 8-10 Common Methods Used to Assess Body Fat



© Fitness & Wellness, Boise, Idaho

Skinfold measures estimate body fat by using a caliper to gauge the thickness of a fold of skin on the back of the arm (over the triceps), below the shoulder blade (subscapular), and in other places (including lower-body sites), and then comparing these measurements with standards.



© Photo Courtesy of Live Measurement, Inc.

Air displacement plethysmography estimates body composition by having a person sit inside a chamber while computerized sensors determine the amount of air displaced by the person's body.



© David Young-Wolff/PhotoEdit

Hydrodensitometry measures body density by weighing the person first on land and then again while submerged in water. The difference between the person's actual weight and underwater weight provides a measure of the body's volume. A mathematical equation using the two measurements (volume and actual weight) determines body density, from which the percentage of body fat can be estimated.



© Photo Courtesy of Hologic, Inc.

Dual energy X-ray absorptiometry (DEXA) uses two low-dose X-rays that differentiate among fat-free soft tissue (lean body mass), fat tissue, and bone tissue, providing a precise measurement of total fat and its distribution in all but extremely obese subjects.



© Geri Engberg Photography

Bioelectrical impedance measures body fat by using a low-intensity electrical current. Because electrolyte-containing fluids, which readily conduct an electrical current, are found primarily in lean body tissues, the leaner the person, the less resistance to the current. The measurement of electrical resistance is then used in a mathematical equation to estimate the percentage of body fat.



Adam Gault/SPL

Waist circumference measures central obesity by placing a nonstretchable measuring tape around the waist just above the bony crest of the hip. The tape runs parallel to the floor and is snug, but does not compress the skin.

REVIEW IT Distinguish between body weight and body composition, including methods to assess each.

The body mass index (BMI) is based on weight in kilograms (kg) relative to height in meters (m) squared. As a useful measure of a person's weight status, the BMI serves as a reliable indicator of chronic disease risks, but it says little about body composition. The ideal amount of body fat varies from person to person, but researchers have found that body fat in excess of 22 percent for young men and 27 percent for young women (the levels rise slightly with age) poses health risks. Central obesity is measured by waist circumference and indicates excess abdominal fat distributed around the trunk of the body. Central obesity contributes to chronic diseases, but whether those risks are greater than fat elsewhere in the body is uncertain.

8.5 Health Risks Associated with Body Weight and Body Fat

LEARN IT Identify relationships between body weight and chronic diseases.

Body weight and body fat correlate with disease risks and life expectancy. The correlation suggests a greater *likelihood* of developing a chronic disease and shortening life expectancy for those with a higher BMI.[17] Not all overweight

and underweight people will get sick and die before their time nor will all normal-weight people live long healthy lives. *Correlations* are not *causes*. For the most part though, people with a BMI between 18.5 and 24.9 have relatively few weight-related health risks; risks increase as BMI falls below or rises above this range, indicating that both too little and too much body fat impair health.[18] Epidemiological data show a J- or U-shaped relationship between body weights and mortality (see Figure 8-11).[19] People who are extremely underweight or extremely obese carry higher risks of early deaths ♦ than those whose weights fall within the healthy, or even the slightly overweight, range.[20] These mortality risks decline with age.

Independently of BMI, factors such as smoking habits raise health risks, and physical fitness lowers them. A man with a BMI of 22 who smokes two packs of cigarettes a day is jeopardizing his health, whereas a woman with a BMI of 32 who walks briskly for an hour a day is improving her health.

Health Risks of Underweight Some underweight people enjoy an active, healthy life, but others are underweight because of malnutrition, smoking habits, substance abuse, or illnesses. Weight and fat measures alone would not reveal these underlying causes, but a complete assessment that includes a diet and medical history, physical examination, and biochemical analysis would.

An underweight person, especially an older adult, may be unable to preserve lean tissue during the fight against a wasting disease such as cancer or a digestive disorder, especially when the disease is accompanied by malnutrition. Without adequate nutrient and energy reserves, an underweight person will have a particularly tough battle against such medical stresses. Underweight women develop menstrual irregularities and become infertile. Those who do conceive may give birth to unhealthy infants. An underweight woman can improve her chances of having a healthy infant by gaining weight prior to conception, during pregnancy, or both. Underweight and significant weight loss are also associated with osteoporosis and bone fractures. For all these reasons, underweight people may benefit from enough of a weight gain to provide an energy reserve and protective amounts of all the nutrients.

Health Risks of Overweight As for excessive body fat, the health risks are so many that it has been designated a disease—obesity. Among the health risks associated with obesity are diabetes, hypertension, cardiovascular disease, sleep apnea (abnormal ceasing of breathing during sleep), osteoarthritis, some cancers, gallbladder disease, kidney stones, respiratory problems (including Pickwickian syndrome, a breathing blockage linked with sudden death), infertility, and complications in pregnancy and surgery. Obese people are more likely to be disabled in their later years. Each year, these obesity-related illnesses cost our nation $147 billion—in fact, as much as, or more than, the medical costs of smoking.[21] An additional $72 billion is estimated in a loss of productivity at work due to mortality and disability.[22]

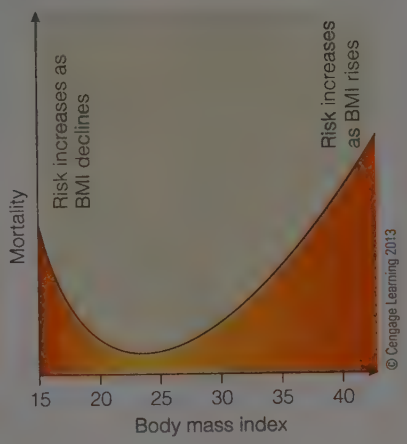
The cost in terms of lives is also great. In fact, obesity is second only to tobacco in causing premature deaths.[23] Mortality is lowest when BMI is in the optimal range of 20.0 to 24.9; it increases as excess weight increases.[24]

Equally important, both central obesity and weight gains of more than 20 pounds (9 kilograms) between early and middle adulthood correlate with increased disease risks. Fluctuations in body weight, as typically occur with "yo-yo" dieting, may also increase the risks of chronic diseases and premature death. In contrast, sustained weight loss improves physical well-being, reduces disease risks, and increases life expectancy.

Cardiovascular Disease The relationship between obesity and cardiovascular disease risk is strong, with links to both elevated blood cholesterol and hypertension.[25] Central obesity may raise the risk of heart attack and stroke as much as the three leading risk factors (high LDL cholesterol, hypertension, and smoking) do. ♦ In addition to body fat, weight gain also increases the risk of cardiovascular

FIGURE 8-11 BMI and Mortality

This J-shaped curve describes the relationship between body mass index (BMI) and mortality and shows that both underweight and overweight present risks of a premature death.



♦ BMI and mortality:
- BMI 22.5–25 = optimal survival
- BMI 30–35 = 3 years' loss of life
- BMI >40 = 10 years' loss of life (equivalent to lifetime of smoking)

♦ Cardiovascular disease risk factors associated with obesity:
- High LDL cholesterol
- Low HDL cholesterol
- High blood pressure (hypertension)
- Diabetes



Smoking is the leading cause of preventable illnesses and early deaths. Obesity is a close second.

disease. Weight loss, on the other hand, can effectively reverse atherosclerosis and lower both blood cholesterol and blood pressure in overweight and obese people.[26] Of course, lean and normal-weight people may also have high blood cholesterol and blood pressure, and these factors are just as dangerous in lean people as in obese people.

Type 2 Diabetes Most adults with type 2 diabetes are overweight or obese.[27] Type 2 diabetes is three times more likely to develop in an obese person than in a nonobese person. Furthermore, the person with type 2 diabetes often has central obesity. Central-body fat cells appear to be larger and more insulin-resistant than lower-body fat cells. The association between **insulin resistance** and obesity is strong, and both are major risk factors for the development of type 2 diabetes.

Diabetes appears to be influenced by weight gains as well as by body weight. A weight gain of more than 10 pounds (4.5 kilograms) after the age of 18 doubles the risk of developing diabetes, even in adults of average weight. In contrast, weight loss is effective in improving glucose tolerance and insulin resistance.

Inflammation and the Metabolic Syndrome Chronic **inflammation** accompanies obesity, and inflammation contributes to chronic diseases.[28] As a person grows fatter, lipids first fill the adipose tissue and then migrate into other tissues such as the muscles and liver. This accumulation of fat, especially in the abdominal region, changes the body's metabolism, resulting in insulin resistance, low HDL, high triglycerides, and high blood pressure.[29] This cluster of symptoms—collectively known as the metabolic syndrome—increases the risks for diabetes, hypertension, and atherosclerosis. ♦ Fat accumulation, especially in the abdominal region, activates genes that code for proteins (adipokines) involved in inflammation.[30] Furthermore, although relatively few immune cells are commonly found in adipose tissue, weight gain significantly increases their number and their role in inflammation. Elevated blood lipids—whether due to obesity or to a high-fat diet—also promote inflammation. Together, these factors help to explain why chronic inflammation accompanies obesity and how obesity contributes to the metabolic syndrome and the progression of chronic diseases.[31] Even in healthy youngsters, body fat correlates positively with chronic inflammation. As might be expected, weight loss reduces

♦ Metabolic syndrome is a cluster of at least three of the following risk factors:
- High blood pressure
- High blood glucose
- High blood triglycerides
- Low HDL cholesterol
- High waist circumference

Chapter 18 provides many more details.

insulin resistance: the condition in which a normal amount of insulin produces a subnormal effect in muscle, adipose, and liver cells, resulting in an elevated fasting glucose; a metabolic consequence of obesity that precedes type 2 diabetes.

inflammation: an immunological response to cellular injury characterized by an increase in white blood cells.

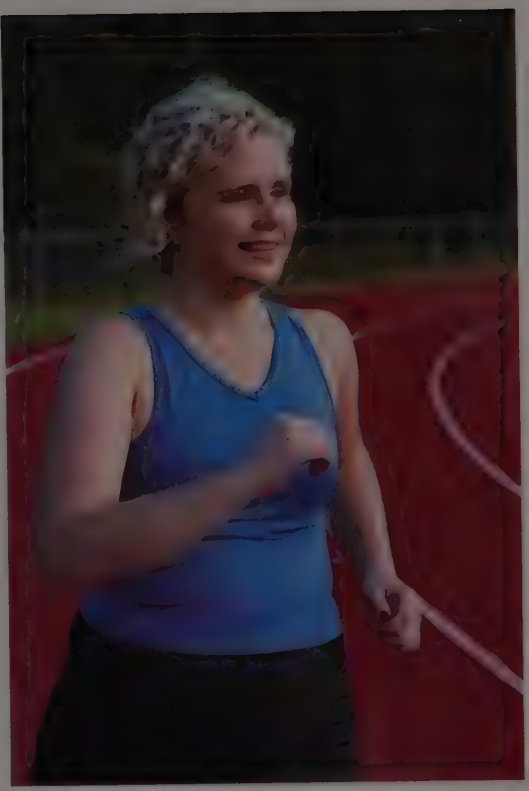
the number of immune cells in adipose tissue and changes gene expression to reduce inflammation.

Cancer The risk of some cancers increases with both body weight and weight gain, but researchers do not fully understand the relationships. One possible explanation may be that obese people have elevated levels of hormones that could influence cancer development. For example, adipose tissue is the major site of estrogen synthesis in women, obese women have elevated levels of estrogen, and estrogen has been implicated in the development of cancers of the female reproductive system—cancers that account for half of all cancers in women.

Fit and Fat versus Sedentary and Slim Importantly, BMI and weight gains and losses do not tell the whole story. Cardiorespiratory and muscular fitness play major roles in health and longevity, independently of body weight.[32] Normal-weight people who are fit have a lower risk of mortality than normal-weight people who are unfit. Furthermore, overweight but fit people have lower risks than normal-weight, unfit ones.[33] Fit people are also likely to gain less weight over the years. Clearly, a healthy body weight is good, but it may not be good enough. Fitness, in and of itself, offers many health benefits, as Chapter 14 confirms.

REVIEW IT Identify relationships between body weight and chronic diseases.

The weight appropriate for an individual depends largely on factors specific to that individual, including body fat distribution, family health history, and current health status. At the extremes, both overweight and underweight carry clear risks to health.



© Steven Frame/Alamy

Being active—even if overweight—is healthier than being sedentary.

This chapter has described energy balance and body composition with a focus on the health problems associated with too much or too little body weight and body fat. Highlight 8 examines the health problems that arise when efforts to control body weight become eating disorders. The next chapter continues the discussion with a look at weight management and the benefits of choosing nutritious foods and exercising regularly.

Nutrition Portfolio

When combined with fitness, a healthy body weight will help you to defend against chronic diseases. Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Energy Balance report; use this report to help you answer the following questions:

- Describe how your daily food intake and physical activity balance with each other.
- What did the diet analysis program estimate as your daily energy requirement? What information was this based on?
- Describe any health risks that may be of concern for a person who continuously has very high "net kcalories" or very low "net kcalories" for many years?

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at www.cengagebrain.com.

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

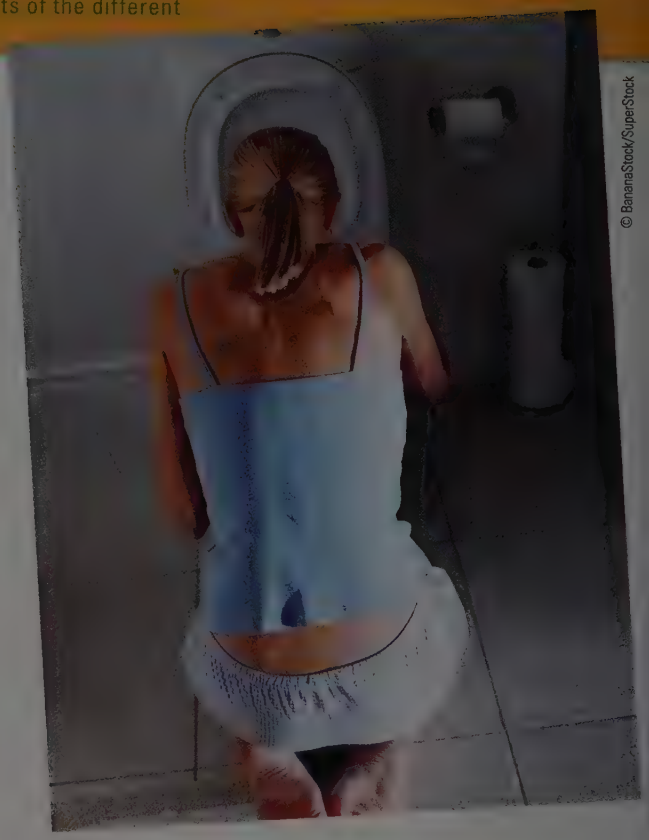
REFERENCES

1. M. B. Katan and D. S. Ludwig, Extra calories cause weight gain: But how much? *Journal of the American Medical Association* 303 (2010): 65–66.
2. D. A. Schoeller, The energy balance equation: Looking back and looking forward are two very different views, *Nutrition Reviews* 67 (2009): 249–254.
3. E. R. Grimm and N. I. Steinle, Genetics of eating behavior: Established and emerging concepts, *Nutrition Reviews* 69 (2011): 52–60; M. de Krom and coauthors, Genetic variation and effects on human eating behavior, *Annual Review of Nutrition* 29 (2009): 283–304.
4. D. Ferriday and J. M. Brunstrom, "I just can't help myself": Effects of food-cue exposure in overweight and lean individuals, *International Journal of Obesity* 35 (2011): 142–149; L. B. Shomaker and coauthors, Eating in the absence of hunger in adolescents: Intake after a large-array meal compared with that after a standardized meal, *American Journal of Clinical Nutrition* 92 (2010): 697–703.
5. M. S. Westerterp-Plantenga and coauthors, Dietary protein, weight loss, and weight maintenance, *Annual Review of Nutrition* 29 (2009): 21–41.
6. J. A. Gilbert and coauthors, Milk supplementation facilitates appetite control in obese women during weight loss: A randomized, single-blind, placebo-controlled trial, *British Journal of Nutrition* 105 (2011): 133–143; E. R. Dove and coauthors, Skim milk compared with a fruit drink acutely reduces appetite and intake in overweight men and women, *American Journal of Clinical Nutrition* 90 (2009): 70–75.
7. M. D. Lane and S. H. Cha, Effect of glucose and fructose on food intake via malonyl-CoA signaling in the brain, *Biochemical and Biophysical Research Communications* 382 (2009): 1–5.
8. H. Schloegl and coauthors, Peptide hormones regulating appetite: Focus on neuroimaging studies in humans, *Diabetes/Metabolism Research and Reviews* 27 (2011): 104–112; K. A. Simpson and S. R. Bloom, Appetite and hedonism: Gut hormones and the brain, *Endocrinology and Metabolism Clinics of North America* 39 (2010): 729–743; S. Zac-Varghese, T. Tan, and S. R. Bloom, Hormonal interactions between gut and brain, *Discovery Medicine* 10 (2010): 543–552; E. Valassi, M. Scacchi, and F. Cavagnini, Neuroendocrine control of food intake, *Nutrition, Metabolism, and Cardiovascular Disease* 18 (2008): 158–168.
9. D. Anschutz and coauthors, Watching your weight? The relations between watching soaps and music television and body dissatisfaction and restrained eating in young girls, *Psychology and Health* 24 (2009): 1035–1050; M. J. Hogan and V. C. Strasburger, Body image, eating disorders, and the media, *Adolescent Medicine: State of the Art Reviews* 19 (2008): 521–546.
10. W. V. Brown and coauthors, Obesity: Why be concerned? *The American Journal of Medicine* 122 (2009): S4–S11; D. P. Guh and coauthors, The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis, *BioMed Central Public Health* 25 (2009): 88.
11. K. M. Flegal and coauthors, Prevalence and trends in obesity among US adults, 1999–2008, *Journal of the American Medical Association* 303 (2010): 235–241.
12. R. Huxley and coauthors, Ethnic comparisons of the cross-sectional relationships between measures of body size with diabetes and hypertension, *Obesity Reviews* 9 (2008): 53–61.
13. ACSM's *Health-Related Physical Fitness Assessment Manual*, 2nd ed., (Baltimore, M.D.: Lippincott Williams & Wilkins, 2008), p. 59.
14. B. J. Arsenault and coauthors, Physical inactivity, abdominal obesity and risk of coronary heart disease in apparently healthy men and women, *International Journal of Obesity* 34 (2010): 340–347; E. J. Jacobs and coauthors, Waist circumference and all-cause mortality in a large US cohort, *Archives of Internal Medicine* 170 (2010): 1293–1301; S. S. Dhaliwal and T. A. Welborn, Central obesity and multivariable cardiovascular risk as assessed by the Framingham prediction scores, *American Journal of Cardiology* 103 (2009): 1403–1407; E. B. Levitan and coauthors, Adiposity and incidence of heart failure hospitalization and mortality: A population-based prospective study, *Circulation Heart Failure* 2 (2009): 202–208; J. P. Després and coauthors, Abdominal obesity and the metabolic syndrome: Contribution to global cardiometabolic risk, *Arteriosclerosis, Thrombosis, and Vascular Biology* 28 (2008): 1039–1049.
15. D. Wormser and coauthors, Separate and combined associations of body-mass index and abdominal adiposity with cardiovascular disease: Collaborative analysis of 58 prospective studies, *The Lancet* 377 (2011): 1085–1095; K. M. Flegal and B. I. Graubard, Estimates of excess deaths associated with body mass index and other anthropometric variables, *American Journal of Clinical Nutrition* 89 (2009): 1213–1219.
16. Position of the American Dietetic Association: Weight management, *Journal of the American Dietetic Association* 109 (2009): 330–346.
17. S. T. Stewart, D. M. Cutler, and A. B. Rosen, Forecasting the effects of obesity and smoking on US life expectancy, *New England Journal of Medicine* 361 (2009): 2252–2260.
18. Flegal and Graubard, 2009.
19. A. Berrington de Gonzalez and coauthors, Body-mass index and mortality among 1.46 million white adults, *New England Journal of Medicine* 363 (2010): 2211–2219; G. Whitlock and coauthors, Body-mass index and cause-specific mortality in 900,000 adults: Collaborative analyses of 57 prospective studies, *Lancet* 373 (2009): 1083–1096; T. Pischon and coauthors, General and abdominal adiposity and risk of death in Europe, *New England Journal of Medicine* 359 (2008): 2105–2120.
20. W. Zheng and coauthors, Association between body-mass index and risk of death in more than 1 million Asians, *New England Journal of Medicine* 364 (2011): 719–729.
21. E. A. Finkelstein and coauthors, Annual medical spending attributable to obesity: Payer- and service-specific estimates, *Health Affairs* 28 (2009): W822–W831.
22. Society of Actuaries, Obesity and its relation to mortality and morbidity costs, www.soa.org/files/pdf/research-2011-obesity-relation-mortality.pdf.
23. H. Jia and E. I. Lubetkin, Trends in quality-adjusted life-years lost contributed by smoking and obesity, *American Journal of Preventive Medicine* 38 (2010): 138–144.
24. Berrington de Gonzalez and coauthors, 2010; Whitlock and coauthors, 2009.
25. C. J. Lavie , R. V. Milani, and H. O. Ventura, Obesity and cardiovascular disease: Risk factor, paradox, and impact of weight loss, *Journal of the American College of Cardiology* 53 (2009): 1925–1932; R. P. Bogers and coauthors, Association of overweight with increased risk of coronary heart disease partly independent of blood pressure and cholesterol levels: A meta-analysis of 21 cohort studies including more than 300,000 persons, *Archives of Internal Medicine* 167 (2007): 1720–1728.
26. I. Shai and coauthors, Dietary intervention to reverse carotid atherosclerosis, *Circulation* 121 (2010): 1200–1208.
27. M. L. Biggs and coauthors, Association between adiposity in midlife and older age and risk of diabetes in older adults, *Journal of the American Medical Association* 303 (2010): 2504–2512.
28. B. B. Aggarwal, Targeting inflammation-induced obesity and metabolic diseases by curcumin and other nutraceuticals, *Annual Review of Nutrition* 30 (2010): 173–199; J. A. Alvarez and coauthors, Fasting and postprandial markers of inflammation in lean and overweight children, *American Journal of Clinical Nutrition* 89 (2009): 1138–1144; A. Cartier and coauthors, Sex differences in inflammatory markers: What is the contribution of visceral adiposity? *American Journal of Clinical Nutrition* 89 (2009): 1307–1314; M. Hamer and A. Steptoe, Prospective study of physical fitness, adiposity, and inflammatory markers in healthy middle-aged men and women, *American Journal of Clinical Nutrition* 89 (2009): 85–89; A. W. Fogarty and coauthors, A prospective study of weight change and systemic inflammation over 9 y, *American Journal of Clinical Nutrition* 87 (2008): 30–35.
29. E. W. Demerath, Causes and consequences of human variation in visceral adiposity, *American Journal of Clinical Nutrition* 91 (2010): 1–2.

30. E. Dalmas and coauthors, Variations in circulating inflammatory factors are related to changes in calorie and carbohydrate intakes early in the course of surgery-induced weight reduction, *American Journal of Clinical Nutrition* 94 (2011): 450–458; J. Korner, S. C. Woods, and K. A. Woodworth, Regulation of energy homeostasis and health consequences in obesity, *The American Journal of Medicine* 122 (2009): S12–S18.
31. P. Calabro and E. T. Yeh, Intra-abdominal adiposity, inflammation, and cardiovascular risk: New insight into global cardiometabolic risk, *Current Hypertension Reports* 10 (2008): 32–38; V. Z. Rocha and P. Libby, The multiple facets of the fat tissue, *Thyroid* 18 (2008): 175–183.
32. V. Hainer, H. Toplak, and V. Stich, Fat or fit: What is more important? *Diabetes Care* 32 (2009): S392–S397.
33. D. E. Larson-Meyer and coauthors, Caloric restriction with or without exercise: The fitness versus fatness debate, *Medicine and Science in Sports and Exercise* 42 (2010): 152–159; R. P. Wildman and coauthors, The obese without cardiometabolic risk factor clustering and the normal weight with cardiometabolic risk factor clustering, *Archives of Internal Medicine* 168 (2008): 1617–1624.

LEARN IT Compare and contrast the diagnoses, characteristics, and treatments of the different eating disorders.

Eating Disorders



© BananaStock/SuperStock

For some people, the struggle with body weight manifests itself as an **eating disorder.** (The accompanying glossary defines this and related terms.) Three eating disorders—anorexia nervosa, bulimia nervosa, and binge eating disorder—are relatively uncommon, but present real concerns because of their health consequences. Findings from a large national survey suggest that 0.9 percent of women and 0.3 percent of men suffer from anorexia nervosa at some time in their lives.[1] Prevalence of bulimia nervosa is slightly higher, with 1.5 percent of women and 0.5 percent of men. Binge eating disorder is higher still, with 3.5 percent of women and 2 percent of men. Many more suffer from other unspecified conditions that, even though they do not meet the strict criteria for an eating disorder, imperil a person's well-being.

Why do so many people in our society suffer from eating disorders? Most experts agree that the causes include multiple factors: sociocultural, psychological, and perhaps neurochemical. Excessive pressure to be thin is at least partly to blame. Family attitudes concerning body shape and eating habits can have profound effects.[2] Young people may have learned to identify discomforts such as anger, jealousy, or disappointment with "feeling fat." They often have other psychological issues such as depression, anxiety, or substance abuse. As weight issues become more of a focus, psychological problems worsen, and the likelihood of developing eating disorders intensifies. Unfortunately, few seek health care for eating disorders. Athletes are among those most likely to develop eating disorders.

The Female Athlete Triad

At age 14, Suzanne was a top contender for a spot on the state gymnastics team. Each day her coach reminded team members that they must weigh no more than their assigned weights to qualify for competition. The coach chastised gymnasts who gained weight, and Suzanne was terrified of being singled out. Convinced that the less she weighed the better she would perform, Suzanne weighed herself several times a day to confirm that she had not exceeded her 80-pound limit. Driven to excel in her sport, Suzanne kept her weight down by eating very little and training very hard. Unlike many of her friends, Suzanne never began to menstruate. A few months before her fifteenth birthday, Suzanne's coach dropped her back to the second-level team. Suzanne blamed her poor performance on a slow-healing stress fracture. Mentally stressed and physically exhausted, she quit gymnastics and began overeating between periods of self-starvation. Suzanne had

GLOSSARY

amenorrhea (ay-MEN-oh-REE-ah): the absence of or cessation of menstruation. *Primary amenorrhea* is menarche delayed beyond 16 years of age. *Secondary amenorrhea* is the absence of three to six consecutive menstrual cycles.

anorexia (an-oh-RECK-see-ah) **nervosa:** an eating disorder characterized by a refusal to maintain a minimally normal body weight and a distortion in perception of body shape and weight.

- **an** = without
- **orex** = mouth
- **nervos** = of nervous origin

binge-eating disorder: an eating disorder with criteria similar to those of bulimia nervosa, excluding purging or other compensatory behaviors.

bulimia (byoo-LEEM-ee-ah) **nervosa:** an eating disorder characterized by repeated episodes of binge eating usually followed by self-induced vomiting, misuse of laxatives or diuretics, fasting, or excessive exercise.

- **buli** = ox

cathartic (ka-THAR-tik): a strong laxative.

disordered eating: eating behaviors that are neither normal nor healthy, including restrained eating, fasting, binge eating, and purging.

eating disorders: disturbances in eating behavior that jeopardize a person's physical or psychological health.

emetic (em-ETT-ic): an agent that causes vomiting.

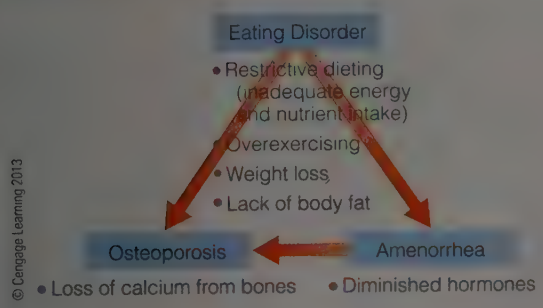
female athlete triad: a potentially fatal combination of three medical problems—disordered eating, amenorrhea, and osteoporosis.

muscle dysmorphia (dis-MORE-fee-ah): a psychiatric disorder characterized by a preoccupation with building body mass.

stress fractures: bone damage or breaks caused by stress on bone surfaces during exercise.

unspecified eating disorders: eating disorders that do not meet the defined criteria for specific eating disorders.

FIGURE H8-1 The Female Athlete Triad



developed the dangerous combination of problems that characterize the **female athlete triad**—disordered eating, amenorrhea, and osteoporosis (see Figure H8-1).[3]

Disordered Eating

Part of the reason many athletes engage in **disordered eating** behaviors may be that they and their coaches have embraced unsuitable weight standards. An athlete's body must be heavier for a given height than a nonathlete's body because the athlete's body is dense, containing more healthy bone and muscle and less fat. When athletes rely only on the scales, they may mistakenly believe they are too fat because weight standards, such as the BMI, do not provide adequate information about body composition.

Many young athletes severely restrict energy intakes to improve performance, enhance the aesthetic appeal of their performance, or meet the weight guidelines of their specific sports. They fail to realize that the loss of lean tissue that accompanies energy restriction actually impairs their physical performance. The increasing incidence of abnormal eating habits among athletes is cause for concern. Male athletes, especially wrestlers and gymnasts, are affected by these disorders as well, but females are most vulnerable. Risk factors for eating disorders among athletes include:

- Young age (adolescence)
- Pressure to excel at a chosen sport
- Focus on achieving or maintaining an "ideal" body weight or body fat percentage
- Participation in sports or competitions that emphasize a lean appearance or judge performance on aesthetic appeal such as gymnastics, wrestling, figure skating, or dance
- Weight-loss dieting at an early age
- Unsupervised dieting

Amenorrhea

The prevalence of **amenorrhea** among premenopausal women in the United States is about 2 to 5 percent overall, but among female athletes, it may be as high as 66 percent. Contrary to previous notions, amenorrhea is *not* a normal adaptation to strenuous physical training: it is a symptom of something going wrong. Amenorrhea is characterized by low blood estrogen, infertility, and often bone mineral losses. Excessive training, depleted body fat, low body weight, and inadequate nutrition all contribute to amenorrhea. However amenorrhea develops, it threatens the integrity of the bones. Bone losses remain significant even after recovery. (Women with bulimia frequently have menstrual irregularities, but because they rarely cease menstruating, they may be spared this loss of bone integrity.)

Osteoporosis

For most people, weight-bearing physical activity, dietary calcium, and (for women) the hormone estrogen protect against the bone loss of osteoporosis. For young women with disordered eating and amenorrhea, strenuous activity can increase bone turnover and impair bone health.[4] Vigorous training combined with inadequate food intake disrupt metabolic and hormonal balances. These disturbances compromise bone health, greatly increasing the risks of **stress fractures.** Stress fractures commonly occur among dancers and other competitive athletes with amenorrhea, low calcium intakes, and disordered eating. Many underweight young athletes have bones like those of postmenopausal women, and they may never recover their lost bone even after diagnosis and treatment—which makes prevention critical. Young athletes should be encouraged to consume 1300 milligrams of calcium each day, to eat nutrient-dense foods, and to obtain enough energy to support both a healthy body weight and the energy expended in physical activity. Nutrition is critical to bone recovery.

Other Dangerous Practices of Athletes

Only females face the threats of the female athlete triad, of course, but many male athletes face pressure to achieve an unrealistic body weight and may develop eating disorders.[5] Each week throughout the season, David drastically restricts his food and fluid intake before a wrestling match in an effort to "make weight." Competitors in judo and wrestling and their coaches believe that competing in a lower weight class will give them a competitive advantage over smaller opponents. To that end, David intensifies his exercise, skips meals, restricts fluids, practices in plastic suits, and trains in heated rooms to lose 4 to 7 pounds rapidly.[6] He does this several times during the competitive season. These athletes hope to replenish the lost fluids, glycogen, and lean tissue during the hours between weigh-in and competition, but the body needs days to correct this metabolic mayhem. Reestablishing fluid and electrolyte balances may take 1 to 2 days, replenishing glycogen stores may take 2 to 3 days, and replacing lean tissue may take even longer.

Ironically, the combination of food deprivation and dehydration impairs physical performance by reducing muscle strength, decreasing anaerobic power, and reducing endurance capacity. For optimal performance, athletes need to first achieve their competitive weight during the off-season and then eat well-balanced meals and drink plenty of fluids during the competitive season.

Some athletes, usually males, go to extreme measures to bulk up and *gain* weight. People afflicted with **muscle dysmorphia** eat high-protein diets, take dietary supplements, weight train for hours at a time, and often abuse steroids in an attempt to increase muscle mass. Their bodies are large and muscular, yet they see themselves as puny 90-pound weaklings. They are preoccupied with the idea that their bodies are too small or inadequately muscular. Like others with distorted body images, people with muscle dysmorphia weigh themselves frequently and center their lives on diet and exercise. Paying attention to diet and pumping iron for fitness is admirable, but obsessing over it can cause serious social, occupational, and physical problems.

Preventing Eating Disorders in Athletes

To prevent eating disorders in athletes and dancers, the performers, their coaches, and their parents must learn about inappropriate body weight ideals, improper weight-loss techniques, eating disorder development, proper nutrition, and safe weight-control methods. Young people naturally search for identity and will often follow the advice of a person in authority without question. Therefore, coaches and dance instructors should never encourage unhealthy weight loss to qualify for competition or to conform to distorted artistic ideals. Athletes who truly need to lose weight should try to do so during the off-season and under the supervision of a health-care professional. Frequent weigh-ins can push young people who are striving to lose weight into a cycle of starving to confront the scale, then bingeing uncontrollably afterward. The erosion of self-esteem that accompanies this cycle can interfere with normal psychological development and set the stage for serious problems later on.

Table H8-1 includes suggestions to help athletes and dancers protect themselves against developing eating disorders. The remaining sections describe eating disorders that anyone, athlete or nonathlete, may experience.

TABLE H8-1 Tips for Combating Eating Disorders

General Guidelines

- Never restrict food amounts to below those suggested for adequacy by the USDA Food Patterns (see Table 2-2 on p. 44).
- Eat frequently. Include healthy snacks between meals. The person who eats frequently never gets so hungry as to allow hunger to dictate food choices.
- If not at a healthy weight, establish a reasonable weight goal based on a healthy body composition.
- Allow a reasonable time to achieve the goal. A reasonable loss of excess fat can be achieved at the rate of about 10 percent of body weight in 6 months.
- Establish a weight-maintenance support group with people who share interests.

Specific Guidelines for Athletes and Dancers

- Replace weight-based goals with performance-based goals.
- Restrict weight-loss activities to the off-season.
- Remember that eating disorders impair physical performance. Seek professional help in obtaining treatment if needed.
- Focus on proper nutrition as an important facet of your training, as important as proper technique.

Anorexia Nervosa

Julie, 18 years old, is a superachiever in school. She watches her diet with great care, and she exercises daily, maintaining a rigorous schedule of self-discipline. She is thin, but she is determined to lose more weight. She is 5 feet 6 inches tall and weighs 104 pounds (roughly 1.68 meters and 47 kilograms). Her BMI is less than 17. She has **anorexia nervosa.**

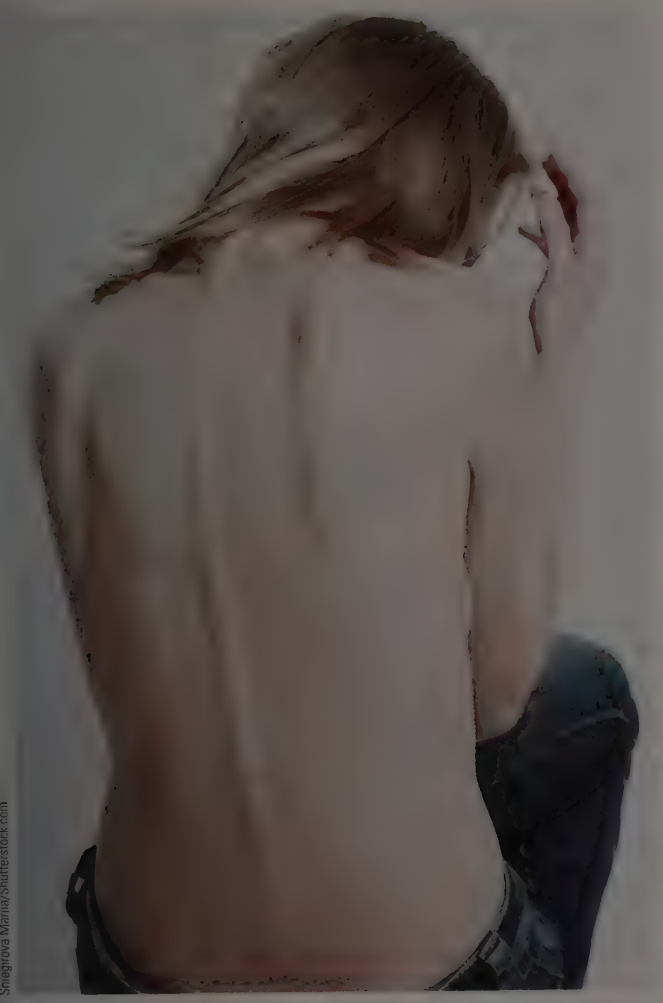
Characteristics of Anorexia Nervosa

Julie is unaware that she is undernourished, and she sees no need to obtain treatment. She developed amenorrhea several months ago and has become moody and chronically depressed. She views normal healthy body weight as too fat and insists that she needs to lose weight, although her eyes are sunk in deep hollows in her face. Julie denies that she is ever tired, although she is close to physical exhaustion and no longer sleeps easily. Her family is concerned, and though reluctant to push her, they have finally insisted that she see a psychiatrist. Julie's psychiatrist has diagnosed anorexia nervosa using specific criteria that describe such characteristics as minimal body weight, distorted body image, and the absence of menstrual cycles.[7] She is prescribed group therapy as a start and if she does not begin to gain weight soon, she may need to enter a residential program or be hospitalized.

Central to the diagnosis of anorexia nervosa is a distorted body image that overestimates personal body fatness. When Julie looks at herself in the mirror, she sees a "fat" 104-pound body. The more Julie overestimates her body size, the more resistant she is to treatment, and the more unwilling she is to examine her faulty values and misconceptions. In fact, she finds value in her condition. Malnutrition and weight loss affect brain functioning and judgment in this way, causing lethargy, confusion, and delirium and influencing mood, anxiety, and emotions.[8]

Anorexia nervosa cannot be self-diagnosed. Many people in our society are engaged in the pursuit of thinness, and denial runs high among people with anorexia nervosa. Some women have all the attitudes and behaviors associated with the condition, but without the dramatic weight loss.

How can a person as thin as Julie continue to starve herself? Julie uses tremendous discipline against her hunger to strictly limit her portions of low-fat, high-fiber, low-kcalorie foods.[9] She will deny her hunger, and having adapted to eating so little food, she feels full after nibbling on a few carrot sticks. She knows the kcalorie intake of various foods and the kcalorie expenditure of different physical activities. If she feels that she has gained an ounce of weight, she



Sniegirova Marina/Shutterstock.com

People with anorexia nervosa see themselves as fat, even when they are dangerously underweight.

runs or jumps rope until she is sure she has exercised it off. If she fears that the food she has eaten outweighs her physical activity, she may take laxatives to hasten the passage of food from her system. She drinks water incessantly to fill her stomach, risking dangerous mineral imbalances. She is desperately hungry. In fact, she is starving, but she doesn't eat because her need for self-control dominates.

Many people, on learning of this disorder, say they wish they had "a touch" of it to get thin. They mistakenly think that people with anorexia nervosa feel no hunger. They also fail to recognize the pain of the associated psychological and physical trauma.

The starvation of anorexia nervosa damages the body just as the starvation of war and poverty does. In fact, most people with anorexia nervosa are malnourished. Their bodies have been depleted of both body fat and protein. Victims are dying to be thin—quite literally. In young people, growth ceases and normal development falters. They lose so much lean tissue that their basal metabolic rate slows. In addition, the heart pumps inefficiently and irregularly, the heart muscle becomes weak and thin, the chambers diminish in size, and the blood pressure falls. Minerals that help to regulate heartbeat become unbalanced. Many deaths occur due to multiple organ system failure when the heart, kidneys, and liver cease to function.

Starvation brings other physical consequences as well, such as loss of brain tissue, impaired immune response, anemia, and a loss of digestive functions that worsen malnutrition. Peristalsis becomes sluggish, the stomach empties slowly, and the lining of the intestinal tract atrophies. The pancreas slows its production of digestive enzymes. The deteriorated GI tract fails to provide sufficient digestive enzymes and absorptive surfaces for handling any food that is eaten. The person may suffer from diarrhea, further worsening malnutrition.

Other effects of starvation include altered blood lipids, high blood vitamin A and vitamin E, low blood proteins, dry thin skin, abnormal nerve functioning, reduced bone density, low body temperature, low blood pressure, and the development of fine body hair (the body's attempt to keep warm). The electrical activity of the brain becomes abnormal, and insomnia is common. Both women and men lose their sex drives.

Women with anorexia nervosa develop amenorrhea. (It is one of the diagnostic criteria.) In young girls, the onset of menstruation is delayed. Menstrual periods typically resume with recovery, although some women never restart even after they have gained weight. Should an underweight woman with anorexia nervosa become pregnant, she is likely to give birth to an underweight baby—and low-birthweight babies face many health problems (as Chapter 15 explains). Mothers with anorexia nervosa may underfeed their children, who then fail to grow and may also suffer the other consequences of starvation.

Treatment of Anorexia Nervosa

Treatment of anorexia nervosa requires a multidisciplinary approach.[10] Teams of physicians, nurses, psychiatrists, family therapists, and dietitians work together to resolve two sets of issues and behaviors: those relating to food and weight and those involving relationships with oneself and others.

The first dietary objective is to stop weight loss while establishing regular eating patterns. Appropriate diet is crucial to recovery and must be tailored to each individual's needs. Because body weight is low and fear of weight gain is high, initial food intake may be small—perhaps only 1200 kcalories per day. A variety of foods and foods with a higher energy density help to ensure greater success.[11] As eating becomes more comfortable, clients should gradually increase energy intake. Initially, clients may be unwilling to eat for themselves. Those who do eat will have a good chance of recovering without additional interventions. Even after recovery, however, energy intakes and eating behaviors may not fully return to normal. Furthermore, weight gains may be slow because energy needs may be slightly elevated due to anxiety, abdominal pain, and cigarette smoking.

Because anorexia nervosa is like starvation physically, health-care professionals classify clients based on indicators of malnutrition. Low-risk clients need nutrition counseling. Intermediate-risk clients may need supplements such as high-kcalorie, high-protein formulas in addition to regular meals. High-risk clients may require hospitalization and may need to be fed by tube at first to prevent death.[12] Residential programs that provide intensive behavioral treatment may be most appropriate for those who do not respond to less intensive approaches.[13]

Denial runs high among those with anorexia nervosa. Few seek treatment on their own. About half of the women who are treated can maintain their body weight at 85 percent or more of a healthy weight, and at that weight, many of them may begin menstruating again. The other half have poor to fair treatment outcomes, relapse into abnormal eating behaviors, or die. Anorexia nervosa has one of the highest mortality rates among psychiatric disorders—most commonly from cardiac complications or by suicide.[14] Much like treatment for drug addictions, treatment for eating disorders engages family members. Therapists help family members to understand how their past interactions have enabled the client to continue destructive behaviors and how new ways of interacting can support change.[15]

Before drawing conclusions about someone who is extremely thin or who eats very little, remember that diagnosis requires professional assessment. Several national organizations offer information for people who are seeking help with anorexia nervosa, either for themselves or for others.

Bulimia Nervosa

Kelly is a charming, intelligent, 30-year-old flight attendant of normal weight who thinks constantly about food. She alternates between starving herself and secretly bingeing, and when she has eaten too much, she makes herself vomit. Most readers recognize these symptoms as those of **bulimia nervosa.**

Characteristics of Bulimia Nervosa

Bulimia nervosa is distinct from anorexia nervosa and is more prevalent, although the true incidence is difficult to establish because bulimia nervosa is not as physically apparent. More men suffer from bulimia nervosa than from anorexia nervosa, but bulimia nervosa is still more common in women than in men. The secretive nature of bulimic behaviors makes recognition of the problem difficult, but once it is recognized, diagnosis is based on such criteria as number and frequency of binge eating episodes, inappropriate compensatory behaviors, and distorted body image.[16]

Like the typical person with bulimia nervosa, Kelly is single, female, and white. She is well educated and close to her ideal body weight, although her weight fluctuates over a range of 10 pounds or so every few weeks. She prefers to weigh less than the weight that her body maintains naturally.

Kelly seldom lets her eating disorder interfere with work or other activities, although a third of all bulimics do. From early childhood, she has been a high achiever and emotionally dependent on her parents. As a young teen, Kelly frequently followed severely restricted diets but could never maintain the weight loss. Kelly feels anxious at social events and cannot easily establish close personal relationships. She is usually depressed, is often impulsive, and has low self-esteem. When crisis hits, Kelly responds by replaying events, worrying excessively, and blaming herself but never asking for help—behaviors that interfere with effective coping.

Like the person with anorexia nervosa, the person with bulimia nervosa spends much time thinking about body image and food. The preoccupation with food manifests itself in secret binge-eating episodes, which usually progress through several emotional stages: anticipation and planning, anxiety, urgency to begin, rapid and uncontrollable consumption of food, relief and relaxation, disappointment, and finally shame or disgust.

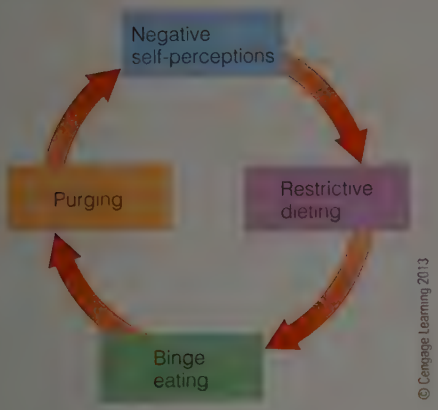
A bulimic binge is characterized by a sense of no control over eating. During a binge, the person consumes food for its emotional comfort and cannot stop eating or control what or how much is eaten. A typical binge occurs periodically, in secret, usually at night, and lasts an hour or more. Because a binge frequently follows a period of restrictive dieting, eating is accelerated by intense hunger. Energy restriction followed by bingeing can set in motion a pattern of weight cycling, which may make weight loss and maintenance more difficult over time.

During a binge, Kelly consumes thousands of kcalories of easy-to-eat, low-fiber, high-fat, and, especially, high-carbohydrate foods. Typically, she chooses cookies, cakes, and ice cream—and she eats the entire bag of cookies, the whole cake, and every last spoonful in a carton of ice cream. After the binge, Kelly pays the price with swollen hands and feet, bloating, fatigue, headache, nausea, and pain.

To purge the food from her body, Kelly may use a **cathartic**—a strong laxative that can injure the lower intestinal tract. Or she may induce vomiting, with or without the use of an **emetic**—a drug intended as first aid for poisoning. These purging behaviors are often accompanied by feelings of shame or guilt. Hence a vicious cycle develops: negative self-perceptions followed by dieting, bingeing, and purging, which in turn lead to negative self-perceptions (see Figure H8-2).

On first glance, purging seems to offer a quick and easy solution to the problems of unwanted kcalories and body weight. Many people perceive such behavior as neutral or even positive, when, in fact, binge eating and purging have serious physical consequences. Signs of subclinical malnutrition are evident in a compromised immune system. Fluid and mineral imbalances caused by vomiting or diarrhea can lead to abnormal heart rhythms and injury to the kidneys. Urinary tract infections can lead to kidney failure. Vomiting causes irritation and infection of the pharynx, esophagus, and salivary glands; erosion of the teeth; and dental caries. The esophagus may rupture or tear, as may the stomach. Sometimes the eyes

> **FIGURE H8-2 The Vicious Cycle of Restrictive Dieting and Binge Eating**



become red from pressure during vomiting. The hands may be calloused or cut by the teeth while inducing vomiting. Overuse of emetics depletes potassium concentrations and can lead to death by heart failure.

Unlike Julie, Kelly is aware that her behavior is abnormal, and she is deeply ashamed of it. She wants to recover, and this makes recovery more likely for her than for Julie, who clings to denial. Feeling inadequate ("I can't even control my eating"), Kelly tends to be passive and to look to others for confirmation of her sense of worth. When she experiences rejection, either in reality or in her imagination, her bulimia nervosa becomes worse. If Kelly's depression deepens, she may seek solace in drug or alcohol abuse or in other addictive behaviors. Clinical depression is common in people with bulimia nervosa, and the rates of substance abuse are high.

Treatment of Bulimia Nervosa

Kelly needs to establish regular eating patterns. She may also benefit from a regular exercise program. Weight maintenance, rather than cyclic weight gains and losses, is the treatment goal. Major steps toward recovery include discontinuing purging and restrictive dieting habits and learning to eat three meals a day plus snacks. Initially, energy intake should provide enough food to satisfy hunger and maintain body weight. Table H8-2 offers diet strategies to correct the eating problems of bulimia nervosa. Most women diagnosed with bulimia nervosa recover within 5 to 10 years, with or without treatment, but treatment probably speeds the recovery process. Cognitive behavioral therapy may be more effective than other types of treatment.[17] A mental health professional should be on the treatment team to help clients with their depression and addictive behaviors.

Anorexia nervosa and bulimia nervosa are distinct eating disorders, yet they sometimes overlap in important ways. Anorexia victims may purge, and victims of both disorders are overly concerned with body image and have a tendency to drastically undereat. Many perceive

TABLE H8-2 Diet Strategies for Combating Bulimia Nervosa

Planning Principles

- Plan meals and snacks; record plans in a food diary prior to eating.
- Plan meals and snacks that require eating at the table and using utensils.
- Refrain from finger foods.
- Refrain from "dieting" or skipping meals.

Nutrition Principles

- Eat a well-balanced diet and regularly timed meals consisting of a variety of foods.
- Include raw vegetables, salad, or raw fruit at meals to prolong eating times.
- Choose whole-grain, high-fiber breads, pasta, rice, and cereals to increase bulk.
- Consume adequate fluid, particularly water.

Other Tips

- Choose foods that provide protein and fat for satiety and bulky, fiber-rich carbohydrates for immediate feelings of fullness.
- Try including soups and other water-rich foods for satiety.
- Choose portions that meet the definition of "a serving" according to the USDA Food Patterns (pp. 42–43).
- For convenience (and to reduce temptation) select foods that naturally divide into portions. Select one potato, rather than rice or pasta that can be overloaded onto the plate; purchase yogurt and cottage cheese in individual containers; look for small packages of precut steak or chicken; choose frozen dinners with measured portions.
- Include 30 minutes of physical activity every day—exercise may be an important tool in defeating bulimia.

© Cengage Learning 2013

foods as "forbidden" and "give in" to an eating binge. The two disorders can also appear in the same person, or one can lead to the other. Treatment is challenging and relapses are not unusual. Other people have **unspecified eating disorders** that fall short of the criteria for anorexia nervosa or bulimia nervosa but share several of the same features. One such condition is **binge-eating disorder**.

Binge-Eating Disorder

Charlie is a 40-year-old schoolteacher who has been overweight all his life. His friends and family are forever encouraging him to lose weight, and he has come to believe that if he only had more willpower, dieting would work. He periodically gives dieting his best shot—restricting energy intake for a day or two only to succumb to uncontrollable cravings, especially for high-fat foods. Like Charlie, up to half of the obese people who try to lose weight periodically binge; unlike people with bulimia nervosa, however, they typically do not purge. Such an eating disorder does not meet the criteria for either anorexia nervosa or bulimia nervosa—yet such compulsive overeating is a problem and occurs in people of normal weight as well as those who are severely overweight. Obesity alone is not an eating disorder.

Clinicians note differences between people with bulimia nervosa and those with binge-eating disorder. People with binge-eating

disorder consume less during a binge, rarely purge, and exert less restraint during times of dieting. Similarities also exist, including feeling out of control, disgusted, depressed, embarrassed, guilty, or distressed because of their self-perceived gluttony.

There are also differences between obese binge eaters and obese people who do not binge. Those with binge-eating disorder report higher rates of self-loathing, disgust about body size, depression, and anxiety. Their eating habits differ as well. Obese binge eaters tend to consume more kcalories and more dessert and snack-type foods during regular meals and binges than obese people who do not binge. Binge eating may incur health risks greater than those of obesity alone.[18]

Binge eating is a behavioral disorder that can be resolved with treatment. Even a simple Internet-based treatment program can help.[19] Reducing binge eating makes participation in weight-control programs easier. It also improves physical health, mental health, and the chances of success in breaking the cycle of rapid weight losses and gains.

Eating Disorders in Society

Society plays a central role in eating disorders. Adolescent girls who read magazine articles on dieting and weight loss are likely to engage in unhealthy eating habits. Further proof of society's influence is found in the demographic distribution of eating disorders—they are known only in developed nations, and they become more prevalent as wealth increases and food becomes plentiful. Some people point to the vomitoriums of ancient times and claim that bulimia nervosa is not new, but the two are actually distinct. Ancient people were eating for pleasure, without guilt, and in the company of others; they vomited so that they could rejoin the feast. Bulimia nervosa is a disorder of isolation and is often accompanied by low self-esteem.

Chapter 8 describes how our society sets unrealistic ideals for body weight, especially in women, and devalues those who do not conform to them. Anorexia nervosa and bulimia nervosa are not a form of rebellion against these unreasonable expectations, but rather an exaggerated acceptance of them. In fact, some people fail to recognize the health dangers and endorse eating disorders as a lifestyle choice. Some 200 websites encourage, support, and motivate users to continue their lives with anorexia and bulimia.[20]

The incidence and prevalence of eating disorders in young people has increased steadily since the 1950s.[21] Most alarming is the rising prevalence at progressively younger ages. Restrained eating, fasting, binge eating, purging, fear of fatness, and distortion of body image are extraordinarily common among children and adolescents. Most are "on diets," and many are poorly nourished. Some eat too little food to support normal growth, thus they miss out on their adolescent growth spurts and may never catch up. Many eat so little that hunger propels them into binge-purge cycles. Disordered eating behaviors set a pattern that likely continues into young adulthood.[22]

Perhaps a person's best defense against these disorders is to learn to appreciate his or her own uniqueness. When people discover and honor their body's real physical needs, they become unwilling to sacrifice health for conformity. To respect and value oneself may be lifesaving.

REFERENCES

1. J. I. Hudson and coauthors, The prevalence and correlates of eating disorders in the National Comorbidity Survey Replication, *Biological Psychiatry* 61 (2007): 348–358.
2. R. Rodgers and H. Chabrol, Parental attitudes, body image disturbance and disordered eating amongst adolescents and young adults: A review, *European Eating Disorders Review* 17 (2009): 137–151.
3. D. L. Nichols, C. F. Sanborn, and E. V. Essery, Bone density and young athletic women: An update, *Sports Medicine* 37 (2007): 1001–1014; American College of Sports Medicine, Position stand: The female athlete triad, *Medicine and Science in Sports and Exercise* 39 (2007): 1867–1882.
4. M. T. Barrack and coauthors, Physiologic and behavioral indicators of energy deficiency in female adolescent runners with elevated bone turnover, *American Journal of Clinical Nutrition* 92 (2010): 652–659; M. T. Barrack and coauthors, Dietary restraint and low bone mass in female adolescent endurance runners, *American Journal of Clinical Nutrition* 87 (2008): 36–43.
5. J. L. Glazer, Eating disorders among male athletes, *Current Sports Medicine Reports* 7 (2008): 332–337.
6. G. G. Artioli and coauthors, Prevalence, magnitude, and methods of rapid weight loss among judo competitors, *Medicine and Science in Sports and Exercise* 42 (2010): 436–442.
7. American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders,* (Washington, D.C.: American Psychiatric Association, 2000).
8. W. Kaye, Neurobiology of anorexia and bulimia nervosa, *Physiology and Behavior* 94 (2008): 121–135.
9. M. Misra and coauthors, Nutrient intake in community-dwelling adolescent girls with anorexia nervosa and in healthy adolescents, *American Journal of Clinical Nutrition* 84 (2006): 698–706.
10. Position of the American Dietetic Association: Nutrition intervention in the treatment of anorexia nervosa, bulimia nervosa, and other eating disorders, *Journal of the American Dietetic Association* 106 (2006): 2073–2082.
11. J. E. Schebendach and coauthors, Dietary energy density and diet variety as predictors of outcome in anorexia nervosa, *American Journal of Clinical Nutrition* 87 (2008): 810–816.
12. E. Attia and B. T. Walsh, Behavioral management for anorexia nervosa, *New England Journal of Medicine* 360 (2009): 500–506.
13. Attia and Walsh, 2009.
14. J. M. Holm-Denoma and coauthors, Deaths by suicide among individuals with anorexia as arbiters between competing explanations of the anorexia-suicide link, *Journal of Affective Disorders* 107 (2008): 231–236.
15. J. Treasure and coauthors, The assessment of the family of people with eating disorders, *European Eating Disorders Review* 16 (2008): 247–255.
16. American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders* (Washington, D.C.: American Psychiatric Association, 2000).
17. ECRI Institute, *Bulimia Nervosa: Comparative Efficacy of Available Psychological and Pharmacological Treatments,* as cited in M. Mitka, Reports weighs options for bulimia nervosa treatment, *Journal of the American Medical Association* 305 (2011): 875.
18. J. I. Hudson and coauthors, Longitudinal study of the diagnosis of components of the metabolic syndrome in individuals with binge-eating disorder, *American Journal of Clinical Nutrition* 91 (2010): 1568–1573.

19. M. Jones and coauthors, Randomized, controlled trial of an Internet-facilitated intervention for reducing binge eating and overweight in adolescents, *Pediatrics* 121 (2008): 453–462.
20. D. L. G. Borzekowski and coauthors, e-Ana and e-Mia: A content analysis of pro-eating disorder web sites, *American Journal of Public Health* 100 (2010): 1526–1534.
21. D. S. Rosen and the Committee on Adolescence, Clinical report: Identification and management of eating disorders in children and adolescents, *Pediatrics* 126 (2010): 1240–1253.
22. D. Neumark-Sztainer and coauthors, Dieting and disordered eating behaviors from adolescence to young adulthood: Findings from a 10-year longitudinal study, *Journal of the American Dietetic Association* 111 (2011): 1004–1011.



CENGAGE LEARNING'S GLOBAL NUTRITION WATCH

Gastric surgery is an option for some cases of clinically severe obesity. There are several surgical options available, each with benefits and risks. Go to Weight Management/Diets → Obesity to compare the risks and benefits of surgery with those of other weight-loss strategies. Under what circumstances would surgery be the best decision?

9

Weight Management: Overweight, Obesity, and Underweight

Nutrition in Your Life

Are you pleased with your body weight? If so, you are a rare individual. Most people in our society think they should weigh more or less (mostly less) than they do. Usually, their primary concern is appearance, but they often understand that physical health is also somehow related to body weight. One does not necessarily cause the other—that is, an ideal body weight does not ensure good health. Instead, both depend on diet and physical activity. A well-balanced diet and active lifestyle support good health—and help maintain body weight within a reasonable range. In the Nutrition Portfolio at the end of this chapter, you can consider whether your eating habits and physical activities are supporting good health and a reasonable body weight.

The previous chapter described how body weight is stable when energy in equals energy out. Weight gains occur when energy intake exceeds energy expended, and conversely, weight losses occur when energy expended exceeds energy intake. At the extremes, both overweight and underweight present health risks. **Weight management** is a key component of good health.

This chapter emphasizes overweight and obesity, partly because they have been more intensively studied and partly because they represent a major health problem in the United States and a growing concern worldwide. Information on underweight is presented at the end of the chapter. The highlight that follows this chapter examines fad diets.

9.1 Overweight and Obesity

LEARN IT Describe how body fat develops and why it can be difficult to maintain weight gains and losses.

Despite our preoccupation with body image and weight loss, the prevalence of overweight and obesity in the United States continues to be high.[1] In the past

weight management: maintaining body weight in a healthy range by preventing gradual weight gains over time and losing weight if overweight, and by preventing weight losses and gaining weight if underweight.

LEARNING GPS

9.1 Overweight and Obesity 261
LEARN IT Describe how body fat develops and why it can be difficult to maintain weight gains and losses.
- Fat Cell Development 262
- Fat Cell Metabolism 262
- Set-Point Theory 263

9.2 Causes of Overweight and Obesity 264
LEARN IT Review some of the causes of obesity.
- Genetics and Epigenetics 264
- Environment 266

9.3 Problems of Overweight and Obesity 268
LEARN IT Discuss the physical, social, and psychological consequences of overweight and obesity.
- Health Risks 268
- Perceptions and Prejudices 268
- Dangerous Interventions 269

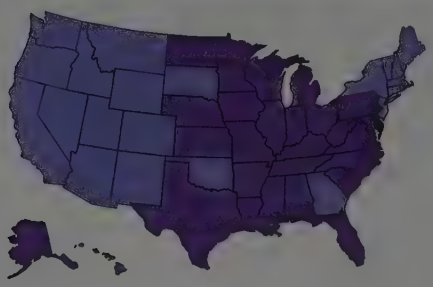
9.4 Aggressive Treatments for Obesity 270
LEARN IT Explain the risks and benefits, if any, of several aggressive ways to treat obesity
- Drugs 270
- Surgery 271

9.5 Weight-Loss Strategies 272
LEARN IT Outline reasonable strategies for achieving and maintaining a healthy body weight.
- Set Reasonable Goals 272
- Eating Patterns 274
- Physical Activity 277
- Environmental Influences 280
- Behavior and Attitude 281
- Weight Maintenance 283
- Prevention 284
- Community Programs 284

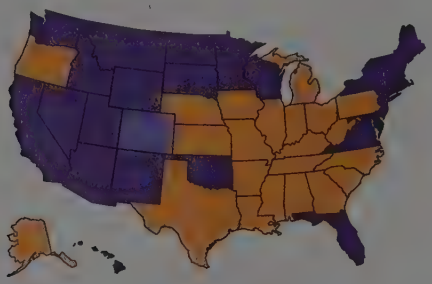
9.6 Underweight 285
LEARN IT Summarize strategies for gaining weight.
- Problems of Underweight 285
- Weight-Gain Strategies 286

Highlight 9 The Latest and Greatest Weight-Loss Diet—Again 292
LEARN IT Contrast the differences between popular fad diets and weight-loss diets based on sound nutrition.

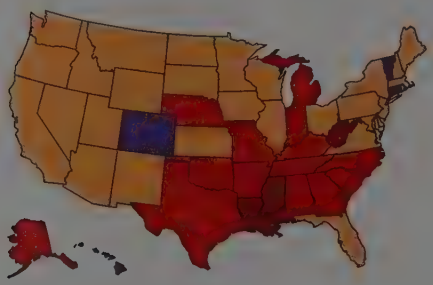
FIGURE 9-1 Increasing Prevalence of Obesity (BMI ≥ 30) among US Adults



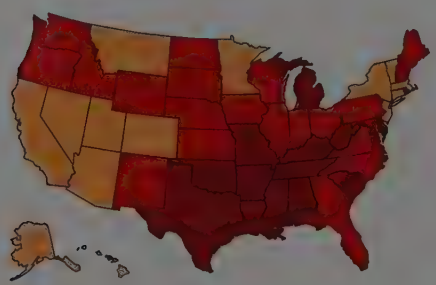
1995: No state had a prevalence rate less than 10%, all states had prevalence rates between 10–19%, and no state had a prevalence rate greater than or equal to 20%.



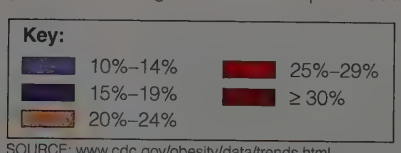
2000: Only Colorado had a prevalence rate less than 15%, the other states had prevalence rates between 15–24%, and no state had a prevalence rate greater than or equal to 25%.



2005: No state had a prevalence rate less than 15%, most states had prevalence rates between 20–29%, and 3 states had a prevalence rate greater than or equal to 30%.



2010: No state had a prevalence rate less than 20%, most states had prevalence rates between 20–29%, and 12 states had a prevalence rate greater than or equal to 30%.



SOURCE: www.cdc.gov/obesity/data/trends.html

three decades, obesity increased in every state, in both genders, and across all ages, races, and educational levels (see Figure 9-1).[2] An estimated 68 percent of the adults in the United States are now considered overweight or obese, as defined by a BMI of 25 or greater.[3] ♦ The prevalence of overweight is especially high among women, the poor, blacks, and Mexican Americans.

The prevalence of overweight among children in the United States has also risen at an alarming rate. An estimated 34 percent of children and adolescents aged 2 to 19 years are either overweight or obese.[4] Chapter and Highlight 16 present information on overweight during childhood and adolescence.

Obesity in the United States is widespread. Prevalence increased rapidly over the past four decades, but seems to have leveled out in recent years. This **epidemic** of obesity has spread worldwide, affecting 1.5 billion adults and 43 million children younger than age 5.[5] Contrary to popular opinion, obesity is not limited to industrialized nations; people in developing countries also suffer from obesity-related problems. Before examining the suspected causes of obesity and the various strategies used to treat it, it is helpful to understand the development and metabolism of body fat.

Fat Cell Development

When "energy in" exceeds "energy out," much of the excess energy is stored in the fat cells of adipose tissue. The amount of fat in adipose tissue reflects both the *number* and the *size* of the fat cells.* The number of fat cells increases most rapidly during the growing years of late childhood and early puberty. After growth ceases, fat cell number may continue to increase whenever energy balance is positive.[6] Obese people have more fat cells than healthy-weight people; their fat cells are also larger.

As fat cells accumulate triglycerides, they expand in size (review Figure 5-18 on p. 144). When the cells enlarge, they stimulate cell proliferation so that their numbers increase again. Thus obesity develops when a person's fat cells increase in number, in size, or quite often both. Figure 9-2 illustrates fat cell development.

When "energy out" exceeds "energy in," the size of fat cells dwindles, but not their number. People with extra fat cells tend to regain lost weight rapidly; with weight gain, their many fat cells readily fill. In contrast, people with an average number of enlarged fat cells may be more successful in maintaining weight losses; when their cells shrink, both cell size and number are normal. Prevention of obesity is most critical, then, during the growing years of childhood and adolescence when fat cells increase in number.[7] Researchers are exploring ways to induce fat cell death—which would decrease the number.[8]**

As mentioned, excess fat first fills the body's natural storage site—adipose tissue. If fat is still abundant, the excess is deposited in organs such as the heart and liver and plays a key role in the development of diseases such as heart failure and fatty liver, respectively.[9]*** As adipose tissue produces adipokines, metabolic changes that indicate disease risk—such as insulin resistance—become apparent and chronic inflammation develops.[10] The adipokine profile begins to improve with as little as a 5 percent weight loss and a decrease in fat cell size, suggesting that other metabolic changes might also occur at that time to improve disease risks.[11]

Fat Cell Metabolism

The enzyme **lipoprotein lipase (LPL)** is a major determinant in the development of obesity.[12] Its role is to remove triglycerides from the blood for storage in both adipose tissue and muscle cells. Obese people generally have much more LPL activity in their adipose cells than lean people do (their muscle cell LPL activity is similar, though). This high LPL activity makes fat storage especially efficient. Consequently, even modest excesses in energy intake have a more dramatic impact on obese people than on lean people. When obese people lose weight, their LPL activity diminishes.[13]

The activity of LPL in different regions of the body is partially influenced by gender. In women, fat cells in the breasts, hips, and thighs produce abundant LPL,

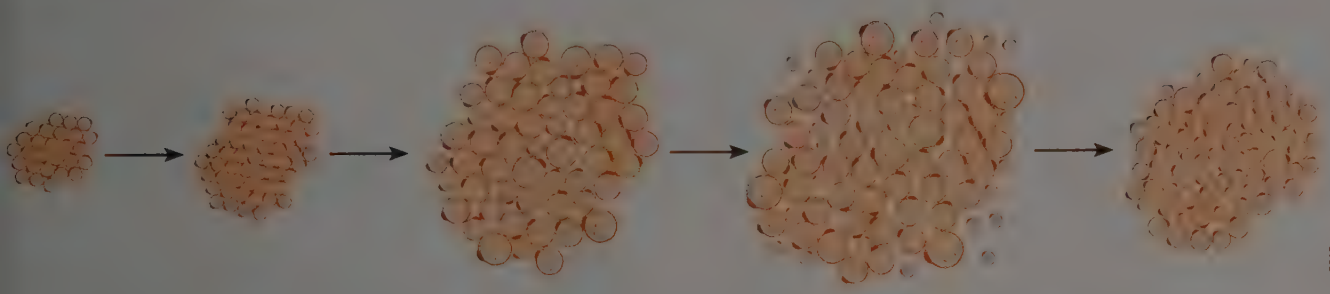
*Obesity due to an increase in the *number* of fat cells is *hyperplastic obesity.* Obesity due to an increase in the *size* of fat cells is *hypertrophic obesity.*

**Cell death is known as as *apoptosis.*

***The adverse effect of fat in nonadipose tissue is known as *lipotoxicity.*

> **FIGURE 9-2 Fat Cell Development**

Fat cells are capable of increasing their size by 20-fold and their number by several thousandfold.



During growth, fat cells increase in number.

When energy intake exceeds expenditure, fat cells increase in size.

When fat cells have enlarged and energy intake continues to exceed energy expenditure, fat cells may increase in number again.

With fat loss, the size of the fat cells shrinks but not the number.

© Cengage Learning 2013

storing fat in those body sites; in men, fat cells in the abdomen produce abundant LPL. This enzyme activity explains why men tend to develop central obesity around the abdomen (apple-shaped) whereas women more readily develop lower-body fat around the hips and thighs (pear-shaped).

Gender differences are also apparent in the activity of the lipase enzymes controlling the release and breakdown of fat in various parts of the body. The release of lower-body fat is less active in women than in men, whereas the release of upper-body fat is similar. Furthermore, the rate of fat breakdown is lower in women than in men. Consequently, women may have a more difficult time losing fat in general, and from the hips and thighs in particular.

Enzyme activity may also explain why some people who lose weight regain it so easily. After weight loss, adipose LPL activity increases. Apparently, weight loss serves as a signal to the gene that produces the LPL enzyme, saying "Make more of the enzyme that stores fat." People easily regain weight after having lost it because they are battling against enzymes that want to store fat. Not only is fat storage efficient, but fat oxidation is not. Dietary fat oxidation correlates negatively with body fatness: obese people have the least activity.[14] The activities of these and other proteins provide an explanation for the observation that some inner mechanism seems to set a person's body weight or composition at a fixed point; the body will make adjustments to restore that **set point** if the person tries to change it.

♦ BMI:
- Underweight: <18.5
- Healthy weight: 18.5–24.9
- Overweight: 25.0–29.9
- Obese: ≥30

Set-Point Theory

Many physiological variables, such as blood glucose, blood pH, and body temperature, remain fairly stable under a variety of conditions. The hypothalamus and other regulatory centers constantly monitor and delicately adjust conditions to maintain homeostasis. The stability of such complex systems may depend on set-point regulators that maintain variables within specified limits.

Researchers have confirmed that after weight gains or losses, the body adjusts its metabolism to restore the original weight. Energy expenditure increases after weight gain and decreases after weight loss. These changes in energy expenditure differ from those that would be expected based on body composition alone, and they help to explain why it can be difficult for an underweight person to maintain weight gains and an overweight person to maintain weight losses.

REVIEW IT Describe how body fat develops and why it can be difficult to maintain weight gains and losses.

Fat cells develop by increasing in number and size. Obesity prevention depends on maintaining a reasonable number of fat cells. With weight gains or losses, the body adjusts in an attempt to return to its set-point weight.

epidemic (ep-ih-DEM-ick): the appearance of a disease (usually infectious) or condition that attacks many people at the same time in the same region.
- **epi** = upon
- **demos** = people

lipoprotein lipase (LPL): an enzyme that hydrolyzes triglycerides passing by in the bloodstream and directs their parts into the cells, where they can be metabolized or reassembled for storage.

set point: the point at which controls are set (for example, on a thermostat). The set-point theory that relates to body weight proposes that the body tends to maintain a certain weight by means of its own internal controls.

9.2 Causes of Overweight and Obesity

LEARN IT Review some of the causes of obesity.

Why do people accumulate excess body fat? The obvious answer is that they take in more energy from foods and beverages than they expend in physical activity and metabolic processes. But that answer falls short of explaining why they do this. Is it genetic? Environmental? Cultural? Behavioral? Socioeconomic? Psychological? Metabolic? All of these? Most likely. Many factors contribute to the development of obesity and most are interrelated. This section reviews these possible causes of overweight and obesity.

Genetics and Epigenetics Genetics plays a true causative role in relatively few cases of obesity, for example, in Prader-Willi syndrome—a genetic disorder characterized by excessive appetite, massive obesity, short stature, and often mental retardation. Most cases of obesity, however, do not stem from a single gene, yet genetic influences do seem to be involved.[15] Highlight 6 describes epigenetics—the influence of environmental factors, such as diet and physical activity, on gene expression. Obesity provides a classic example.[16]

Researchers have found that adopted children tend to be more similar in weight to their biological parents than to their adoptive parents.[17] Studies of twins yield similar findings: compared with fraternal twins, identical twins are twice as likely to weigh the same.[18] These findings suggest an important role for genetics in determining a person's *predisposition* to obesity.[19] In other words, genes interact with the diet and activity patterns that lead to obesity and the metabolic pathways that influence satiety and energy balance. Even identical twins with identical genes become different over the years as epigenetic changes accumulate. This raises an important point: you cannot change the genome you inherit, but you can influence the epigenome. Physical activity, for example, can minimize the genetic influences on BMI.[20] Likewise, high-fat diets and low physical activity can accentuate the genetic influences on obesity.[21]

Clearly, something genetic makes a person more or less likely to gain or lose weight when overeating or undereating. Some people gain more weight than others on comparable energy intakes. Given an extra 1000 kcalories a day for 100 days, some pairs of identical twins gain less than 10 pounds while others gain up to 30 pounds. Within each pair, the amounts of weight gained, percentages of body fat, and locations of fat deposits are similar. Similarly, some people lose more weight than others following comparable exercise routines.

Researchers have been examining the human genome in search of genetic and epigenetic answers to obesity questions.[22] As the section on protein synthesis in Chapter 6 describes, each cell expresses only the genes for the proteins it needs, and each protein performs a unique function. The following paragraphs describe only a couple of the proteins that help explain appetite control, energy regulation, and obesity development.[23]

Leptin Researchers have identified an obesity gene, called *ob*, that is expressed primarily in the adipose tissue and codes for the protein **leptin.** Leptin acts as a hormone, primarily in the hypothalamus. Leptin maintains homeostasis by regulating food intake and energy expenditure in response to adipose tissue.[24] When body fat increases, leptin increases—which suppresses appetite. When body fat decreases, leptin decreases—which stimulates appetite and suppresses energy expenditure.[25]

Mice with a defective *ob* gene do not produce leptin and can weigh up to three times as much as normal mice and have five times as much body fat (see Figure 9-3). When injected with a synthetic form of leptin, the mice rapidly lose body fat. (Because leptin is a protein, it would be destroyed during digestion if given orally; consequently, it must be given by injection.) The fat cells not only lose fat, but they self-destruct (reducing cell number), which may explain why weight gains are delayed when the mice are fed again.

leptin: a protein produced by fat cells under direction of the *ob* gene that decreases appetite and increases energy expenditure.

- **leptos** = thin

FIGURE 9-3 Mice with and without Leptin Compared

Both of these mice have a defective *ob* gene. Consequently, they do not produce leptin. They both became obese, but the one on the right received daily injections of leptin, which suppressed food intake and increased energy expenditure, resulting in weight loss.



Without leptin, this mouse weighs almost three times as much as a normal mouse.

With leptin treatment, this mouse lost a significant amount of weight but still weighs almost one and a half times as much as a normal mouse.

Photos: © Courtesy Amgen, Inc., Art © Cengage Learning 2013

Although extremely rare, a genetic deficiency of leptin or genetic mutation of its receptor has been identified in human beings as well.[26] Extremely obese children with barely detectable blood levels of leptin have little appetite control; they are constantly hungry and eat considerably more than their siblings or peers. Given daily injections of leptin, these children lose a substantial amount of weight, confirming leptin's role in regulating appetite and body weight.

Not too surprisingly, leptin injections are effective in suppressing appetite and supporting weight loss only when overeating and obesity are the result of a leptin deficiency. Very few obese people have a leptin deficiency, however. In fact, leptin levels increase as BMI increases. Leptin rises but fails to suppress appetite or enhance energy expenditure—a condition researchers describe as leptin resistance.[27] Interestingly, excessive fructose consumption seems to induce leptin resistance and accelerate fat storage.[28]

Ghrelin Another protein, known as **ghrelin**, also acts as a hormone primarily in the hypothalamus. In contrast to leptin, ghrelin is secreted primarily by the stomach cells and promotes weight gain by stimulating appetite and promoting efficient energy storage.[29]

Ghrelin triggers the desire to eat. Blood levels of ghrelin typically rise before and fall after a meal in proportion to the kcalories ingested—reflecting the hunger and satiety that precede and follow eating. On average, ghrelin levels are high whenever the body is in negative energy balance, as occurs during low-kcalorie diets, for example. This response may help explain why weight loss is so difficult to maintain. Weight loss is more successful with exercise and after gastric bypass surgery, in part because ghrelin levels are relatively low. Ghrelin levels decline again whenever the body is in positive energy balance, as occurs with weight gains.

Some research indicates that ghrelin also promotes sleep. Interestingly, a lack of sleep increases the hunger hormone ghrelin and decreases the satiety hormone leptin—which may help to explain the association between inadequate sleep and overweight.[30]

These two proteins—leptin and ghrelin—illustrate some of the complex factors involved in the regulation of food intake and energy homeostasis. Scientists have identified numerous proteins expressed by dozens of genes linked to obesity and several others associated with fat distribution in the body.[31] Each of these genes have slight variations that differ among individuals.[32] Furthermore, these genes interact with one another and with the environment. The complexity of it all creates a multitude of possible genetic explanations.[33]

Uncoupling Proteins Genes also code for proteins involved in energy metabolism. These proteins may influence the storing or expending of energy with different

ghrelin (GRELL-in): a protein produced by the stomach cells that enhances appetite and decreases energy expenditure

- **ghre** = growth



© Nico Kai/Getty Images

The food industry spends billions of dollars a year on advertising. The message? "Eat more."

efficiencies or in different types of fat. The body has two types of fat: white and **brown adipose tissue.**[34] White adipose tissue stores fat for other cells to use for energy; brown adipose tissue releases stored energy as heat. Recall from Chapter 7 that when fat is oxidized, some of the energy is released in heat and some is captured in ATP. In brown adipose tissue, oxidation is uncoupled from ATP formation, producing heat only.[35]* By radiating energy away as heat, the body expends, rather than stores, energy. In contrast, efficient coupling leads to fat storage.[36] In other words, weight gains or losses may depend on whether the body dissipates the energy from an ice cream sundae as heat or stores it in body fat.

Brown fat and heat production is particularly important in newborns and in animals exposed to cold weather, especially those that hibernate. They have plenty of brown adipose tissue. In contrast, most human adults have little brown fat—less than 1 percent of all fat cells and interspersed among the white fat cells. Brown fat activity is most apparent during exposure to cold.[37] Importantly, brown fat quantity is inversely related with BMI; overweight and obese individuals have less brown fat activity than others.[38] The role of brown fat in body weight regulation is not yet understood, but such an understanding may prove most useful in developing obesity treatments.[39]

Uncoupling proteins are active not only in brown fat, but also in white fat and many other tissues. Their actions seem to influence the basal metabolic rate (BMR) and oppose the development of obesity. Animals with abundant amounts of these uncoupling proteins resist weight gain, whereas those with minimal amounts gain weight easily. Similarly, people with a genetic variant of an uncoupling protein have lower metabolic rates and are more overweight than others.

Environment With obesity rates rising and the **gene pool** remaining relatively unchanged, environment must also play a role in obesity. Obesity reflects the interactions between genes and the environment.[40] An **obesogenic environment** includes all of the circumstances that we encounter daily that push us toward fatness. Over the past 4 decades, the demand for physical activity has decreased as the abundance of food has increased.[41]

Keep in mind that genetic and environmental factors are not mutually exclusive; in fact, their *interactions* create the epigenetics that provide a greater understanding of obesity and related diseases.[42] Genes can influence eating behaviors, for example, and food and activity behaviors influence the genes that regulate body weight. Interestingly, even social relationships can influence the development of obesity.[43] The likelihood that a person will become obese increases when a friend, sibling, or spouse becomes obese.

Overeating One explanation for obesity is that overweight people overeat, although diet histories may not always reflect high intakes. Diet histories are not always accurate records of actual intakes; both normal-weight and obese people commonly misreport their dietary intakes. Most importantly, current dietary intakes may not reflect the eating habits that led to obesity. Obese people who had a positive energy balance for years and accumulated excess body fat may not currently have a positive energy balance. This reality highlights an important point: the energy-balance equation must consider time. Both present *and* past eating and activity patterns influence current body weight.

We live in an environment that exposes us to an abundance of high-kcalorie, high-fat foods that are readily available, relatively inexpensive, heavily advertised, and reasonably tasty. Food is available everywhere, all the time—thanks largely to fast food. Our highways are lined with fast-food restaurants. Convenience stores and service stations offer fast food and snacks as well. Fast food is available in our schools, malls, and airports. The mere proximity of fast food increases the risk of obesity.[44] It's convenient and it's available morning, noon, and night—and all

brown adipose tissue: masses of specialized fat cells packed with pigmented mitochondria that produce heat instead of ATP.

gene pool: all the genetic information of a population at a given time.

obesogenic (oh-BES-oh-JEN-ick) **environment:** all the factors surrounding a person that promote weight gain, such as increased food intake, especially of unhealthy choices, and decreased physical activity.

*In *coupled reactions*, the energy released from the breakdown of one compound is used to create a bond in the formation of another compound. In *uncoupled reactions*, the energy is released as heat.

times in between. Consequently, we are eating more meals more frequently than in decades past—and energy intake has risen accordingly.[45]

Most alarming are the extraordinarily large portions and ready-to-go combo-meals. Eating large portion sizes multiple times a day accounts for much of the weight increase seen over the decades.[46] People buy the large portions and combinations, perceiving them to be a good value, but then they eat more than they need—a bad deal. In fact, one research study calculated that for the 67 cents extra to upsize a meal, consumers receive an extra 400 kcalories, an extra 36 grams of body fat, and an extra $1 to $7 in health-care costs.[47]

Simply put, large portion sizes deliver more kcalories.[48] And portion sizes of virtually all foods and beverages have increased markedly in the past several decades, most notably at fast-food restaurants. Not only have portion sizes increased over time, but they are now two to eight times larger than standard serving sizes. The trend toward large portion sizes parallels the increasing prevalence of overweight and obesity in the United States, beginning in the 1970s, increasing sharply in the 1980s, and continuing today.

Restaurant food, especially fast food, contributes significantly to the development of obesity. Fast food is often energy-dense food, which increases energy intake, BMI, and body fatness. The combination of large portions and energy-dense foods is a double whammy. Reducing portion sizes is somewhat helpful, but the real kcalorie savings come from lowering the energy density. Low-energy density foods such as fruits and vegetables can help with weight loss.



© Joao Virissimo/Shutterstock.com

"Want fries with that?" A supersize portion delivers more than 600 kcalories.

Physical Inactivity Our environment fosters physical inactivity as well. Life requires little exertion—escalators carry us up stairs, automobiles take us across town, and remote controls change television channels from a distance. Modern technology has replaced physical activity at home, at work, and in transportation.[49] Inactivity contributes to weight gain and poor health. Most physical inactivity occurs when watching television, playing video games, and using the computer. The more time people spend in these sedentary activities, the more likely they are to be overweight—and to incur the metabolic risk factors of heart disease (high blood lipids, high blood pressure, and high blood glucose).[50]

Sedentary activities contribute to weight gain in several ways. First, they require little energy beyond the resting metabolic rate. Second, they replace time spent in more vigorous activities. Third, watching television influences food purchases and correlates with between-meal snacking on the high-kcalorie, solid fat and added sugars foods and beverages most heavily advertised.

Some obese people are so extraordinarily inactive that even when they eat less than lean people, they still have an energy surplus. Reducing their food intake further would incur nutrient deficiencies and jeopardize health. Physical activity is a necessary component of nutritional health. People must be physically active if they are to eat enough food to deliver all the nutrients they need without unhealthy weight gain. In fact, *to prevent weight gain*, the DRI ♦ suggests an accumulation of 60 minutes of moderately intense physical activities every day in addition to the less intense activities of daily living. Recommendations *to lose weight* encourage even greater duration, intensity, or frequency of physical activity (as a later section of the chapter discusses).

♦ DRI for physical activity: 60 min/day (moderate intensity)

People may be obese, therefore, not because they eat too much, but because they move too little—both in purposeful exercise and in the activities of daily life. Studies report that the differences in the time obese and lean people spend lying, sitting, standing, and moving accounts for about 350 kcalories a day. In general, lean people tend to be more spontaneously active in their occupations and their leisure time.[51] The energy expended in these everyday spontaneous activities—called *nonexercise activity thermogenesis (NEAT)*—plays a pivotal role in energy balance and weight management.

REVIEW IT Review some of the causes of obesity.

Obesity has many causes and most interact, creating a complex scenario. Environmental factors, such as overeating and physical inactivity, may influence a person's genetic predisposition to obesity.



© Istockphoto.com/Spaulin

Lack of physical activity fosters obesity.

9.3 Problems of Overweight and Obesity

LEARN IT Discuss the physical, social, and psychological consequences of overweight and obesity.

An estimated 59 percent of US adults are trying to lose weight at any given time.[52] Some of these people may not even need to lose weight. Others may benefit from weight loss, but they will not be successful. Relatively few people succeed in losing weight, and even fewer succeed permanently. For many, improving diet and activity habits to simply prevent further weight gains may be sufficient.[53] Whether a person will benefit from weight loss is a question of health.

Health Risks Chapter 8 describes some of the health problems that commonly accompany obesity. In evaluating the risks to health from obesity, health-care professionals use three indicators:

- Body mass index ♦
- Waist circumference ♦
- Disease risk profile

♦ BMI:
- 25.0–29.9 = overweight
- ≥30 = obese

♦ Waist circumference:
- Men: >40 in (>102 cm)
- Women: >35 in (>88 cm)

Importantly, the disease risk profile takes into account family history, life-threatening diseases, and common risk factors for chronic diseases (such as blood lipid profile). The higher the BMI, the greater the waist circumference, and the more risk factors—the greater the urgency to treat obesity.

People can best decide whether weight loss might be beneficial by considering their health status and motivation. People who are overweight by BMI standards, but otherwise in good health, might not benefit from losing weight; they might focus on preventing further weight gains instead. In contrast, those who are obese and suffering from a life-threatening disease such as diabetes might improve their health substantially by adopting a diet and activity plan that supports weight loss. Motivation is a key component; to lose weight, a person needs to be ready and willing to make lifestyle changes for a lifetime.

Overweight in Good Health Often a person's motivations for weight loss have nothing to do with health. A healthy young woman with a BMI of 26 might want to lose a few pounds for spring break, but doing so might not improve her health. In fact, if she opts for a starvation diet or diet pills, she would be healthier *not* trying to lose weight.

Obese or Overweight with Risk Factors Weight loss is recommended for people who are obese and those who are overweight (or who have a high waist circumference) with two or more risk factors for chronic diseases. ♦ A 50-year-old man with a BMI of 28 who has high blood pressure and a family history of heart disease can improve his health by adopting a diet low in saturated fat and a regular exercise plan.

♦ Obese people and overweight people with two or more of these risk factors require aggressive treatment:
- Hypertension
- Cigarette smoking
- High LDL
- Low HDL
- Impaired glucose tolerance
- Family history of heart disease
- Men ≥45 yr; women ≥55 yr

Obese or Overweight with Life-Threatening Condition Weight loss is also recommended for a person who is either obese or overweight and suffering from a life-threatening condition such as heart disease, diabetes, or sleep apnea. ♦ The health benefits of weight loss are clear. For example, a 30-year-old man with a BMI of 40 might be able to prevent or control diabetes by losing 75 pounds. Although the effort required to do so may be great, it may be no greater than the effort and consequences of living with diabetes.

♦ Obese people and overweight people with any of these diseases require aggressive treatment:
- Heart disease
- Diabetes (type 2)
- Sleep apnea (interruption of breathing during sleep)

Perceptions and Prejudices Many people assume that every obese person can achieve slenderness and should pursue that goal. First consider that most obese people do not—for whatever reason—successfully lose weight and maintain their losses. Then consider the prejudice involved in that assumption. People come with varying weight tendencies, just as they come with varying potentials

for height and physical talents, yet we do not expect tall people to shrink or fast runners to slow down in an effort to become "normal."

Social Consequences Large segments of our society place such enormous value on thinness that obese people face prejudice and discrimination on the job, at school, and in social situations: they are judged on their appearance more than on their character.[54] Socially, obese people are negatively stereotyped as lazy and lacking in self-control.[55] Such a critical view of overweight is not prevalent in many other cultures, including segments of our own society. Instead, overweight is simply accepted or even embraced as a sign of robust health and beauty. To free society of its obsession with body weight and prejudice against obesity, people must first learn to judge others—and themselves—for who they are and not for what they weigh.

Psychological Problems Psychologically, obese people may suffer embarrassment when others treat them with hostility and contempt, and many have come to view their own bodies as flawed. Feelings of rejection, shame, and depression are common among obese people. Anxiety and depression, in turn, may contribute to the development of obesity, which perpetuates the problem.[56]

Most weight-loss programs assume that the problem can be solved simply by applying willpower and hard work. If determination were the only factor involved, though, the success rate would be far greater than it is. Overweight people may readily assume blame for failure to lose weight and maintain the losses when, in fact, it is the programs that have failed. Ineffective treatment and its associated sense of failure add to a person's psychological burden. Figure 9-4 illustrates how the devastating psychological effects of obesity and dieting perpetuate themselves.

> **FIGURE 9-4 The Psychology of Weight Cycling**



Dangerous Interventions

Some people attach so many dreams of happiness to weight loss that they willingly risk huge sums of money for the slightest chance of success. As a result, weight-loss schemes flourish. Of the tens of thousands of claims, treatments, and theories for losing weight, few are effective—and many are downright dangerous. The negative effects must be carefully considered before embarking on any weight-loss program. Some interventions entail greater dangers than the risk of being overweight. Physical, metabolic, and psychosocial problems may arise from fad diets and "yo-yo" dieting.[57] Wise consumers scrutinize fad diets, magic potions, and wonder gizmos with a healthy dose of skepticism.

Some of the nation's most popular diet books and weight-loss programs have misled consumers with unsubstantiated claims and deceptive testimonials. Furthermore, they fail to provide an assessment of the short- and long-term results of their treatment plans, even though such evaluations are possible and would permit consumers to make informed decisions. Of course, some weight-loss programs are better than others in terms of cost, approach, and customer satisfaction. Reputable weight-loss programs will explain the risks associated with their plans and provide honest predictions of success.

Fad Diets **Fad diets** often sound good, but they typically fall short of delivering on their promises. They espouse exaggerated or false theories of weight loss and advise consumers to follow inadequate diets. Some fad diets are hazardous to health as Highlight 9 explains. Adverse reactions can be as minor as headaches, nausea, and dizziness or as serious as death. The "How To" on p. 295 offers guidelines for identifying unsound weight-loss schemes and fad diets.

Weight-Loss Products Millions of people in the United States use nonprescription weight-loss products. Most of them are women, especially young overweight women, but almost 10 percent are of normal weight.

In their search for weight-loss magic, some consumers turn to "natural" herbal products and dietary supplements, even though few have proved to be effective and many have proved to be harmful.[58] For example, in addition to the many cautions that accompany the use of all herbal remedies, consumers should be aware that St. John's wort is often prepared in combination with the herbal stimulant ephedrine. Ephedrine-containing supplements promote modest short-term weight loss (about 2 pounds a month), but with great risks. These supplements

fad diets: popular eating plans that promise quick weight loss. Most fad diets severely limit certain foods or overemphasize others (for example, never eat potatoes or pasta or eat cabbage soup daily).



© Richard Levine / Alamy

So many promises, so little success.

have been implicated in numerous heart attacks and seizures, resulting in about 100 deaths. For this reason, the FDA has banned the sale of ephedrine-containing supplements, but they are still readily available on the Internet.* Similarly, the FDA has issued warnings for another herbal weight loss supplement called Que She, which contains not only ephedrine but two weight-loss drugs that have been withdrawn from the market and another drug used to treat heart conditions.

Highlight 18 explores the possible benefits and potential dangers of herbal products and other alternative therapies. As it explains, dietary supplements do not need to be approved by the FDA, and manufacturers do not need to test the safety or effectiveness of any product. In other words, consumers cannot assume that an herbal product or dietary supplement is safe or effective just because it is available on the market. In fact, the FDA has identified more than 70 products that contain undeclared, active pharmaceutical ingredients that can have serious consequences such as seizures and heart attacks.[59] These ingredients are not listed on the labels, and consumers have no way of knowing what the products actually contain. Anyone considering whether to use dietary supplements for weight loss should consult with a physician and research the product with the FDA (**www.fda.gov**).

Other Gimmicks Other gimmicks don't help with weight loss either. Hot baths do not speed up metabolism so that pounds can be lost in hours. Steam and sauna baths do not melt the fat off the body, although they may dehydrate people so that they lose water weight. Brushes, sponges, wraps, creams, and massages intended to move, burn, or break up fat do nothing of the kind.

REVIEW IT Discuss the physical, social, and psychological consequences of overweight and obesity.

The question of whether a person should lose weight depends on many factors: among them are the extent of overweight, age, health, and genetic makeup. Not all obesity will cause disease or shorten life expectancy. Just as there are unhealthy, normal-weight people, there are healthy, overweight people. Some people may risk more in the process of losing weight than in remaining overweight. Fad diets and weight-loss supplements can be as physically and psychologically damaging as excess body weight.

9.4 Aggressive Treatments for Obesity

LEARN IT Explain the risks and benefits, if any, of several aggressive ways to treat obesity.

The appropriate strategies for weight reduction depend on the degree of obesity and the risk of disease. An overweight person in good health may need only to improve eating habits and increase physical activity, but someone with **clinically severe obesity** may need more aggressive treatment options—drugs or surgery. Drugs appear to be modestly effective and safe, at least in the short term; surgery appears to be dramatically effective but can have severe complications, at least for some people.

Drugs Based on new understandings of obesity's genetic basis and its classification as a chronic disease, much research effort has focused on drug treatments for obesity. Experts reason that if obesity is a chronic disease, it should be treated as such—and the treatment of most chronic diseases includes drugs. The challenge, then, is to develop an effective drug—or more likely, a combination of drugs—that

clinically severe obesity: a BMI of 40 or greater or a BMI of 35 or greater with additional medical problems. A less preferred term used to describe the same condition is *morbid obesity.*

*Ephedrine is an amphetamine-like substance extracted from the Chinese ephedra herb *ma huang.* The FDA has banned the sale of *ma huang* in the United States, and it is illegal in Canada.

TABLE 9-1 FDA Approved Drugs for Weight Loss

Product	Action	Side Effects
Orlistat (OR-leh-stat)	Inhibits pancreatic lipase activity in the GI tract, thus blocking digestion and absorption of dietary fat and limiting energy intake	Cramping, diarrhea, gas, frequent bowel movements, reduced absorption of fat-soluble vitamins; rare cases of liver injury
Phentermine (FEN-ter-mean), diethylpropion (DYE-eth-ill-PRO-pee-on), phendimetrazine (FEN-dye-MEH-tra-zeen)	Enhances the release of the neurotransmitter norepinephrine, which suppresses appetite	Increased blood pressure and heart rate, insomnia, nervousness, dizziness, headache

NOTE: Weight-loss drugs are most effective when taken as directed and used in combination with a reduced-kcalorie diet and increased physical activity.

© Cengage Learning 2013

can be used over time without adverse side effects or the potential for abuse.[60] Weight-loss drugs should be prescribed only to those with medical risks—not for cosmetic reasons—and in tandem with a healthy diet and activity program.

Several drugs for weight loss have been tried over the years, with varying degrees of effectiveness and safety.[61] When used as part of a long-term, comprehensive weight-loss program, drugs can help with modest weight loss. Because weight regain commonly occurs with the discontinuation of drug therapy, treatment must be long term. Yet the long-term use of drugs poses risks. We don't yet know whether a person would be harmed more from maintaining a 100-pound excess or from taking a drug for a decade to keep the 100 pounds off. Physicians must prescribe drugs appropriately, inform consumers of the potential risks, and monitor side effects carefully. Table 9-1 presents the FDA-approved drugs to treat obesity.

Some physicians prescribe drugs that have not been approved for weight loss, a practice known as "off-label" use. These drugs have been approved for other conditions (such as seizures) and incidentally cause modest weight loss. Physicians using off-label drugs must be well-informed of the drugs' use and effects and monitor their patients' responses closely.

Surgery The prevalence of clinically severe obesity (BMI >40) is increasing at an incredibly rapid rate. At this level of obesity, lifestyle changes and modest weight losses can improve disease risks a little, but the most effective treatment is surgery.[62] ♦ More than 200,000 such surgeries are performed in the United States annually. As Figure 9-5 (p. 272) shows, the two most common surgical procedures effectively limit food intake by reducing the capacity of the stomach. In addition, gastric bypass suppresses hunger by reducing production of gastrointestinal hormones.[63] The results are significant: depending on the type of surgery, initial weight loss is 20 to 32 percent of body weight and 14 to 25 percent after 10 years. Importantly, most people experience dramatic improvements in their diabetes, blood lipids, and blood pressure.[64] Improvements in depression and anxiety are not as likely.[65] Whether surgery is a reasonable option for obese teens is the subject of much debate among pediatricians and bariatric surgeons (see Chapter 16).[66]

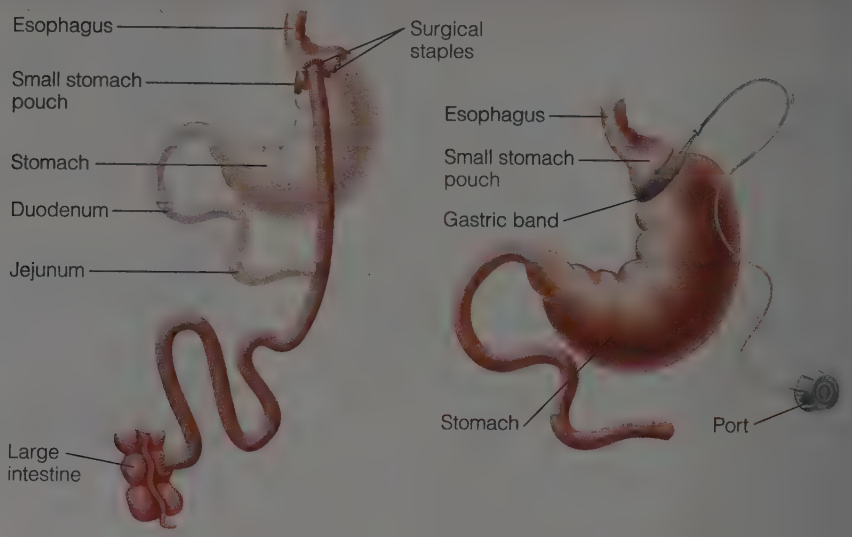
♦ Surgery may be an option for people with all of the following conditions:
- Unable to achieve adequate weight loss with diet and exercise
- BMI ≥40 or BMI ≥35 with weight-related health problems (such as diabetes or hypertension)
- No medical or psychological contraindications
- Understanding of risks and strong motivation to comply with post-surgery treatment plan

Because the long-term safety and effectiveness of surgery depend, in large part, on compliance with dietary instructions, nutrition care plays an important role in follow-up treatment.[67] Vitamin and mineral deficiencies are common, and dietary supplements are routinely prescribed.[68] Weight regain may occur and psychological problems—such as disordered eating behaviors—may also develop.[69] Lifelong medical supervision is necessary, but the possible health benefits of weight loss—improved blood lipid profile, blood pressure, and insulin sensitivity—may outweigh the risks. Overall risk of death and health problems is lower for obese people after successful surgery than for obese people who do not pursue surgery.[70]

Another surgical procedure removes some fat deposits by liposuction. This cosmetic procedure has little effect on body weight (less than 10 pounds), but can alter body shape slightly in specific areas. Liposuction is a popular procedure in part because of its perceived safety, but immediate and delayed complications can arise.[71] Furthermore, removing adipose tissue by way of liposuction does not provide the health benefits that typically accompany weight loss. In other words, liposuction does not improve blood pressure, inflammation, blood lipid profile, or insulin sensitivity. Perhaps most surprisingly, a year after liposuction, body fat returns and redistributes itself from the thighs to the abdomen.[72]

FIGURE 9-5 Gastric Surgery Used in the Treatment of Clinically Severe Obesity

Both of these surgical procedures limit the amount of food that can be comfortably eaten.



© Cengage Learning 2013

In gastric bypass, the surgeon constructs a small stomach pouch and creates an outlet directly to the small intestine, bypassing most of the stomach, the entire duodenum, and some of the jejunum. (Dark areas highlight the flow of food through the GI tract; pale areas indicate bypassed sections.)

Advantages:
- No foreign object in abdomen or need for adjustments
- More durable, reliable, and effective

In gastric banding, the surgeon uses a gastric band to reduce the opening from the esophagus to the stomach. The size of the opening can be adjusted by inflating or deflating the band by way of a port placed in the abdomen just beneath the skin.

Advantages:
- No malabsorption
- More flexible, less invasive, safer

REVIEW IT Explain the risks and benefits, if any, of several aggressive ways to treat obesity.

Overweight and obese people may benefit most from improving eating and activity habits. Those with high risks of medical problems may need more aggressive treatment, including drugs or surgery. Such treatments may offer benefits, but also incur some risks.

9.5 Weight-Loss Strategies

LEARN IT Outline reasonable strategies for achieving and maintaining a healthy body weight.

From the bustling activity of a cell making fat to the inactivity of a person watching television, the factors contributing to obesity are numerous and complex. Each interacts with many others. Efforts to combat obesity must integrate healthy eating patterns, physical activities, supportive environments, and psychosocial support.[73]

Set Reasonable Goals Successful weight-loss strategies embrace small changes, moderate losses, and reasonable goals. People who lose 10 to 20 pounds in a year by consistently choosing nutrient-dense foods and engaging in regular physical activity are much more likely to maintain the loss and reap health benefits than if they were to lose more weight in less time by adopting a radical fad diet. In keeping with this philosophy, the *Dietary Guidelines for Americans* advise those who need to lose weight to "consume fewer kcalories from foods and beverages, increase physical activity, and reduce time in sedentary behaviors."



> DIETARY GUIDELINES FOR AMERICANS 2010

Strive to achieve and maintain a healthy body weight through improved eating and physical activity behaviors.

Even modest weight loss brings health benefits. Modest weight loss, even when a person is still overweight, can improve blood glucose and reduce the risks of heart disease by lowering blood pressure and blood cholesterol, especially for those with central obesity.[74] Improvements in physical capabilities and quality of life become evident with even a 5- to 10-pound weight loss.[75] For these reasons, parameters such as blood pressure, blood cholesterol, or even vitality are more useful than body weight in marking success. People less concerned with disease risks may prefer to set goals for personal fitness, such as being able to play with children or climb stairs without becoming short of breath. Importantly, they can focus on healthy eating and activity habits instead of weight loss.

Whether the goal is health or fitness, expectations need to be reasonable. Unreachable targets ensure frustration and failure. When realistic yet moderately challenging goals are achieved or exceeded, people enjoy rewards instead of finding disappointment.

Research findings highlight the great disparity between lofty expectations and reasonable success.[76] Before beginning a weight-loss program, obese women identified the weights they would describe as "dream," "happy," "acceptable," and "disappointing" (see Figure 9-6). All of these weights were below their starting weight. Their goals far exceeded the 5 to 10 percent weight loss recommended by experts, or even the 15 percent reported by the most successful weight-loss studies. Even their "disappointing" weights exceeded recommended goals. Close to a year later, and after an average loss of 35 pounds, almost half of the women did not achieve even their "disappointing" weights. They did, however, experience more physical, social, and psychological benefits than they had predicted for that weight. Still, in a culture that overvalues thinness, these women were not satisfied with a 16 percent reduction in weight—not because their efforts were unsuccessful, but because their goals and expectations were unrealistic.

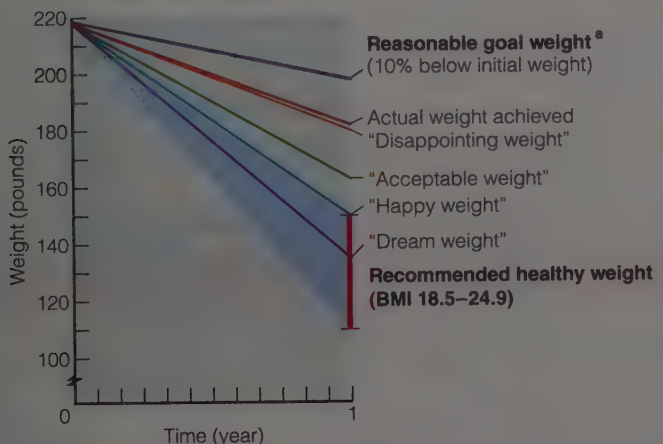
Depending on initial body weight, a reasonable rate of weight loss for overweight adults is ½ to 2 pounds a week, ♦ or 10 percent of body weight over 6 months. For a person weighing 250 pounds, a 10 percent loss is 25 pounds, or about 1 pound a week for 6 months. Such gradual weight losses are more likely to be maintained than rapid losses. Keep in mind that pursuing good health is a lifelong journey.

♦ Safe rate for weight loss:
- ½ to 2 lbs/week (0.2 to 0.9 kg)
- 10% body weight/6 mo

For a person weighing 110 kg, a 10% loss is 11 kg, or about 0.5 kg a week for 6 months.

> FIGURE 9-6 Reasonable Weight Goals vs Unrealistic Expectations Compared

Obese women achieved remarkable success during a year's weight-loss program, but they were disappointed because they had set unrealistic expectations at the beginning.



[a]Reasonable goal weights reflect pounds lost over time. Given more time, reasonable goals may eventually fall within the recommended weight range.

Most adults are keenly aware of their body weights and shapes and realize that what they eat and what they do can make a difference to some extent. Those who are most successful at weight management seem to have fully incorporated healthful eating and physical activity into their daily lives.

Eating Patterns

Contrary to the claims of fad diets, no single food plan is magical, and no specific food must be included or avoided in a weight-management program. In designing an eating pattern, people need only consider foods that they like or can learn to like, that are available, and that are within their means. Creating a healthful eating pattern is the first step. The important next step is following it for the rest of one's life. Achieving and maintaining a healthy weight requires permanent lifestyle changes.

Be Realistic about Energy Intake

The main characteristic of a weight-loss diet is that it provides less energy than the person needs to maintain present body weight. If food energy is restricted too severely, dieters may not receive sufficient nutrients and may lose lean tissue. Rapid weight loss usually means excessive loss of lean tissue, a lower BMR, and a rapid weight gain to follow. In addition, restrictive eating may create stress or foster unhealthy behaviors of eating disorders as described in Highlight 8.[77]

Energy intake should provide nutritional adequacy without excess—that is, somewhere between deprivation and complete freedom to eat whatever, whenever. A reasonable suggestion is to increase activity and reduce food intake enough to create a deficit of 500 to 1000 kcalories per day for adults with a BMI of 35 or greater and 300 to 500 kcalories per day for adults with a BMI of 27 to 35. Such a deficit produces a weight loss of 1 to 2 pounds per week—a rate that supports the loss of fat efficiently while retaining lean tissue.[78] In general, weight-loss diets need to provide about 1200 kcalories per day for women and 1600 kcalories a day for men.

Some people skip meals, typically breakfast, in an effort to reduce energy intake, but research suggests such a strategy may be counterproductive. Breakfast frequency is inversely associated with obesity—that is, people who frequently eat breakfast have a lower BMI than those who tend to skip breakfast.[79] Furthermore, when people eat breakfast, their overall diet quality is better and daily energy density is lower—two factors that support healthy body weight.[80]



> **DIETARY GUIDELINES FOR AMERICANS 2010**
Control total kcalorie intake to manage body weight. For people who are overweight or obese, this will mean consuming fewer kcalories from foods and beverages.

Emphasize Nutritional Adequacy

Healthy diet plans make nutritional adequacy a priority. Nutritional adequacy is difficult to achieve on fewer than 1200 kcalories a day, and most healthy adults need never consume any less. A plan that provides an adequate intake supports a healthier and more successful weight loss than a restrictive plan that creates feelings of starvation and deprivation, which can lead to an irresistible urge to binge.

Table 9-2 specifies the amounts of foods from each food group for diets providing 1200 to 1600 kcalories. Such an intake would allow most people to lose weight

TABLE 9-2 Daily Amounts from Each Food Group for 1200- to 1600-kCalorie Diets

Food Group	1200 kCalories	1400 kCalories	1600 kCalories
Fruit	1 c	1½ c	1½ c
Vegetables	1½ c	1½ c	2 c
Grains	4 oz	5 oz	5 oz
Protein foods	3 oz	4 oz	5 oz
Milk and milk products	2½ c	2½ c	3 c
Oils	4 tsp	4 tsp	5 tsp

© Cengage Learning 2013

and still meet their nutrient needs with careful, nutrient-dense food selections. Keep in mind, too, that well-balanced diets that emphasize fruits, vegetables, whole grains, lean protein foods, and low-fat milk products offer many health rewards even when they don't result in weight loss. A dietary supplement providing vitamins and minerals—especially iron and calcium for women—at or below 100 percent of the Daily Values can help people following low-kcalorie diets to achieve nutrient adequacy.

Eat Small Portions As mentioned earlier, portion sizes at markets, at restaurants, and even at home have increased dramatically over the years. We have come to expect large portions, and we have learned to clean our plates. Many of us pay more attention to these external cues defining how much to eat than to our internal cues of hunger and satiety. For health's sake, we may need to learn to eat less food at each meal—one piece of chicken for dinner instead of two, a teaspoon of butter on vegetables instead of a tablespoon, and one cookie for dessert instead of six. The goal is to eat enough food for adequate energy, abundant vitamins and minerals, and some pleasure, but not more. This amount should leave a person feeling satisfied—not stuffed.

Keep in mind that even fat-free and low-fat foods can deliver a lot of kcalories when a person eats large quantities. A low-fat cookie or two can be a sweet treat even on a weight-loss diet, but larger portions defeat the savings.

People who have difficulty making low-kcalorie selections or controlling portion sizes may find it easier to use prepared meal plans. Prepared meals that provide low-kcalorie, nutritious meals or snacks can support weight loss while easing the task of diet planning.[81] Ideally, those using a prepared meal plan will also receive counsel from a registered dietitian to learn how to select appropriately from conventional food choices as well.

Slow Down Eating can be a pleasurable experience, and taking the time to savor the flavors can help with weight management. Eating slowly, taking small bites, and chewing thoroughly all help to decrease food intake.[82] A person who slows down and savors each bite eats less before hormones signal satiety and the end of a meal.[83] Consequently, energy intake is lower when meals are eaten slowly.[84] Savoring each bite also activates the pleasure centers of the brain. Some research suggests that people may overeat when the brain doesn't sense enough gratification from food.[85] Faster eating correlates with higher weights.[86]

Lower Energy Density Most people take their cues about how much to eat based on portion sizes, and the larger the portion size, the more they eat. To lower energy intake, a person can either reduce the portion size or reduce the energy density. Reducing energy density while maintaining food quantity, especially by including fruits and vegetables, seems to be a successful strategy to control hunger and lose weight.[87] Figure 9-7 illustrates how water, fiber, and fat influence energy density, and the accompanying "How To" feature (p. 276) compares foods based

> FIGURE 9-7 Energy Density

Decreasing the energy density (kcal/g) of foods allows a person to eat satisfying portions while still reducing energy intake. To lower energy density, select foods high in water or fiber and low in fat.



Selecting grapes with their high water content instead of raisins increases the volume and cuts the energy intake.



Even at the same weight and similar serving sizes, the fiber-rich broccoli delivers twice the fiber for about one-third the energy.



By selecting the water-packed tuna (on the right) instead of the oil-packed tuna (on the left), a person can enjoy the same amount for fewer kcalories.

Photos: © Matthew Ferruggio, Art © Cengage Learning 2013

>How To

Compare Foods Based on Energy Density

Chapter 2 describes how to evaluate foods based on their nutrient density—their nutrient contribution per kcalorie. Another way to evaluate foods is to consider their energy density—their energy contribution per gram. This example compares carrot sticks with french fries. The conclusion is no surprise, but understanding the mathematics may offer valuable insight into the concept of energy density. A carrot weighing 72 grams delivers 31 kcalories. To calculate the energy density, divide kcalories by grams:

$$\frac{31 \text{ kcal}}{72 \text{ g}} = 0.43 \text{ kcal/g}$$

Do the same for french fries weighing 50 grams and contributing 167 kcalories:

$$\frac{167 \text{ kcal}}{50 \text{ g}} = 3.34 \text{ kcal/g}$$

The more kcalories per gram, the greater the energy density. French fries are more energy dense than carrots. They provide more energy per gram—and per bite. Considering a food's energy density is especially useful in planning diets for weight management. Foods with a high energy density help with weight gain, whereas foods with a low energy density help with weight loss.



© Matthew Farruggio

TRY IT Compare the energy density of a hard-boiled egg (50 grams and 78 kcalories) with light tuna canned in water (57 grams and 66 kcalories).

on their energy density. Foods containing water, those rich in fiber, and those low in fat help to lower energy density, providing more satiety for fewer kcalories. Because a low-energy-density diet is a low-fat, high-fiber diet rich in many vitamins and minerals, it supports good health in addition to weight loss.

Remember Water In addition to lowering the energy density of foods, water helps with weight management in other ways. For one, foods with high water content (such as broth-based soups) increase fullness, reduce hunger, and consequently reduce energy intake. For another, drinking a large glass of water before a meal eases hunger, fills the stomach, and consequently reduces energy intake.[88] Importantly, water adds no kcalories. The average US diet delivers an estimated 75 to 150 kcalories a day from sweetened beverages. Simply replacing nutrient-poor, energy-dense beverages with water could save a person up to 15 pounds a year. Water also helps the GI tract adapt to a high-fiber diet.

Focus on Fiber High-fiber foods such as fresh fruits, vegetables, legumes, and whole grains may help with weight management.[89] By offering abundant vitamins, minerals, and fiber but little fat, these foods tend to be relatively low in energy and high in nutrients. Eating high-fiber foods also takes time, which eases hunger and promotes satiety.[90]

Choose Fats Sensibly One way to lower energy intake is to lower fat intake. Lowering the fat content of a food lowers its energy density—for example, selecting fat-free milk instead of whole milk. That way, a person can consume the usual amount (say, a cup of milk) at a lower energy intake (85 instead of 150 kcalories).

Fat has a weak satiating effect, and satiation plays a key role in determining food intake during a meal. Consequently, a person eating a high-fat meal increases energy intake in two ways—more food and more fat kcalories. For these reasons, measure fat with extra caution. (Review p. 152 for strategies to lower fat in the diet.) Be careful not to take this advice to extremes, however; too little fat incurs health risks as well, as Chapter 5 explains.

Whether a low-fat diet is the best option for weight loss is the subject of some controversy and much debate. An important point to notice in any discussion on weight-loss diets is total energy intake. A low-fat diet supports weight loss only when energy intake is less than energy expenditure.

Select Carbohydrates Carefully Another popular way to lower energy intake is to lower carbohydrate intake. Highlight 4's discussion of carbohydrate-restricted and carbohydrate-modified diets reaches the same conclusion as the previous paragraph on low-fat diets: they work only when energy intake is less than energy expenditure.

Chapter 4 describes how foods with added sugars increase energy intake and contribute to weight gain. Limiting consumption of foods with added sugars can help with weight management. One way people try to control weight is to use foods and beverages sweetened with artificial sweeteners. Using artificial sweeteners instead of sugars can lower energy intake and may support modest weight loss, although evidence is lacking.[91] In fact, some research indicates a relationship between artificial sweetener use and weight gain.[92]

To what extent artificial sweeteners can help someone lose weight depends in part on the person's motivations and actions. For example, one person might drink an artificially sweetened beverage now so as to be able to eat a high-kcalorie food later. This person's energy intake might stay the same or increase. A person trying to control energy intake might drink an artificially sweetened beverage now and choose a low-kcalorie food later. This plan would help reduce the person's total energy intake. Using artificial sweeteners will not automatically lower energy intake. To control energy intake successfully, a person needs to make informed diet and activity decisions throughout the day.

Watch for Other Empty kCalories A person trying to achieve or maintain a healthy weight needs to pay attention not only to fat and sugar, but to alcohol too. Not only does alcohol add kcalories, but accompanying mixers can also add both kcalories and fat, especially in creamy drinks such as piña coladas (review Table H7-3 on p. 226). Furthermore, drinking alcohol reduces a person's inhibitions, which can sabotage weight-control efforts—at least temporarily.

A person who adopts a lifelong "eating plan for good health" rather than a "diet for weight loss" will be more likely to keep the lost weight off. Table 9-3 provides several tips for successful weight management.

Physical Activity Whether trying to minimize weight gains or support weight losses, the best approach includes physical activity.[93] To prevent weight gains and



© Corbis

If you want to lose weight, steer clear of the empty kcalories in fancy coffee drinks. A 16-ounce café mocha delivers 400 kcalories—half of them from fat.

TABLE 9-3 Weight-Loss Strategies

Food	Activities
• To maintain weight, consume foods and drinks to meet, not exceed, kcalorie needs. To lose weight, energy out should exceed energy in by about 500 kcalories/day. • Emphasize foods with a low energy density and a high nutrient density; make legumes, whole grains, vegetables, and fruits central to your diet plan. • Eat slowly. • Drink water before you eat and while you eat; drink plenty of water throughout the day. • Track food and kcalorie intake. • Plan ahead to make better food choices. • Limit kcalorie intake from solid fats and added sugars. • Reduce portions, especially of high-kcalorie foods. • Cook and eat more meals at home, instead of eating out. When eating out, think about choosing healthy options.	• Limit screen time. • Increase physical activity. • Choose moderate- or vigorous-intensity physical activities. • Avoid inactivity. Some physical activity is better than none. • Slowly build up the amount of physical activity you choose.

© Cengage Learning 2013

support weight losses, current recommendations advise 200 to 300 minutes of moderately intense physical activity a week in addition to activities of daily life.[94] People who combine diet and exercise typically lose more fat, retain more muscle, and regain less weight than those who only follow a weight-loss diet. Even when they do not lose more weight, they seem to follow their diet plans more closely and maintain their losses better than those who do not exercise. Consequently, they benefit from taking in a little less energy from the diet as well as from expending a little more energy in physical activity. Importantly, those who exercise reap important health benefits—reduced abdominal obesity and improved blood pressure, insulin resistance, and cardiorespiratory fitness—regardless of weight loss.[95] Fitness benefits—such as strength and balance—also improve when exercise is part of a weight-loss program.[96] Chapter 14 presents the many benefits of physical activity; the focus here is on its role in weight management.



> DIETARY GUIDELINES FOR AMERICANS 2010

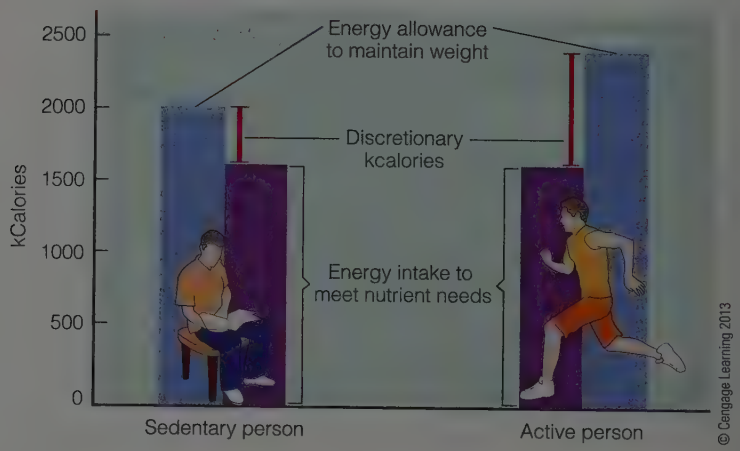
Increase physical activity and reduce time spent in sedentary behaviors.

Activity and Energy Expenditure Table 8-2 (p. 238) shows how much energy each of several activities uses. The number of kcalories spent in an activity depends on body weight, intensity, and duration. For example, a person who weighs 150 pounds and walks 3½ miles in 60 minutes expends about 315 kcalories. That same person running 3 miles in 30 minutes uses a similar amount. By comparison, a 200-pound person running 3 miles in 30 minutes expends an additional 100 kcalories or so. The goal is to expend as much energy as your time allows. The greater the energy deficit created by exercise, the greater the fat loss. And be careful not to compensate for the energy expended in exercise by eating more food.[97] Otherwise, energy balance won't shift, and fat loss will be less significant.

Activity and Discretionary kCalories Chapter 2 introduced the concept of discretionary kcalories as the difference between the kcalories needed to supply nutrients and those needed to maintain energy balance. Because exercise expends energy, the energy allowance to maintain weight increases with increased physical activity—yet the energy needed to deliver needed nutrients remains about the same. In this way, physical activity increases discretionary kcalories (see Figure 9-8). Having more discretionary kcalories puts a little wiggle room in a weight-loss diet for such options as second helpings, sweet treats, or alcoholic beverages on occasion. Of course, selecting nutrient-dense foods and *not* using discretionary kcalories will maximize weight loss.

Activity and Metabolism Activity also contributes to energy expenditure in an indirect way—by speeding up metabolism. It does this both immediately and over

> FIGURE 9-8 ***Animated*** **Influence of Physical Activity on Discretionary kCalories**



the long term. On any given day, metabolism remains elevated for several hours after vigorous and prolonged exercise.[98] This postexercise effect may raise the energy expenditure of exercise up to 15 percent. Over the long term, a person who engages in daily vigorous activity gradually develops more lean tissue. Metabolic rate rises accordingly, and this supports continued weight loss or maintenance.[99]

Activity and Body Composition Physically active people have less body fat than sedentary people do—even if they have the same BMI. Physical activity, even without weight loss, changes body composition: body fat decreases and lean body mass increases. Furthermore, strength training exercises specifically prevent increases in body fat and abdominal fat.[100]

Activity and Appetite Control Many people think that exercising will increase hunger, but not necessarily.[101] Active people do have healthy appetites, but appetite is suppressed after a workout and satiation during a meal and satiety between meals is enhanced.[102] The body has released fuels from storage to support the exercise, so glucose and fatty acids are abundant in the blood. At the same time, the body has suppressed its digestive functions. Hard physical work and eating are not compatible. A person must calm down, put energy fuels back in storage, and relax before eating. At that time, a physically active person may eat more than a sedentary person, but not so much as to fully compensate for the energy expended in exercise.

Exercise may also help curb the inappropriate appetite that accompanies boredom, anxiety, or depression. Weight-management programs encourage people who feel the urge to eat when not particularly hungry to exercise instead. The activity passes time, relieves anxiety, and prevents inappropriate eating.

Activity and Psychological Benefits Activity also helps reduce stress, which is especially helpful for people who respond to stress with inappropriate eating. In addition, a fit person looks and feels healthy and, as a result, gains self-esteem. High self-esteem motivates a person to continue seeking good health and fitness, which keeps the beneficial ♦ cycle going. Chapter 14 presents additional benefits of physical activity.

Choosing Activities Clearly, physical activity is a plus in a weight-management program. What kind of physical activity is best? People should choose activities that they enjoy and are willing to do regularly. What schedule of physical activity is best? It doesn't matter; a person can benefit from either several short bouts of exercise or one continuous workout. Any activity is better than being sedentary. For an active life, limit sedentary activities, engage in strength and flexibility activities, enjoy leisure activities often, engage in vigorous activities regularly, and be as active as possible every day.

Health-care professionals frequently advise people to engage in activities of low-to-moderate intensity for a long duration, such as an hour-long, fast-paced walk. The reasoning behind such advice is that walking offers the health benefits of aerobic physical activity with low risk of injury. It can be done almost anywhere at any time. A person who stays with an activity routine long enough to enjoy the rewards will be less inclined to give it up and will, over the long term, reap many health benefits. A regular walking program can prevent or slow the weight gain that commonly occurs in most adults.[103] An average of 60 minutes a day of moderate-intensity activity ♦ or an expenditure of at least 2000 kcalories per week is especially helpful for weight management.[104] Higher levels of duration, frequency, or intensity produce greater losses.

In addition to exercise, a person can incorporate hundreds of energy-expending activities into daily routines: take the stairs instead of the elevator, walk to the neighbor's apartment instead of making a phone call, and rake the leaves instead of using a blower. Remember that sitting uses more kcalories than lying down, standing uses more kcalories than sitting, and moving uses more kcalories than standing. A 175-pound person who replaces a 30-minute television program with a 2-mile walk a day can expend enough energy to lose (or at least not gain) 18 pounds in a year. Meeting an activity goal of 10,000 steps a day is another way to support a healthy BMI. By wearing a pedometer, a person can easily increase


© Tomasz Trojanowski/Shutterstock.com

The key to good health is to combine sensible eating with regular exercise.

♦ Benefits of physical activity in a weight-management program:
- Short-term increase in energy expenditure (from exercise and from a slight rise in metabolism)
- Long-term increase in BMR (from an increase in lean tissue)
- Improved body composition
- Appetite control
- Stress reduction and control of stress eating
- Physical, and therefore psychological, well-being
- Improved self-esteem

♦ Estimated energy expended when walking at a moderate pace = 1 kcal/mi/kg body weight

physical activity, lose weight, and lower blood pressure without measuring miles or watching the clock. The point is to be active. Walk. Run. Swim. Dance. Cycle. Climb. Skip. Do whatever you enjoy doing—and do it often.

Spot Reducing People sometimes ask about "spot reducing." Unfortunately, muscles do not "own" the fat that surrounds them. Fat cells all over the body release fat in response to the demand of physical activity for use by whatever muscles are active. Specific exercises—whether moderate or intense—do not influence the site of adipose tissue loss.[105]

Exercise can help with trouble spots in another way, though. The "trouble spot" for most men is the abdomen, their primary site of fat storage. During aerobic exercise, abdominal fat readily releases its stores, providing fuel to the physically active body. With regular exercise and weight loss, men will deplete these abdominal fat stores before those in the lower body. Women may also deplete abdominal fat with exercise, but their "trouble spots" are more likely to be their hips and thighs.

In addition to aerobic activity, strength training can help to improve the tone of muscles in a trouble area, and stretching to gain flexibility can help with associated posture problems. A combination of aerobic, strength, and flexibility workouts best improves fitness and physical appearance.

Environmental Influences

Chapter 8 describes how hormones regulate hunger, satiety, and satiation, but people don't always pay close attention to such internal signals. Instead, their eating behaviors are often dictated by environmental factors—those surrounding the eating experience as well as those pertaining to the food itself. Changing any of these factors can influence how much a person eats.

Atmosphere The environment surrounding a meal or snack influences its duration. When the lighting, décor, aromas, and sounds of an environment are pleasant and comfortable, people tend to spend more time eating and thus eat more. A person needn't eat under neon lights with offensive music to eat less, of course. Instead, after completing a meal, remove food from the table and enjoy the ambience—without the presence of visual cues to stimulate additional eating.

Accessibility Among the strongest influences on how much we eat are the accessibility, ease, and convenience of obtaining food. In general, the less effort needed to obtain food, the more likely food will be eaten. Think about it. Are you more likely to eat if half a leftover pizza is in your refrigerator or if you have to drive to the grocery store, buy a frozen pizza, and bake it for 45 minutes? Having food nearby and visible encourages eating—regardless of hunger. The message is clear. For people wanting to eat fewer empty-kcalorie foods, keep them out of sight in an inconvenient place, or better yet, don't even bring them home. In contrast, a bowl of fruit on the counter and vegetables in the refrigerator promote healthy eating options.

Socializing People tend to eat more when socializing with others. Pleasant conversations extend the duration of a meal, allowing a person more time to eat more, and the longer the meal, the greater the consumption. In addition, by taking a visual cue from companions, a person might eat more when others at the table eat large portions or go to the buffet line for seconds.[106] One way to eat less is to pace yourself with the person who seems to be eating the least and slowest.

Social interactions also distract a person from paying attention to how much has been eaten. In some cases, socializing with friends during a meal may provide comfort and lower a person's motivation to limit consumption. In other cases, socializing with unfamiliar people during a meal—during a job interview or blind date, for example—may create stress and reduce food consumption. To eat less while socializing, pay attention to portion size.

Distractions Distractions influence food intake by initiating eating, interfering with internal controls to stop eating, and extending the duration of eating. Some people start eating dinner when a favorite television program comes on, regardless of hunger. Other people continue eating breakfast until they finish reading the newspaper. Such mindless eating can easily become overeating. Distractions interfere

with a person's ability to monitor and regulate how much is consumed. If distractions are a part of the eating experience, extra care is needed to control portion sizes.

Multiple Choices When offered a large assortment of foods, or several flavors of the same food, people tend to eat more. To limit intake, then, focus on a limited number of foods per meal. Be careful not to misunderstand and abandon variety in diet planning. Eating a variety of nutrient-dense foods from each of the food groups is still a healthy plan.

Package and Portion Sizes As noted earlier, the sizes of packages in grocery stores as well as portion sizes at restaurants and at home have increased dramatically in recent decades, contributing to the increase in obesity in the United States. Put simply, we tend to clean our plates and finish the package. The larger the bag of potato chips, the greater the intake. To keep from overeating, repackage snacks into smaller containers or eat a measured portion from a plate, not directly from the package.



© moodboard / SuperStock

Eating from the package while distracted by television is a weight-gaining combination.

Serving Containers We often use plates, utensils, and glasses as visual cues to guide our decisions on how much to eat and drink. If you plan to eat a bowl of ice cream, it matters whether the bowl you select holds 8 ounces or 24 ounces. Large dinner plates and wide glasses create illusions and misperceptions about quantities consumed. A scoop of mashed potatoes on a small plate looks larger than the same-size scoop on a large plate, leading a person to underestimate the amount of food eaten. To control portion sizes, use small bowls and plates, small serving spoons, and tall, narrow glasses. Of course, using a small plate will not result in less food eaten if multiple servings are taken.

Behavior and Attitude

Changes in behavior and attitude can be very effective in supporting efforts to achieve and maintain appropriate body weight and composition. **Behavior modification** focuses on how to change behaviors to increase energy expenditure and decrease energy intake. A person must commit to taking action. Adopting a positive, matter-of-fact attitude helps to ensure success. Healthy eating and activity choices are an essential part of healthy living and should simply be incorporated into the day—much like brushing one's teeth or wearing a safety belt.

Become Aware of Behaviors To solve a problem, a person must first identify all the behaviors that created the problem. Keeping a record will help to identify eating and exercise behaviors that may need changing (see Figure 9-9, p. 282). Such self-monitoring raises awareness and establishes a baseline against which to measure future progress.[107]

In this era of technology, many companies have developed weight-loss applications for smartphones to help users manage their daily food and physical activity behaviors. Applications include diet analysis tools that can track eating habits, scanning devices that can quickly enter food data, customized activity and meal plans that can be sent to users, and support programs that deliver encouraging messages and helpful tips. Social media sites allow users to upload progress reports and receive texts. Using these applications can help a person become more aware of behaviors that lead to weight gains and losses.

Change Behaviors Behavior modification strategies ♦ focus on learning desired eating and activity behaviors and eliminating unwanted behaviors. With so many possible behavior changes, a person can feel overwhelmed. Start with small time-specific goals for each behavior—for example, "I'm going to take a 30-minute walk after dinner every evening" instead of "I'm going to run in a marathon someday." Practice desired behaviors until they become routine. Addressing multiple behaviors that focus on a common goal simultaneously may better support changes

♦ Examples of behavioral strategies to support weight change:

- Do not grocery shop when hungry.
- Eat slowly (pause during meals, chew thoroughly, put down utensils between bites).
- Exercise when watching television.

behavior modification: the changing of behavior by the manipulation of antecedents (cues or environmental factors that trigger behavior), the behavior itself, and consequences (the penalties or rewards attached to behavior).

> FIGURE 9-9 Food Record

The entries in a food record should include the times and places of meals and snacks, the types and amounts of foods eaten, and a description of the individual's feelings when eating. The diary should also record physical activities: the kind, the intensity level, the duration, and the person's feelings about them.

Time	Place	Activity or food eaten	People present	Mood
10:30–10:40	School vending machine	6 peanut butter crackers and 12 oz. cola	by myself	Starved
12:15–12:30	Restaurant	Sub sandwich and 12 oz. cola	friends	relaxed & friendly
3:00–3:45	Gym	Weight training	work out partner	tired
4:00–4:10	Snack bar	Small frozen yogurt	by myself	OK

© Cengage Learning 2013

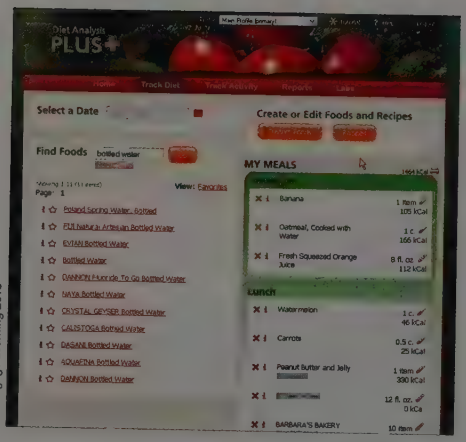
than taking on one at a time. Using a reward system also seems to effectively support weight-loss efforts.[108]

Cognitive Skills Successful behavior changes depend in part on two cognitive skills—problem solving and cognitive restructuring. Problem solving skills enable a person to identify the problem, generate potential solutions, list the pros and cons of each, implement the most feasible solution, and evaluate whether behaviors should be continued or abandoned.[109] Cognitive restructuring requires a person to replace negative thoughts that derail success with positive thoughts that support behavior change.

The effectiveness of cognitive behavioral therapy in weight-loss extends to other health behaviors as well. Overweight smokers who participated in a cognitive program for weight management lost weight, made healthy food choices, increased their confidence to manage their eating and smoking habits, decreased the number of cigarettes smoked, and increased their readiness to quit smoking.[110] Such research highlights the need to include dietary strategies in smoking cessation programs. Smoking a cigarette overrides feelings of hunger. When smokers receive a hunger signal, they can quiet it with cigarettes instead of food. Such behavior ignores body signals and postpones energy and nutrient intake. Indeed, smokers tend to weigh less than nonsmokers and to gain weight when they stop smoking. People contemplating giving up cigarettes should know that the average weight gain is about 10 pounds in the first year. Smokers wanting to quit should prepare for the possibility of weight gain and adjust their diet and activity habits so as to maintain weight during and after quitting.

Personal Attitude For many people, overeating and being overweight have become an integral part of their identity. Those who fully understand their personal relationships with food are best prepared to make healthful changes in eating and activity behaviors.

Sometimes habitual behaviors that are hazardous to health, such as smoking or drinking alcohol, contribute positively by helping people adapt to stressful situations. Similarly, many people overeat to cope with the stresses of life. Weight gains, in turn, contribute to psychosocial stress, thus creating an unhealthy cycle.[111] To break out of that pattern, they must first identify the particular stressors that trigger the urge to overeat. Then, when faced with these situations, they must learn and practice problem-solving skills that will help them to respond appropriately. Learning to reduce episodes of emotional eating can lead to weight loss.[112]



© Cengage Learning 2013

Diet analysis programs help people identify high-kcalorie foods and monitor their eating habits.

All this is not to imply that psychotherapy holds the magic answer to a weight problem. Still, efforts to improve one's general well-being may result in healthy eating and activity habits even when weight loss is not the primary goal. When the problems that trigger the urge to overeat are resolved in alternative ways, people may find they eat less. They may begin to respond appropriately to internal cues of hunger rather than inappropriately to external cues of stress. Sound emotional health supports a person's ability to take care of physical health in all ways—including nutrition, weight management, and fitness.

Support Groups Group support can prove helpful when making life changes. Some people find it useful to join a group such as Take Off Pounds Sensibly (TOPS), Weight Watchers (WW), Overeaters Anonymous (OA), or others. Some dieters prefer to form their own self-help groups or find support online. The Internet offers numerous opportunities for weight-loss education and counseling that may be effective alternatives to face-to-face or telephone counseling programs.[113] As always, consumers need to choose wisely and avoid rip-offs.

Weight Maintenance

People who are successful often experience much of their weight loss within half a year and then reach a plateau. This slowdown can be disappointing, but it should be recognized as an opportunity for the body to adjust to its new weight. Reaching a plateau provides a little relief from the distraction of weight-loss dieting. An appropriate goal at this point is to continue the eating and activity behaviors that will maintain weight. Attempting to lose additional weight at this point would require major effort and would almost certainly meet with failure.

The prevalence of **successful weight-loss maintenance** is difficult to determine, in part because researchers have used different criteria. Some look at success after 1 year and others after 5 years; some quantify success as 10 or more pounds lost and others as 5 or 10 percent of initial body weight lost. Furthermore, most research studies examine the success of one episode of weight loss in a structured program, but this scenario does not necessarily reflect the experiences of the general population. In reality, most people have lost weight several times in their lifetimes and did so on their own, not in a formal program. An estimated one out of every six overweight adults in the United States has successfully maintained at least a 10 percent loss for at least a year.[114]

Those who are successful in maintaining their weight loss have established regular exercise regimens and careful eating patterns, taking in less energy than the



© Blend Images/Dan Bannister/Jupiterimages

Maintaining a healthy body weight requires maintaining the vigorous physical activities and careful eating habits that supported weight loss.

successful weight-loss maintenance: achieving a weight loss of at least 10 percent of initial body weight and maintaining the loss for at least 1 year.

national average. Because these people are more efficient at storing fat, they do not have the same flexibility in their food and activity habits as their friends who have never been overweight.[115] With weight loss, metabolism shifts downward so that formerly overweight people require less energy than might be expected given their current body weight and body composition. This decrease in energy expenditure persists over time.[116] Consequently, to keep weight off, they must either eat less or exercise more than people the same size who have never been obese. Put simply, it takes more to prevent weight *regain* than to prevent weight gain.

Physical activity plays a key role in preventing weight gains and maintaining weight losses.[117] Those who exercise vigorously are far more successful than those who are inactive. Weight maintenance may require a person to expend at least 2500 kcalories in physical activity per week.[118] To accomplish this, a person might exercise either moderately (such as brisk walking at 4 miles per hour) for 60 minutes a day or vigorously (such as fast bicycling at 18 miles per hour) for 30 minutes a day, for example. Being active during both work hours and leisure time also helps a person expend more energy and maintain weight loss.[119]

In addition to limiting energy intake and exercising regularly, one other strategy helps with weight maintenance: frequent self-monitoring. People who weigh themselves periodically and monitor their eating and exercise habits regularly can detect weight gains in the early stages and promptly initiate changes to prevent relapse.

Losing weight and maintaining the loss may not be easy, but it is possible. Strategies of those who have been successful may differ in the details, but in general, most do the following:[120]

- Eat a low-kcalorie diet (usually small portions four to five times a day).
- Follow a diet that is high in nutrient density and low in energy density.
- Eat breakfast (curbs hunger).
- Be physically active regularly (at least 60 minutes of moderate activity daily).
- Monitor weight frequently (take prompt action with small gains).
- Limit television time (less than 10 hours a week).
- Consult a registered dietitian, physician, or other support person (or group).

Importantly, people who are successful losing weight find that it gets easier with time—the changes in diet and activity patterns become permanent.

Prevention Given the information presented up to this point in the chapter, the adage "An ounce of prevention is worth a pound of cure" seems particularly apropos. Obesity is a major risk factor for numerous diseases, and losing weight is challenging and often temporary. Strategies for preventing weight gain ♦ are very similar to those for losing weight, with one exception: they begin early. Over the years, they become an integral part of a person's life. It is much easier for a person to resist doughnuts for breakfast if he rarely eats them. Similarly, a person will have little trouble walking each morning if she has always been active.

♦ To prevent weight gain:
- Eat regular meals and limit snacking
- Drink water instead of high-kcalorie beverages
- Select sensible portion sizes and limit daily energy intake to no more than energy expended
- Become physically active and limit sedentary activities



> DIETARY GUIDELINES FOR AMERICANS 2010
Maintain appropriate kcalorie balance during each stage of life—childhood, adolescence, adulthood, pregnancy and lactation, and older age.

Community Programs Reversing the US obesity epidemic is a challenge in an environment of abundant food and physical inactivity. Success may depend on community actions to promote healthy lifestyle choices.[121] Table 9-4 lists health strategies to prevent obesity in the United States.[122] Whether changes in public policy—such as a tax on sugared beverages and snack foods—will influence diet habits or simply generate revenues remains to be seen.[123] Clearly, effective strategies will need to reach beyond individuals to address social networks, community institutions, and government policies.[124]

TABLE 9-4 Community Strategies to Prevent Obesity

- Promote the availability of affordable healthy food and beverages.
- Support healthy food and beverage choices.
- Encourage breastfeeding.
- Encourage physical activity and limit sedentary activity, especially among children and youth.
- Create safe communities that support physical activity.
- Encourage communities to organize for change.

© Cengage Learning 2013

REVIEW IT Outline reasonable strategies for achieving and maintaining a healthy body weight.

A surefire remedy for obesity has yet to be found, although many people find a combination of approaches to be most effective. Diet and exercise shift energy balance so that more energy is expended than is taken in. Behavior modification and cognitive restructuring retrain habits to support a healthy eating and activity plan. Such a plan requires time, individualization, and sometimes the assistance of a registered dietitian or support group.

9.6 Underweight

LEARN IT Summarize strategies for gaining weight.

Underweight is a far less prevalent problem than overweight, affecting no more than 2 percent of US adults (review Figure 8-7 on p. 243).[125] Whether an underweight person needs to gain weight is a question of health and, like weight loss, a highly individual matter. There are no compelling reasons for people who are healthy at their present weight to try to gain weight. Those who are thin because of malnourishment or illness, however, might benefit from a diet that supports weight gain. Medical advice can help make the distinction.

Thin people may find gaining weight difficult. Unlike the genes expressed in obesity, the genes in lean people protect against energy excesses.[126] Those who wish to gain weight for appearance's sake or to improve their athletic performance need to be aware that healthful weight gains can be achieved only by physical conditioning combined with high energy intakes. On a high-kcalorie diet alone, a person may gain weight, but it will be mostly fat. Even if the gain improves appearance, it can be detrimental to health and might impair athletic performance. Therefore, in weight gain, as in weight loss, physical activity and energy intake are essential components of a sound plan.

Problems of Underweight

The causes of underweight may be as diverse as those of overweight—genetic tendencies; hunger, appetite, and satiety irregularities; psychological traits; and metabolic factors. Habits learned early in childhood, especially food aversions, may perpetuate themselves.

The high demand for energy to support physical activity and growth may contribute to underweight. An active, growing boy may need more than 4000 kcalories a day to maintain his weight and may be too busy to take time to eat adequately. In addition, underweight people may find it hard to gain weight because they are expending energy in adaptive thermogenesis. So much energy may be expended adapting to a higher food intake that at first as many as 750 to 800 extra kcalories a day may be needed to gain a pound a week. Like those who want to lose weight, people who want to gain must learn new habits and learn to like new foods. They are also similarly vulnerable to potentially harmful schemes.

As described in Highlight 8, the underweight condition anorexia nervosa sometimes develops in people who employ self-denial to control their weight. They go to such extremes that they become severely undernourished, achieving final body weights of 70 pounds or even less. One difference between a person with anorexia nervosa and other underweight people is that starvation is intentional. (See Highlight 8 for a review of anorexia nervosa and other eating disorders.)

underweight: a body weight so low as to have adverse health effects; generally defined as BMI <18.5.

Weight-Gain Strategies

Adequacy and balance are the key diet planning strategies for weight gain. Meals focus on energy-dense foods to provide many kcalories in a small volume and exercise to build muscle. By using the USDA Food Pattern recommendations for the higher kcalorie levels (see Table 2-2 on p. 44), a person can gain weight while meeting nutrient needs.

Energy-Dense Foods Energy-dense foods (the very ones eliminated from a successful weight-loss diet) hold the key to weight gain. Pick the highest-kcalorie items from each food group—that is, milk shakes instead of fat-free milk, salmon instead of snapper, avocados instead of cucumbers, a cup of grape juice instead of a small apple, and whole-wheat muffins instead of whole-wheat bread. Because fat provides more than twice as many kcalories per teaspoon as sugar does, fat adds kcalories without adding much bulk.

Although eating high-kcalorie, high-fat foods is not healthy for most people, it may be essential for an underweight individual who needs to gain weight. An underweight person who is physically active and eating a nutritionally adequate diet can afford a few extra kcalories from fat. For health's sake, it is wise to select foods with monounsaturated and polyunsaturated fats instead of those with saturated or *trans* fats: for example, sautéing vegetables in olive oil instead of butter or hydrogenated margarine.

Regular Meals Daily People who are underweight need to make meals a priority and take the time to plan, prepare, and eat each meal. They should eat at least three healthy meals every day. Another suggestion is to eat meaty appetizers or the main course first and leave the soup or salad until later.

Large Portions Underweight people need to learn to eat more food at each meal. For example, they can add extra slices of ham and cheese on a sandwich for lunch, drink milk from a larger glass, and eat cereal from a larger bowl.

The person should expect to feel full. Most underweight individuals are accustomed to small quantities of food. When they begin eating significantly more, they feel uncomfortable. This is normal and passes over time.

Extra Snacks Because a substantially higher energy intake is needed each day, in addition to eating more food at each meal, it is necessary to eat more frequently. Between-meal snacks can readily lead to weight gains. For example, a student might make three sandwiches in the morning and eat them between classes in addition to the day's three regular meals. Snacking on dried fruit, nuts, and seeds is also an easy way to add kcalories.

Juice and Milk Beverages provide an easy way to increase energy intake. Consider that 6 cups of cranberry juice add almost 1000 kcalories to the day's intake. kCalories can be added to milk by mixing in powdered milk or packets of instant breakfast.

For people who are underweight due to illness, liquid dietary supplements are often recommended because a weak person can swallow them easily. Used in addition to regular meals, these high-protein, high-kcalorie formulas can help an underweight person maintain or gain weight easily.

Exercising to Build Muscles To gain weight, use strength training primarily, and increase energy intake to support that exercise. Eating extra food to provide an additional 500 to 1000 kcalories a day above normal energy needs is enough to support the exercise as well as to build muscle.[127]

REVIEW IT Summarize strategies for gaining weight.

Both the incidence of underweight and the health problems associated with it are less prevalent than overweight and its associated problems. To gain weight, a person must train physically and increase energy intake by selecting energy-dense foods, eating regular meals, taking larger portions, and consuming extra snacks and beverages. Table 9-5 includes a summary of weight-gain strategies.

Achieving and maintaining a healthy weight requires vigilant attention to diet and physical activity. Taking care of oneself is a lifelong responsibility.

TABLE 9-5 Weight-Gain Strategies

- Energy in should exceed energy out by at least 500 kcalories/day. Eat enough to store more energy than you expend in exercise. Exercise and eat to build muscles.
- Expect weight gain to take time (1 pound per month would be reasonable).
- Emphasize energy-dense foods.
- Eat at least three meals a day.
- Eat large portions of foods and expect to feel full.
- Eat snacks between meals.
- Drink plenty of juice and milk.

© Cengage Learning 2013

Nutrition Portfolio

To enjoy good health and maintain a reasonable body weight, combine sensible eating habits and regular physical activity. Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Energy Balance and Intake vs. Goals reports.

- Calculate your BMI and consider whether you need to lose or gain weight for the sake of good health. If you do need to gain or lose weight, do the Diet Analysis reports give you insight into why you may be overweight or underweight?
- Reflect on your weight over the past year or so and explain any weight gains or losses. Using the Intake vs. Goals report, can you identify areas in which you need to adjust your food intake, perhaps eating more or less?
- Describe the potential risks and possible benefits of fad diets and over-the-counter weight-loss drugs or herbal supplements.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at www.cengagebrain.com.

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. K. M. Flegal and coauthors, Prevalence and trends in obesity among US adults, 1999–2008, *Journal of the American Medical Association* 303 (2010): 235–241.
2. Y. Wang and M. A. Beydoun, The obesity epidemic in the United States—Gender, age, socioeconomic, racial/ethnic, and geographic characteristics: A systematic review and meta-regression analysis, *Epidemiological Reviews* 29 (2007): 6–28.
3. C. L. Ogden and M. D. Carroll, Prevalence of overweight, obesity, and extreme obesity among adults: United States, trends 1960–1962 through 2007–2008, *NCHS Health E-Stats*, www.cdc.gov/nchs/data/hestat/obesity_adult_07_08/obesity_adult_07_08.htm, accessed June 2010.
4. Wang and Beydoun, 2007.
5. World Health Organization, www.who.int/features/factfiles/obesity, updated February 2010.
6. Y. D. Tchoukalova and coauthors, Regional differences in cellular mechanisms of adipose tissue gain with overfeeding, *Proceedings of the National Academic of Sciences of the United States of America* 107 (2010): 18226–18231; R. Drolet and coauthors, Hypertrophy and hyperplasia of abdominal adipose tissues in women, *International Journal of Obesity* 32 (2008): 283–291.
7. K. L. Spalding and coauthors, Dynamics of fat cell turnover in humans, *Nature* 453 (2008): 783–787.
8. C. A. Baile and coauthors, Effect of resveratrol on fat mobilization, *Annals of the New York Academy of Sciences* 1215 (2011): 40–47.
9. M. Krawczyk, L. Bonfrate, and P. Portincasa, Nonalcoholic fatty liver disease, *Best Practice and Research, Clinical Gastroenterology* 24 (2010): 695–708; D. M. Muoio, Metabolism and vascular fatty acid transport, *New England Journal of Medicine* 363 (2010): 291–293; G. Tarantino, S. Savastano, and A. Colao, Hepatic steatosis, low-grade chronic inflammation and hormone/growth factor/adipokine imbalance, *World Journal of Gastroenterology* 16 (2010): 4773–4783.
10. N. Ouchi and coauthors, Adipokines in inflammation and metabolic disease, *Nature Reviews Immunology* 11 (2011): 85–97; C. Stryjecki and D. M. Mutch, Fatty acid-gene interactions, adipokines and obesity, *European Journal of Clinical Nutrition* 65 (2011): 285–297; G. Govindarajan, M. A. Alpert, and L. Tejwani, Endocrine and metabolic effects of fat: Cardiovascular implications, *American Journal of Medicine* 121 (2008): 366–370.
11. K. A. Varady and coauthors, Degree of weight loss required to improve adipokine concentrations and decrease fat cell size in severely obese women, *Metabolism Clinical and Experimental* 58 (2009): 1096–1101.
12. H. Wang and R. H. Eckel, Lipoprotein lipase: From gene to obesity, *American Journal of Physiology: Endocrinology and Metabolism* 297 (2009): E271–E288; P. J. Voshol and coauthors, Effect of plasma triglyceride metabolism on lipid storage in adipose tissue: Studies using genetically engineered mouse models, *Biochimica et Biophysica Acta* 1791 (2009): 479–485.
13. E. Pardina and coauthors, Lipoprotein lipase but not hormone-sensitive lipase activities achieve normality after surgically induced weight loss in morbidly obese patients, *Obesity Surgery* 19 (2009): 1150–1158.
14. K. R. Westerterp and coauthors, Dietary fat oxidation as a function of body fat, *American Journal of Clinical Nutrition* 87 (2008): 132–135.

15. E. Lebenthal, Leptin: Weight management and beyond. Introduction to the symposium, *American Journal of Clinical Nutrition* 89 (2009): 971S–972S.
16. R. A. Waterland, Epigenetic epidemiology of obesity: Application of epigenomic technology, *Nutrition Reviews* 66 (2008): S21–S23.
17. K. Silventoinen and coauthors, The genetic and environmental influences on childhood obesity: A systematic review of twin and adoption studies, *International Journal of Obesity* 34 (2010): 29–40.
18. J. Wardle and coauthors, Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment, *American Journal of Clinical Nutrition* 87 (2008): 398–404.
19. C. M. Lindgren and M. I. McCarthy, Mechanisms of disease: Genetic insights into the etiology of type 2 diabetes and obesity, *Nature Clinical Practice. Endocrinology & Metabolism* 4 (2008): 156–163.
20. S. Li and coauthors, Physical activity attenuates the genetic predisposition to obesity in 20,000 men and women from EPIC-Norfolk prospective population study, *PLoS Medicine* 7 (2010): e1000331; J. M. McCaffery and coauthors, Gene X environment interaction of vigorous exercise and body mass index among male Vietnam-era twins, *American Journal of Clinical Nutrition* 89 (2009): 1011–1018; K. S. Vimaleswaran and coauthors, Physical activity attenuates the body mass index-increasing influence of genetic variation in the *FTO* gene, *American Journal of Clinical Nutrition* 90 (2009): 425–428.
21. E. Sonestedt and coauthors, Fat and carbohydrate intake modify the association between genetic variation in the *FTO* genotype and obesity, *American Journal of Clinical Nutrition* 90 (2009): 1418–1425.
22. R. J. Loos and C. Bouchard, FTO: The first gene contributing to common forms of human obesity, *Obesity Reviews* 9 (2008): 246–250; N. J. Timpson and coauthors, The fat mass- and obesity-associated locus and dietary intake in children, *American Journal of Clinical Nutrition* 88 (2008): 971–978; A. Körner and coauthors, Polygenic contribution to obesity: Genome-wide strategies reveal new targets, *Frontiers of Hormone Research* 36 (2008): 12–36; R. L. Leibel, Energy in, energy out, and the effects of obesity-related genes, *New England Journal of Medicine* 359 (2008): 2603–2604.
23. J. Hall, R. Roberts, and N. Vora, Energy homeostasis: The roles of adipose tissue-derived hormones, peptide YY and ghrelin, *Obesity Facts* 2 (2009): 117–125.
24. J. M. Friedman, Leptin at 14 y of age: An ongoing story, *American Journal of Clinical Nutrition* 89 (2009): 973S–979S; M. Rosenbaum and coauthors, Leptin reverses weight loss–induced changes in regional neural activity responses to visual food stimuli, *Journal of Clinical Investigation* 118 (2008): 2583–2591.
25. K. W. Williams, M. M. Scott, and J. K. Elmquist, From observation to experimentation: Leptin action in the mediobasal hypothalamus, *American Journal of Clinical Nutrition* 89 (2009): 985S–990S; Rosenbaum and coauthors, 2008.
26. I. S. Farooqi and S. O'Rahilly, Leptin: A pivotal regulator of human energy homeostasis, *American Journal of Clinical Nutrition* 89 (2009): 980S–984S.
27. M. G. Myers, M. A. Cowley, and H. Münzberg, Mechanisms of leptin action and leptin resistance, *Annual Review of Physiology* 70 (2008): 537–556.
28. A. Shapiro and coauthors, Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high fat feeding, *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology* 295 (2008): R1370–R1375.
29. T. R. Castañeda and coauthors, Ghrelin in the regulation of body weight and metabolism, *Frontiers in Neuroendocrinology* 31 (2010): 44–60.
30. P. Lyytikäinen and coauthors, Sleep problems and major weight gain: A follow-up study, *International Journal of Obesity* 35 (2011): 109–114; L. Brondel and coauthors, Acute partial sleep deprivation increases food intake in healthy men, *American Journal of Clinical Nutrition* 91 (2010): 1550–1559; A. V. Nedeltcheva and coauthors, Sleep curtailment is accompanied by increased intake of calories from snacks, *American Journal of Clinical Nutrition* 89 (2009): 126–133.
31. H. H. Chen and coauthors, Severe obesity is associated with novel single nucleotide polymorphisms of the *ESR1* and *PPARγ* locus in Han Chinese, *American Journal of Clinical Nutrition* 90 (2009): 255–262; M. Hofker and C. Wijmenga, A supersized list of obesity genes, *Nature Genetics* 41 (2009): 139–140.
32. S. Li and coauthors, Cumulative effects and predictive value of common obesity-susceptibility variants identified by genome-wide association studies, *American Journal of Clinical Nutrition* 91 (2010): 184–190.
33. M. M. Hetherington and J. E. Cecil, Gene-environment interactions in obesity, *Forum of Nutrition* 63 (2010): 195–203; C. Bouchard, Defining the genetic architecture of the predisposition to obesity: A challenging but not insurmountable task, *American Journal of Clinical Nutrition* 91 (2010): 5–6; J. Hebebrand and A. Hinney, Environmental and genetic risk factors in obesity, *Child and Adolescent Psychiatric Clinics of North America* 18 (2009): 83–94.
34. S. Enerbäck, The origins of brown adipose tissue, *New England Journal of Medicine* 360 (2009): 2021–2023.
35. F. S. Celi, Brown adipose tissue: When it pays to be inefficient, *New England Journal of Medicine* 360 (2009): 1553–1556; G. Wolf, Brown adipose tissue: The molecular mechanism of its formation, *Nutrition Reviews* 67 (2009): 167–171.
36. M. Harper, K. Green, and M. D. Brand, The efficiency of cellular energy transduction and its implications for obesity, *Annual Review of Nutrition* 28 (2008): 13–33.
37. M. Saito, High incidence of metabolically active brown adipose tissue in healthy adult humans, *Diabetes* 58 (2009): 1526–1531; W. D. van Marken Lichtenbelt and coauthors, Cold-activated brown adipose tissue in healthy men, *New England Journal of Medicine* 360 (2009): 1500–1508.
38. A. M. Cypess and coauthors, Identification and importance of brown adipose tissue in adult humans, *New England Journal of Medicine* 360 (2009): 1509–1517.
39. E. Ravussin and J. E. Galgani, The implication of brown adipose tissue for humans, *Annual Review of Nutrition* 31 (2011): 33–47; P. Seale, S. Kajimura, and B. M. Spiegelman, Transcriptional control of brown adipocyte development and physiological function: Of mice and men, *Genes and Development* 23 (2009): 788–797; K. A. Virtanen and coauthors, Functional brown adipose tissue in healthy adults, *New England Journal of Medicine* 360 (2009): 1518–1525.
40. L. Qi and Y. A. Cho, Gene-environment interaction and obesity, *Nutrition Reviews* 66 (2008): 684–694.
41. B. A. Swinburn, G. Sacks, and E. Ravussin, Increased food energy supply is more than sufficient to explain the US epidemic of obesity, *American Journal of Clinical Nutrition* 90 (2009): 1453–1456; B. A. Swinburn and coauthors, Estimating the changes in energy flux that characterizes the rise in obesity prevalence, *American Journal of Clinical Nutrition* 89 (2009): 1723–1728; W. P. James, The fundamental drivers of the obesity epidemic, *Obesity Reviews* 9 (2008): S6–S13.
42. I. Romao and J. Roth, Genetic and environmental interactions in obesity and type 2 diabetes, *Journal of the American Dietetic Association* 108 (2008): S24–S28.
43. J. M. McCaffery and coauthors, Effects of social contact and zygosity on 21-y weight change in male twins, *American Journal of Clinical Nutrition* 94 (2011): 404–409.
44. J. Currie and coauthors, The effect of fast food restaurants on obesity and weight gain, *American Economic Journal* 2 (2009): 32–63.
45. B. M. Popkin and K. J. Duffey, Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States, *American Journal of Clinical Nutrition* 91 (2010): 1342–1347; K. J. Duffey and coauthors, Regular consumption from fast food establishments relative to other restaurants is differentially associated with metabolic outcomes in young adults, *Journal of Nutrition* 139 (2009): 2113–2118.
46. K. J. Duffey and B. M. Popkin, Energy density, portion size, and eating occasions: Contributions to increased energy intake in the United States, 1977–2006, *PLoS Medicine* 8 (2011): e1001050.
47. R. N. Close and D. A. Schoeller, The financial reality of overeating, *Journal of the American College of Nutrition* 25 (2006): 203–209.
48. I. H. Steenhuis and W. M. Vermeer, Portion size: Review and framework for interventions, *International Journal of Behavioral Nutrition and Physical Activity* 6 (2009): 58–68.
49. T. S. Church and coauthors, Trends over 5 decades in US occupation-related physical activity and their association with obesity, *PLoS ONE* 6 (2011): e19657.

50. K. Wijndaele and coauthors, Increased cardiometabolic risk is associated with increased TV viewing time, *Medicine and Science in Sports and Exercise* 42 (2010): 1511–1518.
51. J. A. Teske, C. J. Billington, and C. M. Kotz, Neuropeptidergic mediators of spontaneous physical activity and non-exercise activity thermogenesis, *Neuroendocrinology* 87 (2008): 71–90.
52. American on the move: Steps to a healthier way of life, press release, September 10, 2007.
53. J. O. Hill, Can a small-changes approach help address the obesity epidemic? A report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council, *American Journal of Clinical Nutrition* 89 (2009): 477–484.
54. K. E. Giel and coauthors, Weight bias in work settings: A qualitative review, *Obesity Facts* 3 (2010): 33–40; C. Greenleaf, S. B. Martin, and D. Rhea, Fighting fat: How do fat stereotypes influence beliefs about physical education? *Obesity* 16 (2008): S53–S59.
55. G. Horsburgh-McLeod, J. D. Latner, and K. S. O'Brien, Unprompted generation of obesity stereotypes, *Eating and Weight Disorders* 14 (2009): e153–e157.
56. H. Konttinen and coauthors, Emotional eating and physical activity self-efficacy as pathways in the association between depressive symptoms and adiposity indicators, *American Journal of Clinical Nutrition* 92 (2010): 1031–1039; B. Blaine, Does depression cause obesity?: A meta-analysis of longitudinal studies of depression and weight control, *Journal of Health Psychology* 13 (2008): 1190–1197.
57. K. Stohacker and B. K. McFarlin, Influence of obesity, physical inactivity, and weight cycling on chronic inflammation, *Frontiers in Bioscience (Elite Edition)* 2 (2010): 98–104; I. Strychar and coauthors, Anthropometric, metabolic, psychosocial, and dietary characteristics of overweight/obese postmenopausal women with a history of weight cycling: A MONET (Montreal Ottawa New Emerging Team) Study, *Journal of the American Dietetic Association* 109 (2009): 718–724.
58. S. Hasani-Ranjbar and coauthors, A systematic review of the efficacy and safety of herbal medicines used in the treatment of obesity, *World Journal of Gastroenterology* 15 (2009): 3073–3085; C. K. Biesemeier and coauthors, Ethics opinion: Weight loss products and medications, *Journal of the American Dietetic Association* 108 (2008): 2109–2113.
59. P. A. Cohen, American Roulette: Contaminated dietary supplements, *New England Journal of Medicine* 361 (2009): 1523–1525.
60. R. F. Kushner, Anti-obesity drugs, *Expert Opinion on Pharmacotherapy* 9 (2008): 1339–1350.
61. A. Astrup, Drug management of obesity: Efficacy versus safety, *New England Journal of Medicine* 363 (2010): 288–290.
62. A. Nagle, Bariatric surgery: A surgeon's perspective, *Journal of the American Dietetic Association* 110 (2010): 520–523; G. L. Blackburn, S. Wollner, and S. B. Heymsfield, Lifestyle interventions for the treatment of class III obesity: A primary target for nutrition medicine in the obesity epidemic, *American Journal of Clinical Nutrition* 91 (2010): 289S–292S.
63. L. M. Beckman, T. R. Beckman, and C. P. Earthman, Changes in gastrointestinal hormones and leptin after Roux-en-Y gastric bypass procedure: A review, *Journal of the American Dietetic Association* 110 (2010): 571–584.
64. T. H. Inge and coauthors, Reversal of type 2 diabetes mellitus and improvements in cardiovascular risk factors after surgical weight loss in adolescents, *Pediatrics* 123 (2009): 214–222; J. B. Dixon and coauthors, Adjustable gastric banding and conventional therapy for type 2 diabetes: A randomized controlled trial, *Journal of the American Medical Association* 299 (2008): 316–323.
65. C. C. Wee, A 52-year-old woman with obesity, *Journal of the American Medical Association* 302 (2009): 1097–1104.
66. E. H. Livingston, Surgical treatment of obesity in adolescence, *Journal of the American Medical Association* 303 (2010): 559–560.
67. Y. Chen, Acute bariatric surgery complications: Managing parenteral nutrition in the morbidly obese, *Journal of the American Dietetic Association* 110 (2010): 1734–1737; D. Kulick, L. Hark, and D. Deen, The bariatric surgery patient: A growing role for registered dietitians, *Journal of the American Dietetic Association* 110 (2010): 593–599; G. Snyder-Marlow, D. Taylor, and J. Lenhard, Nutrition care for patients undergoing laparoscopic sleeve gastrectomy for weight loss, *Journal of the American Dietetic Association* 110 (2010): 600–607.
68. Snyder-Marlow, Taylor, and Lenhard, 2010; E. T. Aasheim and coauthors, Vitamin status after bariatric surgery: A randomized study of gastric bypass and duodenal switch, *American Journal of Clinical Nutrition* 90 (2009): 15–22; M. Ruz and coauthors, Iron absorption and iron status are reduced after Roux-en-Y gastric bypass, *American Journal of Clinical Nutrition* 90 (2009): 527–532.
69. M. Kruseman and coauthors, Dietary, weight, and psychological changes among patients with obesity, 8 years after gastric bypass, *Journal of the American Dietetic Association* 110 (2010): 527–534.
70. D. R. Flum and the Longitudinal Assessment of Bariatric Surgery (LABS) Consortium, Perioperative safety in the longitudinal assessment of bariatric surgery, *New England Journal of Medicine* 361 (2009): 445–454.
71. P. J. Stephan and J. M. Kenkel, Updates and advances in liposuction, *Aesthetic Surgery Journal* 30 (2010) 83–97.
72. T. L. Hernandez and coauthors, Fat redistribution following suction lipectomy: Defense of body fat and patterns of restoration, *Obesity* 19 (2011): 1388–1395.
73. D. Heber, An integrative view of obesity, *American Journal of Clinical Nutrition* 91 (2010): 280S–283S.
74. D. R. Jacobs and coauthors, Association of 1-y changes in diet pattern with cardiovascular disease risk factors and adipokines: Results from the 1-y randomized Oslo Diet and Exercise Study, *American Journal of Clinical Nutrition* 89 (2009): 509–517.
75. D. R. Young and coauthors, Effects of the PREMIER interventions on health-related quality of life, *Annals of Behavioral Medicine* 40 (2010): 302–312.
76. G. D. Foster and coauthors, Obese patients' perceptions of treatment outcomes and the factors that influence them, *Archives of Internal Medicine* 161 (2001): 2133–2139; G. D. Foster and coauthors, What is a reasonable weight loss? Patients' expectations and evaluations of obesity treatment outcomes, *Journal of Consulting and Clinical Psychology* 65 (1997): 79–85.
77. A. J. Tomiyama and coauthors, Low calorie dieting increases cortisol, *Psychosomatic Medicine* 72 (2010): 357–364.
78. H. M. Seagle and coauthors, Position of the American Dietetic Association: Weight management, *Journal of the American Dietetic Association* 109 (2009): 330–346.
79. M. T. Timlin and coauthors, Breakfast eating and weight change in a 5-year prospective analysis of adolescents: Project EAT (Eating Among Teens), *Pediatrics* 121 (2008): e638.
80. L. Dubois and coauthors, Breakfast skipping is associated with differences in meal patterns, macronutrient intakes and overweight among pre-school children, *Public Health Nutrition* 12 (2009): 19–28; A. K. Kant and coauthors, Association of breakfast energy density with diet quality and body mass index in American adults: National Health and Nutrition Examination Surveys, 1999–2004, *American Journal of Clinical Nutrition* 88 (2008): 1396–1404.
81. C. L. Rock and coauthors, Effect of a free prepared meal and incentivized weight loss program on weight loss and weight loss maintenance in obese and overweight women: A randomized controlled trial, *Journal of the American Medical Association* 304 (2010): 1803–1810; Position of the American Dietetic Association: Weight management, *Journal of the American Dietetic Association* 109 (2009): 330–346.
82. N. Zijlstra and coauthors, Effect of bite size and oral processing time of a semisolid food on satiation, *American Journal of Clinical Nutrition* 90 (2009): 269–275.
83. A. Kokkinos and coauthors, Eating slowly increases the postprandial response of the anorexigenic gut hormones, peptide YY and glucagon-like peptide-1, *Journal of Clinical Endocrinology and Metabolism* 95 (2010): 333–337.
84. A. M. Andrade and coauthors, Eating slowly led to decreases in energy intake within meals in healthy women, *Journal of the American Dietetic Association* 108 (2008): 1186–1191.
85. E. Stice and coauthors, Relation between obesity and blunted striatal response to food is moderated by TaqIA A1 allele, *Science* 322 (2008): 449–452.
86. C. H. Llewellyn and coauthors, Eating rate is a heritable phenotype related to weight in children, *American Journal of Clinical Nutrition* 88 (2008): 1560–1566.

87. B. J. Rolls, Plenary lecture 1: Dietary strategies for the prevention and treatment of obesity, *Proceedings of the Nutrition Society* 3 (2009): 1–10; K. E. Leahy, L. L. Birch, and B. J. Rolls, Reducing the energy density of multiple meals decreases the energy intake of preschool-age children, *American Journal of Clinical Nutrition* 88 (2008): 1459–1468.
88. M. C. Daniels and B. M. Popkin, Impact of water intake on energy intake and weight status: A systematic review, *Nutrition Reviews* 68 (2010): 505–521; B. M. Davy and coauthors, Water consumption reduces energy intake at a breakfast meal in obese older adults, *Journal of the American Dietetic Association* 108 (2008): 1236–1239.
89. B. Buijsse and coauthors, Fruit and vegetable intakes and subsequent changes in body weight in European populations: Results from the project on Diet, Obesity, and Genes (DiOGenes), *American Journal of Clinical Nutrition* 90 (2009): 202–209.
90. N. Schroeder and coauthors, Influence of whole grain barley, whole grain wheat, and refined rice-based foods on short-term satiety and energy intake, *Appetite* 53 (2009): 363–369; P. Vitaglione and coauthors, β-Glucan-enriched bread reduces energy intake and modifies plasma ghrelin and peptide YY concentrations in the short term, *Appetite* 53 (2009): 338–344.
91. US Department of Agriculture and US Department of Health and Human Services, *Dietary Guidelines for Americans, 2010*, available at www.dietaryguidelines.gov; R. D. Mattes and B. M. Popkin, Nonnutritive sweetener consumption in humans: Effects on appetite and food intake and their putative mechanisms, *American Journal of Clinical Nutrition* 89 (2009): 1–14.
92. S. P. Fowler and coauthors, Fueling the obesity epidemic? Artificially sweetened beverage use and long-term weight gain, *Obesity* 16 (2008): 1894–1900.
93. B. H. Goodpaster and coauthors, Effects of diet and physical activity interventions on weight loss and cardiometabolic risk factors in severely obese adults: A randomized study, *Journal of the American Medical Association* 304 (2010): 1795–1802; A. L. Hankinson and coauthors, Maintaining a high physical activity level over 20 years and weight gain, *Journal of the American Medical Association* 304 (2010): 2603–2610.
94. J. E. Donnelly and coauthors, American College of Sports Medicine Position Stand: Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults, *Medicine and Science in Sports and Exercise* 41 (2009): 459–471; Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005).
95. Goodpaster and coauthors, 2010; M. Hamer and G. O'Donovan, Cardiorespiratory fitness and metabolic risk factors in obesity, *Current Opinion in Lipidology* 21 (2010): 1–7; D. E. Larson-Meyer and coauthors, Caloric restriction with or without exercise: The fitness versus fatness debate, *Medicine and Science in Sports and Exercise* 42 (2010): 152–159.
96. D. T. Villareal and coauthors, Weight loss, exercise, or both and physical function in obese older adults, *New England Journal of Medicine* 364 (2011): 1218–1229.
97. J. E. Turner and coauthors, Nonprescribed physical activity energy expenditure is maintained with structured exercise and implicates a compensatory increase in energy intake, *American Journal of Clinical Nutrition* 92 (2010): 1009–1016.
98. A. M. Knab and coauthors, A 45-minute vigorous exercise bout increases metabolic rate for 14 hours, *Medicine and Science in Sports and Exercise* 43 (2011): 1643–1648; K. Ohkawara and coauthors, Twenty-four-hour analysis of elevated energy expenditure after physical activity in a metabolic chamber: Models of daily total energy expenditure, *American Journal of Clinical Nutrition* 87 (2008): 1268–1276.
99. E. P. Kirk and coauthors, Minimal resistance training improves daily energy expenditure and fat oxidation, *Medicine and Science in Sports and Exercise* 41 (2009): 1122–1129.
100. J. W. Bea and coauthors, Resistance training predicts 6-yr body composition change in postmenopausal women, *Medicine and Science in Sports and Exercise* 42 (2010): 1286–1295.
101. J. A. King and coauthors, Influence of brisk walking on appetite, energy intake, and plasma acylated ghrelin, *Medicine and Science in Sports and Exercise* 42 (2010): 485–492.
102. N. A. King and coauthors, Dual process action of exercise on appetite control: Increase in orexigenic drive but improvement in meal-induced satiety, *American Journal of Clinical Nutrition* 90 (2009): 921–927.
103. P. Gordon-Larsen and coauthors, Fifteen-year longitudinal trends in walking patterns and their impact on weight change, *American Journal of Clinical Nutrition* 89 (2009): 19–26.
104. I. M. Lee and coauthors, Physical activity and weight gain prevention, *Journal of the American Medical Association* 303 (2010): 1173–1179.
105. B. J. Nicklas and coauthors, Effect of exercise intensity on abdominal fat loss during calorie restriction in overweight and obese postmenopausal women: A randomized, controlled trial, *American Journal of Clinical Nutrition* 89 (2009): 1043–1052.
106. B. McFerran and coauthors, I'll have what she's having: Effects of social influence and body type on the food choices of others, *Journal of Consumer Research* 36 (2010): 915–929.
107. L. E. Burke, J. Wang, and M. A. Sevick, Self-monitoring in weight loss: A systematic review of the literature, *Journal of the American Dietetic Association* 111 (2011): 92–102.
108. K. G. Volpp and coauthors, Financial incentive–based approaches for weight loss: A randomized trial, *Journal of the American Medical Association* 300 (2008): 2631–2637.
109. M. E. Murawski and coauthors, Problem solving, treatment adherence, and weight-loss outcome among women participating in lifestyle treatment for obesity, *Eating Behaviors* 10 (2009): 146–151.
110. J. Sallit, M. Cuiccazzo, and Z. Dixon, A cognitive-behavioral weight control program improves eating and smoking behaviors in weight-concerned female smokers, *Journal of the American Dietetic Association* 109 (2009): 1398–1405.
111. J. P. Block and coauthors, Psychosocial stress and change in weight among US adults, *American Journal of Epidemiology* 170 (2009): 181–192.
112. G. M. Manzoni and coauthors, Can relaxation training reduce emotional eating in women with obesity? An exploratory study with 3 months of follow-up, *Journal of the American Dietetic Association* 109 (2009): 1427–1432.
113. S. Kodama and coauthors, Effect of web-based lifestyle modification on weight control: A meta-analysis, *International Journal of Obesity* (2011): doi:10.1038/ijo.2011.121; A. G. Digenio and coauthors, Comparison of methods for delivering a lifestyle modification program for obese patients: A randomized trial, *Annals of Internal Medicine* 150 (2009): 255–262; L. P. Svetkey and coauthors, Comparison of strategies for sustaining weight loss: The weight loss maintenance randomized controlled trial, *Journal of the American Medical Association* 299 (2008): 1139–1148.
114. J. L. Kraschnewski and coauthors, Long-term weight loss maintenance in the United States, *International Journal of Obesity* 34 (2010): 1644–1654.
115. S. Phelan and coauthors, Use of artificial sweeteners and fat-modified foods in weight loss maintainers and always-normal weight individuals, *International Journal of Obesity* 33 (2009): 1183–1190.
116. M. Rosenbaum and coauthors, Long-term persistence of adaptive thermogenesis in subjects who have maintained a reduced body weight, *American Journal of Clinical Nutrition* 88 (2008): 906–912.
117. Donnelly and coauthors, 2009; Hankinson and coauthors, 2010; J. L. Unick, J. M. Jakicic, and B. H. Marcus, Contribution of behavior intervention components to 24-month weight loss, *Medicine and Science in Sports and Exercise* 42 (2010): 745–753.
118. V. A. Catenacci and coauthors, Physical activity patterns in the National Weight Control Registry, *Obesity* 16 (2008): 153–161.
119. E. Manthou and coauthors, Behavioral compensatory adjustments to exercise training in overweight women, *Medicine and Science in Sports and Medicine* 42 (2010): 1221–1228.
120. S. N. Grief and R. L. Miranda, Weight loss maintenance, *American Family Physician* 82 (2010): 630–634.
121. L. K. Khan and coauthors, Recommended community strategies and measurements to prevent obesity in the United States, *MMWR Recommendations and Reports* 58 (2009): 1–26; A. M. Wolf and

K. A. Woodworth, Obesity prevention: Recommended strategies and challenges, *The American Journal of Medicine* 122 (2009): S19–S23.
122. Khan and coauthors, 2009.
123. E. A. Finkelstein and coauthors, Impact of targeted beverage taxes on higher- and lower-income households, *Archives of Internal Medicine* 170 (2010): 2028–2034; K. D. Brownell and T. R. Frieden, Ounces of prevention: The public policy case for taxes on sugared beverages, *New England Journal of Medicine* 360 (2009): 1805–1808.
124. T. T. Huang and T. A. Glass, Transforming research strategies for understanding and preventing obesity, *Journal of the American Medical Association* 300 (2008): 1811–1813.
125. C. D. Fryar and C. L. Ogden, Prevalence of underweight among adults aged 20 years and over: United States, 2007–2008, *NCHS Health E-Stats*, www.cdc.gov/nchs/data/hestat/underweight/underweight_adults.htm.
126. J. Shea and coauthors, Changes in the transcriptome of abdominal subcutaneous adipose tissue in response to short-term overfeeding in lean and obese men, *American Journal of Clinical Nutrition* 89 (2009): 407–415.
127. Position Paper: Nutrition and athletic performance: Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine, *Journal of the American Dietetic Association* 100 (2000): 1543–1556.

LEARN IT Contrast the differences between popular fad diets and weight-loss diets based on sound nutrition.

The Latest and Greatest Weight-Loss Diet—Again



© Jerry Arcieri/Corbis

To paraphrase William Shakespeare, "A fad diet by any other name would still be a fad diet." Year after year, "new and improved" diets appear on bookstore shelves and circulate among friends.* People of all sizes eagerly try the best diet ever on the market, hoping that this one will really work. Sometimes these diets seem to work for a while, but more often than not, their success is short-lived. Then another diet takes the spotlight. Here's how Dr. K. Brownell, an obesity researcher at Yale University, describes this phenomenon: "When I get calls about the latest diet fad, I imagine a trick birthday cake candle that keeps lighting up and we have to keep blowing it out."

Realizing that fad diets do not offer a safe and effective long-term plan for weight loss, health professionals speak out, but they never get the candle blown out permanently. New fad diets can keep making outrageous claims because no one requires their advocates to prove what they say. Fad diet gurus do not have to conduct credible research on the benefits or dangers of their diets. They can simply make recommendations and then later, if questioned, search for bits and pieces of research that support the conclusions they have already reached. That's backward. Diet and health recommendations should *follow* years of sound scientific research *before* being offered to the public.

Because anyone can publish anything—in books or on the Internet—peddlers of fad diets can make unsubstantiated statements that fall far short of the truth but sound impressive to the uninformed. They often offer distorted bits of legitimate research. They may start with one or more actual facts but then leap from one erroneous conclusion to the next. Anyone who wants to believe these claims has to wonder how the thousands of scientists working on obesity research over the past century could possibly have missed such obvious connections.

Fad diets come in almost as many shapes and sizes as the people who search them out. Some restrict fats or carbohydrates, some limit portion sizes, some focus on food combinations, and some claim that a person's genetic type or blood type determines the foods best suited to manage weight and prevent disease. Table H9-1 compares some of today's popular diets.

*The Academy of Nutrition and American Dietetics offers evaluations of popular diets for your review. Look for Popular Diet Reviews at their website, **www.eatright.org/media.**

TABLE H9-1 Popular Diets Compared

Diet	Major Premise Promoted	Strong Point(s)	Weak Point(s)
The 4-Hour Body	• Less is more, and small, simple changes produce long-lasting effects.	• Quick results.	• Restricts carbohydrates. • All fruit and milk (except cottage cheese) are excluded and vegetables are limited. • Encourages eating the same small meals repeatedly. • Recommends a weekly binge.
The 17 Day Diet	• Changing the way you eat every few days creates "body confusion," which prevents metabolism from settling into homeostasis. • You can boost metabolism by "eating clean," which means no sugar, no processed food, and no fried foods.	• Quick results. • Prevents boredom by alternating between cycles. • Fairly well-balanced diet that promotes healthy eating.	• No scientific evidence that changing the diet creates "body confusion." • No individualized kcalorie goals. • Promotes its own processed foods.
Atkins Diet	• People are overweight or obese because they have metabolic imbalances caused by eating too many carbohydrates; by restricting carbohydrates, these imbalances can be corrected. • You can lose weight without lowering kcalorie intake.	• Quick, short-term weight loss is achieved.	• Restricts carbohydrates to a level that induces ketosis which can cause nausea, light-headedness, and fatigue and can worsen existing medical problems such as kidney disease. • A diet high in fat such as Atkins can increase the risk of heart disease and some cancers.

© Cengage Learning 2013

TABLE H9-1 Popular Diets Compared (*continued*)

Diet	Major Premise Promoted	Strong Point(s)	Weak Point(s)
Cheater's Diet	• Successful weight loss depends on eliminating boredom and allowing indulgences. • Cheating on weekends "stokes your metabolism."	• Meals are proportioned one-half fruit or vegetables, one-fourth lean protein, and one-fourth whole grains. • Encourages as much exercise as possible.	• No scientific data on cheating boosting metabolism or supporting weight loss.
Cinch!	• A nutrient-dense diet composed mainly of plant-based foods will help you lose weight and lower the risk of disease.	• Plant-based, nutrient-dense diet. • Stresses the importance of exercise.	• A little confusing and dense with facts.
The Dukan Diet	• A high-protein, low-kcalorie diet promotes rapid weight loss and will keep it off for good.	• Encourages daily exercise, moderate salt intake, and lifelong weight management. • Provides a highly structured plan.	• Restricts carbohydrates to a level that induces ketosis which can cause nausea, light-headedness, and fatigue and can worsen medical problems such as kidney disease. • Not suited for vegetarians and others who prefer not to emphasize animal proteins.
Glucose Revolution	• Low glycemic index foods satisfy hunger, control blood glucose, and promote weight loss.	• Emphasizes fiber-rich vegetables, legumes, fruits, and whole grains. • Minimizes saturated fat intake.	• Difficult to know the glycemic index of some foods.
New Sonoma Diet	• Enjoying portion-controlled Coastal California style foods supports weight loss and promotes good health.	• Emphasizes nutrient-dense foods. • Limits processed foods.	• No individualized kcalorie plans.
Ornish Diet	• By strictly limiting fat (both animal and vegetable), you eat fewer kcalories without eating less food.	• High-fiber, low-fat foods in this plan can lower blood cholesterol and blood pressure.	• So little fat that essential fatty acids may be lacking. • Limits fish, nuts, and olive oil, which may protect against heart disease.
South Beach Diet	• Eating "good carbohydrates" such as vegetables, whole-wheat pastas, and brown rice will maintain satiety and resist cravings for "bad carbohydrates" such as white rice and potatoes.	• Encourages consumption of vegetables, lean meats, and fish, and the use of unsaturated oils when cooking. • Restricts fatty meats and cheeses as well as sweets.	• Starchy carbohydrates and all fruits are completely excluded during the first two weeks.
Ultimate Weight Solution Diet	• Foods that require great effort to prepare and eat are nutrient-dense; eating these kinds of foods (raw vegetables, vegetable soups, whole grains, beans, meats, poultry, and fish) will lead to weight loss. • Foods that take little effort to prepare and eat provide excess kcalories relative to nutrients; eating these kinds of foods (fast foods, puddings, high-kcalorie convenience foods, processed foods) leads to uncontrolled eating and weight gain.	• Encourages consumption of lean meats and fish; whole grains; vegetables; fruit; and low-fat milk, yogurt, and cheese. • Restricts fatty meats and cheeses as well as sweets. • Encourages exercise.	• Confusing as to exactly what to eat or how much.
Zone Diet	• Eating the correct proportions of carbohydrates, fat, and protein leads to hormonal balance, weight loss, disease prevention, and increased vitality.	• Promotes weight loss because it is a low-kcalorie diet.	• The diet is rigid, restrictive, and complicated, making it difficult for most people to follow accurately. • The overblown health claims of the diet's proponents are based on misinterpreted science and remain unsubstantiated.

© Cengage Learning 2013

Fad Diets' Appeal

With more than half of our nation's adults overweight and many more concerned about their weight, the market for a weight-loss book, product, or program is huge (no pun intended). Americans spend an estimated $33 billion a year on weight-loss books and products. Even a plan that offers only minimal weight-loss success easily attracts a following.

Perhaps the greatest appeal of fad diets is that they tend to ignore dietary recommendations. Foods such as meats and milk products that need to be selected carefully to limit saturated fat can be eaten with

abandon. Whole grains, legumes, vegetables, and fruits that should be eaten in abundance can now be bypassed. For some people, this is a dream come true: steaks without the potatoes, ribs without the coleslaw, and meatballs without the pasta. Who can resist the promise of weight loss while eating freely from a list of favorite foods?

Dieters are also lured into fad diets by sophisticated—yet often erroneous—explanations of the metabolic consequences of eating certain foods. Terms such as *eicosanoids* and *de novo lipogenesis* are scattered about, often intimidating readers into believing that the authors must be right given their brilliance in understanding the body.

If fad diets were as successful as some people claim, then consumers who tried them would lose weight, and their obesity problems would be solved. But this is not the case. Similarly, if fad diets were as worthless as others claim, then consumers would eventually stop pursuing them. Clearly, this is not happening either. Most fad diets have enough going for them that they work for some people at least for a short time, but they fail to produce long-lasting results for most people.

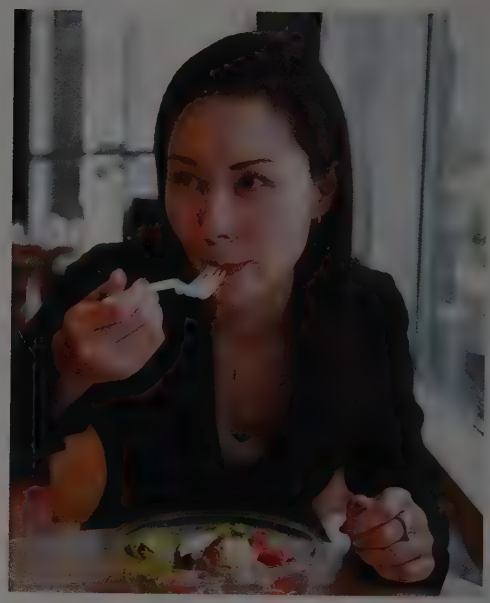
Don't Count kCalories

Who wants to count kcalories? Even experienced dieters find counting kcalories burdensome, not to mention timeworn. They want a new, easy way to lose weight, and fad diet plans seem to offer this boon. But, though fad diets often claim to disregard kcalories, their design typically ensures a low energy intake. Most of the sample menu plans, especially in the early stages, are designed to deliver an average of 1200 kcalories a day.

Even when counting kcalories is truly not necessary, total kcalories tend to be low simply because food intake is so limited. Diets that omit hundreds of foods and several food groups limit a person's options and lack variety. Chapter 2 praises variety as a valuable way to ensure an adequate intake of nutrients, but variety also entices people to eat more food and gain more weight. Without variety, some people lose interest in eating, which further reduces energy intake. Even if the allowed foods are favorites, eating the same foods week after week can become monotonous.

Without its refried beans, tortilla wrapping, and chopped vegetables, a burrito is reduced to a pile of ground beef. Without the baked potato, there's no need for butter and sour cream. Weight loss occurs because of the low energy intake. This is an important point. Any diet can produce weight loss, at least temporarily, if intake is restricted. The real value of a diet is determined by its ability to maintain weight loss and support good health over the long term. The goal is not simply weight loss, but health gains—and most fad diets cannot support optimal health over time. In fact, some weight-loss diets can create or exacerbate health problems.[1]

When food choices are limited, nutrient intakes may be inadequate. To help shore up some of these inadequacies, fad diets often recommend a dietary supplement. Conveniently, many of the companies selling fad diets also peddle these supplements. But as Highlights 10 and 11 explain, foods offer many more health benefits than any supplement can provide. Quite simply, if the diet is inadequate, it needs to be improved.



© ICHIRO/Jupiterimages

The wise consumer seeks a diet that supports not only weight loss, but health gains.

Follow a Plan

Most people need specific instructions and examples to make dietary changes. Popular diets offer dieters a plan. The user doesn't have to decide what foods to eat, how to prepare them, or how much to eat. Unfortunately, these instructions serve only short-term weight-loss needs. They do not provide for long-term changes in lifestyle that will support weight maintenance or health goals.

The success of any weight-loss diet depends on the person adopting the plan and sticking with it. People who prefer a high-protein, low-carbohydrate diet over a high-carbohydrate, low-fat diet, for example, may have more success at sticking with it.[2] Keep in mind, though, that weight loss occurs because of the duration of a low-kcalorie plan—not the proportion of energy nutrients.[3]

The Real Deal

Fad diets attribute magical powers to their weight-loss plans, but in reality, the magic is in tipping the energy balance so that metabolic and physical activities expend more kcalories than foods bring in. Because new diets emerge in the market regularly, it can be challenging to sort the fad diets from the healthy options. Furthermore, it can be difficult determining how a diet's overall quality rates and how it compares with others.

Keep in mind that healthy weight loss requires long-term lifestyle changes in eating and activity habits—not quick, short-term fixes. A healthy plan may not be quick, but it allows for flexibility and a variety of foods, including some favorite treats on occasion.

Some currently popular diet plans offer a sensible approach to weight loss and healthy eating. The challenge is sorting through "the good, the bad, and the ugly." The accompanying "How To" feature offers tips for identifying fad diets and other weight-loss scams. Fad diets may not harm healthy people if used for only a little while, but they cannot support optimal health for long. Chapter 9 includes reasonable approaches to weight management and concludes that the ideal diet is one you can live with for the rest of your life. Keep that criterion in mind when you evaluate the next "latest and greatest weight-loss diet" that comes along.

>How To

Identify a Fad Diet or Weight-Loss Scam

It may be a fad diet or weight-loss scam if it:

- Sounds too good to be true.
- Recommends using a single food consistently as the key to the program's success.
- Promises quick and easy weight loss with no effort. "Lose weight while you sleep!"
- Eliminates an entire food group such as grains or milk and milk products.
- Guarantees an unrealistic outcome in an unreasonable time period. "Lose 10 pounds in 2 days!"
- Bases evidence for its effectiveness solely on anecdotal stories.
- Requires you to buy special products that are not readily available in the marketplace at affordable prices.
- Specifies a proportion for the energy nutrients that falls outside the recommended ranges—carbohydrate (45 to 65 percent), fat (20 to 35 percent), and protein (10 to 35 percent).
- Claims to alter your genetic code or reset your metabolism.
- Fails to mention potential risks or additional costs.
- Promotes products or procedures that have not been proven safe and effective.
- Neglects plans for weight maintenance following weight loss.

TRY IT Review an advertisement for a popular weight-loss plan and explain why you think it might—or might not—be a fad diet.

REFERENCES

1. P. Sjögren and coauthors, Mediterranean and carbohydrate-restricted diets and mortality among elderly men: A cohort study in Sweden, *American Journal of Clinical Nutrition* 92 (2010): 967–974; T. D. Barnett, N. D. Barnard, and T. L. Radak, Development of symptomatic cardiovascular disease after self-reported adherence to the Atkins diet, *Journal of the American Dietetic Association* 109 (2009): 1263–1265; M. Miller and coauthors, Comparative effects of three popular diets on lipids, endothelial function, and c-reactive protein during weight maintenance, *Journal of the American Dietetic Association* 109 (2009): 713–717.
2. T. M. Larsen and coauthors, Diets with high or low protein content and glycemic index for weight-loss maintenance, *New England Journal of Medicine* 363 (2010): 2102–2113.
3. E. A. Delbridge and coauthors, One-year weight maintenance after significant weight loss in healthy overweight and obese subjects: Does diet composition matter? *American Journal of Clinical Nutrition* 90 (2009): 1203–1214; G. D. Foster and coauthors, Weight and metabolic outcomes after 2 years on a low-carbohydrate versus low-fat diet: A randomized trial, *Annals of Internal Medicine* 153 (2010): 147–157; W. S. Yancy and coauthors, A randomized trial of a low-carbohydrate diet vs orlistat plus a low-fat diet for weight loss, *Archives of Internal Medicine* 170 (2010): 136–145; F. M. Sacks and coauthors, Comparison of weight-loss diets with different compositions of fat, protein, and carbohydrates, *New England Journal of Medicine* 360 (2009): 859–873.



CENGAGE LEARNING'S
NUTRITION
GLOBAL NUTRITION RESOURCE CENTER

Vitamin C's role in strengthening the immune system has led it to be touted as a remedy for many ailments, including the common cold. Go to Nutrition Basics and Tools → Vitamins, Minerals, and Water to review its other benefits. What benefit or harm could come from increasing intake of water-soluble vitamins beyond DRI guidelines?

10 The Water-Soluble Vitamins: B Vitamins and Vitamin C

LEARNING GPS

10.1 The Vitamins—An Overview 297

LEARN IT Describe how vitamins differ from the energy nutrients and how fat-soluble vitamins differ from water-soluble vitamins.

10.2 The B Vitamins 300

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the B vitamins.

- Thiamin 301
- Riboflavin 302
- Niacin 305
- Biotin 307
- Pantothenic Acid 308
- Vitamin B_6 309
- Folate 310
- Vitamin B_{12} 315
- Choline 318
- Nonvitamins 318
- Interactions among the B Vitamins 319

10.3 Vitamin C 322

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin C.

- Vitamin C Roles 323
- Vitamin C Recommendations 324
- Vitamin C Deficiency 325
- Vitamin C Toxicity 325
- Vitamin C Food Sources 326

Highlight 10 Vitamin and Mineral Supplements 331

LEARN IT Present arguments for and against the use of dietary supplements.

Nutrition in Your Life

If you were playing a word game and your partner said "vitamins," how would you respond? If "pills" and "supplements" immediately come to mind, you may be missing the main message of the vitamin story—that hundreds of foods deliver more than a dozen vitamins that participate in thousands of activities throughout your body. Quite simply, foods supply vitamins to support all that you are and all that you do—and supplements of any one of them, or even a combination of them, can't compete with foods in keeping you healthy. In the Nutrition Portfolio at the end of this chapter, you can determine whether the foods you are eating are meeting your water-soluble vitamin needs.

Earlier chapters focused on the energy-yielding nutrients—carbohydrates, fats, and proteins. This chapter begins with an overview of the vitamins and then examines each of the water-soluble vitamins; the next chapter features the fat-soluble vitamins.

10.1 The Vitamins—An Overview

LEARN IT Describe how vitamins differ from the energy nutrients and how fat-soluble vitamins differ from water-soluble vitamins.

Researchers first recognized that foods contain substances that are "vital to life" in the early 1900s.[1] Since then, the world of vitamins has opened up dramatically. The vitamins are powerful substances, as their *absence* attests. Vitamin A deficiency can cause blindness; a lack of the B vitamin niacin can cause dementia; and a lack of vitamin D can retard bone growth. The consequences of deficiencies are so dire, and the effects of restoring the needed vitamins so dramatic, that people spend billions of dollars every year in the belief that vitamin supplements will cure a host of ailments (see Highlight 10). Vitamins certainly support sound nutritional health, but they do not cure all ills. Furthermore, vitamin supplements do not offer the many benefits that come from vitamin-rich foods.

vitamins: organic, essential nutrients required in small amounts by the body for health. Vitamins regulate body processes that support growth and maintain life.

- **vita** = life
- **amine** = containing nitrogen (the first vitamins discovered contained nitrogen)

The *presence* of the vitamins also attests to their power. The B vitamin folate helps to prevent birth defects and vitamin K allows blood to clot. As you will see, the vitamins' roles in supporting optimal health extend far beyond preventing deficiency diseases. In fact, some of the credit given to low-fat diets in preventing disease actually belongs to the vitamins found in vegetables, fruits, and whole grains (see Highlight 11 for more on vitamins in disease prevention).

The vitamins differ from carbohydrates, fats, and proteins in the following ways:

- *Structure.* Vitamins are individual units; they are not linked together (as are molecules of glucose or amino acids). Appendix C presents the chemical structure for each of the vitamins.
- *Function.* Vitamins do not yield energy when metabolized; many of them do, however, assist the enzymes that participate in the release of energy from carbohydrates, fats, and proteins.
- *Food contents.* The amounts of vitamins people ingest from foods and the amounts they require daily are measured in *micrograms* (μg) or *milligrams* (mg), rather than grams (g). ♦

♦ For perspective, a dollar bill weighs about 1 g.
1 g = 1000 mg
1 mg = 1000 μg
Appendix K explains how to convert a measurement from one unit of measure to another.

The vitamins are similar to the energy-yielding nutrients, though, in that they are vital to life, organic, and available from foods.

Bioavailability The amount of vitamins available from foods depends not only on the quantity provided by a food but also on the amount absorbed and used by the body—referred to as the vitamins' **bioavailability.** The quantity of vitamins in a food can be determined relatively easily. Researchers analyze foods to determine the vitamin contents and publish the results in tables of food composition such as Appendix H. Determining the bioavailability of a vitamin is a more complex task because it depends on many factors, including:

- Efficiency of digestion and time of transit through the GI tract
- Previous nutrient intake and nutrition status
- Method of food preparation (raw, cooked, or processed)
- Source of the nutrient (synthetic, fortified, or naturally occurring)
- Other foods consumed at the same time

Chapters 10 through 13 describe factors that inhibit or enhance the absorption of individual vitamins and minerals. Experts consider these factors when estimating recommended intakes.

Precursors Some of the vitamins are available from foods in inactive forms known as **precursors,** or provitamins. Once inside the body, the precursor is converted to an active form of the vitamin. For example, beta-carotene, a red-orange pigment found in fruits and vegetables, is a precursor to vitamin A. Thus, in measuring a person's vitamin intake, it is important to count both the amount of the active vitamin and the potential amount available from its precursors. The discussions and summary tables throughout this chapter and the next indicate which vitamins have precursors.

Organic Nature Fresh foods naturally contain vitamins, but because they are organic, vitamins can be readily destroyed during processing.[2] Therefore, processed foods should be used sparingly, and fresh foods should be handled with care during storage and in cooking. Prolonged heating may destroy much of the thiamin in food. Because riboflavin can be destroyed by the ultraviolet rays of the sun or by fluorescent light, foods stored in transparent glass containers are most likely to lose riboflavin. Oxygen destroys vitamin C, so losses occur when foods are cut, processed, and stored; these losses may be enough to reduce its action in the body. Table 10-1 summarizes ways to minimize nutrient losses in the kitchen, and Chapter 19 provides more details.

Solubility As you may recall, carbohydrates and proteins are hydrophilic and lipids are hydrophobic. The vitamins divide along the same lines—the hydrophilic, water-soluble ones are the B vitamins and vitamin C; the hydrophobic, fat-soluble ones are vitamins A, D, E, and K. As each vitamin was discovered, it was given a name and sometimes a letter and number as well. Many of the vitamins have multiple names, which has led to some confusion. The margin lists the standard



© Polara Studios, Inc.

To minimize vitamin losses, wrap cut fruits and vegetables or store them in airtight containers.

bioavailability: the rate at and the extent to which a nutrient is absorbed and used.

precursors: substances that precede others; with regard to vitamins, compounds that can be converted into active vitamins; also known as *provitamins.*

TABLE 10-1 Minimizing Nutrient Losses

- To slow the degradation of vitamins, refrigerate (most) fruits and vegetables.
- To minimize the oxidation of vitamins, store fruits and vegetables that have been cut in airtight wrappers, and store juices that have been opened in closed containers (and refrigerate them).
- To prevent vitamin losses during washing, rinse fruits and vegetables before cutting (not after).
- To minimize vitamin losses during cooking, use a microwave oven or steam vegetables in a small amount of water. Add vegetables after water has come to a boil. Use the cooking water in mixed dishes such as casseroles and soups. Avoid high temperatures and long cooking times.

© Cengage Learning 2013

names, ♦ and summary tables throughout this chapter and the next provide the common alternative names.

Solubility is apparent in the food sources of the different vitamins, and it affects their absorption, transport, storage, and excretion by the body. The water-soluble vitamins are found in the watery compartments of foods; the fat-soluble vitamins usually occur together in the fats and oils of foods. On being absorbed, the water-soluble vitamins move directly into the blood. Like fats, the fat-soluble vitamins must first enter the lymph, then the blood. Once in the blood, many of the water-soluble vitamins travel freely, whereas many of the fat-soluble vitamins require transport proteins. Upon reaching the cells, water-soluble vitamins freely circulate in the water-filled compartments whereas fat-soluble vitamins are held in fatty tissues and the liver until needed. The kidneys, monitoring the blood that flows through them, detect and remove small excesses of water-soluble vitamins; large excesses, however, may overwhelm the system, creating adverse effects. Fat-soluble vitamins tend to remain in fat-storage sites in the body rather than being excreted, and so are more likely to reach toxic levels when consumed in excess.

Because the body stores fat-soluble vitamins, they can be eaten in large amounts once in a while and still meet the body's needs over time. Water-soluble vitamins are retained for varying lengths of time in the body. The water-soluble vitamins must be eaten more regularly than the fat-soluble vitamins, although a single day's omission from the diet does not create a deficiency.

Toxicity Knowledge about some of the amazing roles of vitamins has prompted many people to take vitamin supplements, assuming that "more is better." Just as an inadequate intake can cause harm, so can an excessive intake. Even some of the water-soluble vitamins have adverse effects when taken in large doses.

That a vitamin can be both essential and harmful may seem surprising, but the same is true of most nutrients. The effects of every substance depend on its dose, and this is one reason consumers should not self-prescribe supplements. Figure 10-1 shows three possible relationships between dose levels and effects.

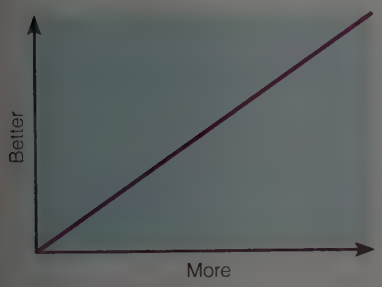
♦ **Water-soluble vitamins:**

- B vitamins:
  - Thiamin
  - Riboflavin
  - Niacin
  - Biotin
  - Pantothenic acid
  - Vitamin B_6
  - Folate
  - Vitamin B_{12}
- Vitamin C

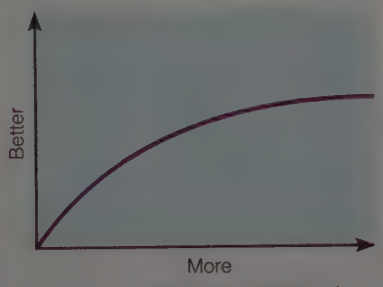
Fat-soluble vitamins:

- Vitamin A
- Vitamin D
- Vitamin E
- Vitamin K

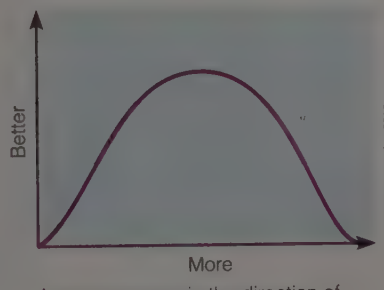
FIGURE 10-1 Dose Levels and Effects



As you progress in the direction of more, the effect gets better and better, with no end in sight (real life is seldom, if ever, like this).



As you progress in the direction of more, the effect reaches a maximum and then a plateau, becoming no better with higher doses.



© Cengage Learning 2013

As you progress in the direction of more, the effect reaches an optimum at some intermediate dose and then declines, showing that more is better up to a point and then harmful. That too much can be as harmful as too little represents the situation with most nutrients.

TABLE 10-2 Water-Soluble and Fat-Soluble Vitamins Compared

	Water-Soluble Vitamins: B Vitamins and Vitamin C	Fat-Soluble Vitamins: Vitamins A, D, E, and K
Absorption	Directly into the blood	First into the lymph, then the blood
Transport	Travel freely	Many require transport proteins
Storage	Circulate freely in water-filled parts of the body	Stored in the cells associated with fat
Excretion	Kidneys detect and remove excess in urine	Less readily excreted; tend to remain in fat-storage sites
Toxicity	Possible to reach toxic levels when consumed from supplements	Likely to reach toxic levels when consumed from supplements
Requirements	Needed in frequent doses (perhaps 1 to 3 days)	Needed in periodic doses (perhaps weeks or even months)

NOTE: Exceptions occur, but these differences between the water-soluble and fat-solule vitamins are valid generalizations.

The third diagram in Figure 10-1 represents the situation with nutrients—more is better up to a point, but beyond that point, still more can be harmful.

The Committee on Dietary Reference Intakes (DRI) addresses the possibility of adverse effects from high doses of nutrients by establishing Tolerable Upper Intake Levels (UL). The UL defines the highest amount of a nutrient that is likely not to cause harm for most healthy people when consumed daily. The risk of harm increases as intakes rise above the UL. Of the nutrients discussed in this chapter, niacin, vitamin B_6, folate, choline, and vitamin C have UL, and these values are presented in their respective summary tables. Data are lacking to establish UL for the remaining B vitamins, but this does not mean that excessively high intakes would be without risk. (The inside front cover pages present UL for the vitamins and minerals.)

REVIEW IT Describe how vitamins differ from the energy nutrients and how fat-soluble vitamins differ from water-soluble vitamins.

The vitamins are essential nutrients needed in tiny amounts in the diet both to prevent deficiency diseases and to support optimal health. The water-soluble vitamins are the B vitamins and vitamin C; the fat-soluble vitamins are vitamins A, D, E, and K. Table 10-2 summarizes the differences between the water-soluble and fat-soluble vitamins.

The discussion of B vitamins that follows begins with a brief description of each of them, then offers a look at the ways they work together. Thus, a preview of the individual vitamins is followed by a discussion of their interactions.

10.2 The B Vitamins

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the B vitamins.

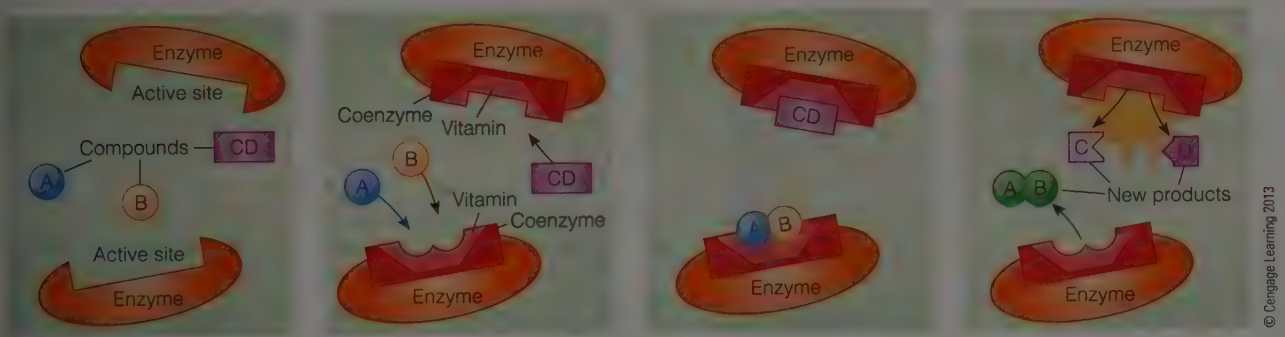
Despite supplement advertisements that claim otherwise, the vitamins do not provide the body with fuel for energy. It is true, though, that without B vitamins the body would lack energy. The energy-yielding nutrients—carbohydrate, fat, and protein—are used for fuel; the B vitamins help the body to use that fuel. Several of the B vitamins—thiamin, riboflavin, niacin, pantothenic acid, and biotin—form part of the **coenzymes** that assist enzymes in the release of energy from carbohydrate, fat, and protein. Other B vitamins play other indispensable roles in metabolism. Vitamin B_6 assists enzymes that metabolize amino acids. Folate and vitamin B_{12} help cells to multiply. Among these cells are the red blood cells and the cells lining the GI tract—cells that deliver energy to all the others.

The vitamin portion of a coenzyme allows a chemical reaction to occur; the remaining portion of the coenzyme binds to the enzyme. Without its coenzyme, an enzyme cannot function. Thus symptoms of B vitamin deficiencies directly reflect the disturbances of metabolism caused by a lack of coenzymes. Figure 10-2 illustrates coenzyme action.

coenzymes: complex organic molecules that work with enzymes to facilitate the enzymes' activity. Many coenzymes have B vitamins as part of their structures.

FIGURE 10-2 Coenzyme Action

Some vitamins form part of the coenzymes that enable enzymes either to synthesize compounds (as illustrated by the lower enzymes in this figure) or to dismantle compounds (as illustrated by the upper enzymes).



Without coenzymes, compounds A, B, and CD don't respond to their enzymes.

With the coenzymes in place, compounds are attracted to their sites on the enzymes . . .

. . . and the reactions proceed instantaneously. The coenzymes often donate or accept electrons, atoms, or groups of atoms.

The reactions are completed with either the formation of a new product, AB, or the breaking apart of a compound into two new products, C and D, and the release of energy.

© Cengage Learning 2013

The following sections describe the roles of individual B vitamins and note many coenzymes and metabolic pathways. Keep in mind that a later discussion assembles these pieces of information into a whole picture. The following sections also present the recommendations, deficiency and toxicity symptoms, and food sources for each vitamin. For thiamin, riboflavin, niacin, vitamin B_6, folate, vitamin B_{12}, and vitamin C, sufficient data were available to establish an RDA; for biotin, pantothenic acid, and choline, an Adequate Intake (AI) was set; only niacin, vitamin B_6, folate, choline, and vitamin C have Tolerable Upper Intake Levels (UL).[3] These values appear in the summary tables and figures that follow and on the pages of the inside front cover.

Thiamin

Thiamin is the vitamin part of the coenzyme TPP (thiamin pyrophosphate) that assists in energy metabolism. The TPP coenzyme participates in the conversion of pyruvate to acetyl CoA (described in Chapter 7). The reaction removes 1 carbon from the 3-carbon pyruvate to make the 2-carbon acetyl CoA and carbon dioxide (CO_2). In a similar step in the TCA cycle, TPP helps convert a 5-carbon compound to a 4-carbon compound. Besides playing these pivotal roles in energy metabolism, thiamin occupies a special site on the membranes of nerve cells. Consequently, nerve activity and muscle activity in response to nerves depend heavily on thiamin.

Thiamin Recommendations

Dietary recommendations are based primarily on thiamin's role in enzyme activity. Generally, thiamin needs will be met if a person eats enough food to meet energy needs—if that energy comes from nutritious foods. The average thiamin intake in the United States and Canada meets or exceeds recommendations.

Thiamin Deficiency and Toxicity

People who fail to eat enough food to meet energy needs risk nutrient deficiencies, including thiamin deficiency. Inadequate thiamin intakes have been reported among the nation's malnourished and homeless people. Similarly, people who derive most of their energy from empty-kcalorie foods and beverages risk thiamin deficiency. Alcohol provides a good example of how empty kcalories can lead to thiamin deficiency. Alcohol contributes energy but provides few, if any, nutrients and often displaces food. In addition, alcohol impairs thiamin absorption and enhances thiamin excretion in the urine, doubling the risk of deficiency. An estimated four out of five alcoholics are thiamin deficient.*

Prolonged thiamin deficiency can result in the disease **beriberi**, which was first observed in Indonesia when the custom of polishing rice became widespread.[4] Rice

thiamin (THIGH-ah-min): a B vitamin. The coenzyme form is *TPP* (*thiamin pyrophosphate*).

beriberi: the thiamin-deficiency disease.

- **beri** = weakness
- **beriberi** = "I can't, I can't"

*Severe thiamin deficiency in alcohol abusers is called the *Wernicke-Korsakoff* (VER-nee-key KORE-sah-kof) *syndrome*. Symptoms include disorientation, loss of short-term memory, jerky eye movements, and staggering gait.

FIGURE 10-3 Thiamin-Deficiency Symptom—The Edema of Beriberi

Physical examination confirms that this person has wet beriberi. Notice how the impression of the physician's thumb remains on the leg.



© NMSB/Custom Medical Stock Photo

provided 80 percent of the energy intake of the people of that area, and the germ and bran of the rice grain was their principal source of thiamin. When the germ and bran were removed in the preparation of white rice, beriberi became rampant.

Beriberi is often described as "dry" or "wet." Dry beriberi reflects damage to the nervous system and is characterized by muscle weakness in the arms and legs. Wet beriberi reflects damage to the cardiovascular system and is characterized by dilated blood vessels, which cause the heart to work harder and the kidneys to retain salt and water, resulting in edema. Typically, both types of beriberi appear together, with one set of symptoms predominating. Figure 10-3 presents the edema of beriberi. No adverse effects have been associated with excesses of thiamin, and no UL has been determined.

Thiamin Food Sources Before examining Figure 10-4, you may want to read the accompanying "How To" feature, which describes the content in this and similar figures found in this chapter and the next three chapters. When you look at Figure 10-4, notice that thiamin occurs in small quantities in many nutritious foods. The long red bar near the bottom of the graph shows that meats in the pork family are exceptionally rich in thiamin. Yellow bars confirm that grains—whole grains or enriched—are a reliable source of thiamin.

As mentioned earlier, prolonged cooking can destroy thiamin. Also, like other water-soluble vitamins, thiamin leaches into water when foods are boiled or blanched. Cooking methods that require little or no water such as steaming and microwave heating conserve thiamin and other water-soluble vitamins. The accompanying table provides a summary of thiamin.

Riboflavin Like thiamin, **riboflavin** serves as a coenzyme in many reactions, most notably in energy metabolism. The coenzyme forms of riboflavin are FMN (flavin mononucleotide) and FAD (flavin adenine dinucleotide); both can accept and then donate two hydrogens (see Figure 10-5, p. 304). During energy metabolism,

riboflavin (RYE-boh-flay-vin): a B vitamin. The coenzyme forms are *FMN (flavin mononucleotide)* and *FAD (flavin adenine dinucleotide)*.

How To

Evaluate Foods for Their Nutrient Contributions

Figure 10-4 is the first of a series of figures in this and the next three chapters that present the vitamins and minerals in foods. Each figure presents the same 24 foods, which were selected to ensure a variety of choices representative of each of the food groups as suggested by the USDA Food Patterns. For example, a bread, a cereal, and a pasta were chosen from the grain group. The suggestion to include a variety of vegetables was also considered: dark green vegetables (broccoli); orange and red vegetables (carrots); starchy vegetables (potatoes); legumes (pinto beans) and other vegetables (tomato juice). The selection of fruits followed suggestions to use whole fruits (bananas); citrus fruits (oranges); melons (watermelon); and berries (strawberries). Items were selected from the milk group and protein foods in a similar way. In addition to the 24 foods that appear in all of the figures, three different foods were selected for each of the nutrients to add variety and often reflect excellent, and sometimes unusual, sources.

Notice that the figures list the food, the serving size, and the food energy (kcalories) on the left. The amount of the nutrient per serving is presented in the graph on the right along with the RDA (or AI) for adults, so you can see how many servings would be needed to meet recommendations.

The colored bars show at a glance which food groups best provide a nutrient: yellow for grains; green for vegetables; purple for fruits; white for milk and milk products; brown for legumes; and red for protein foods. Because the USDA Food Patterns include legumes with both the protein foods group and the vegetable group and because legumes are especially rich in many vitamins and minerals, they have been given their own color to highlight their nutrient contributions.

Notice how the bar graphs shift in the various figures. Careful study of all of the figures taken together will confirm that variety is the key to nutrient adequacy.

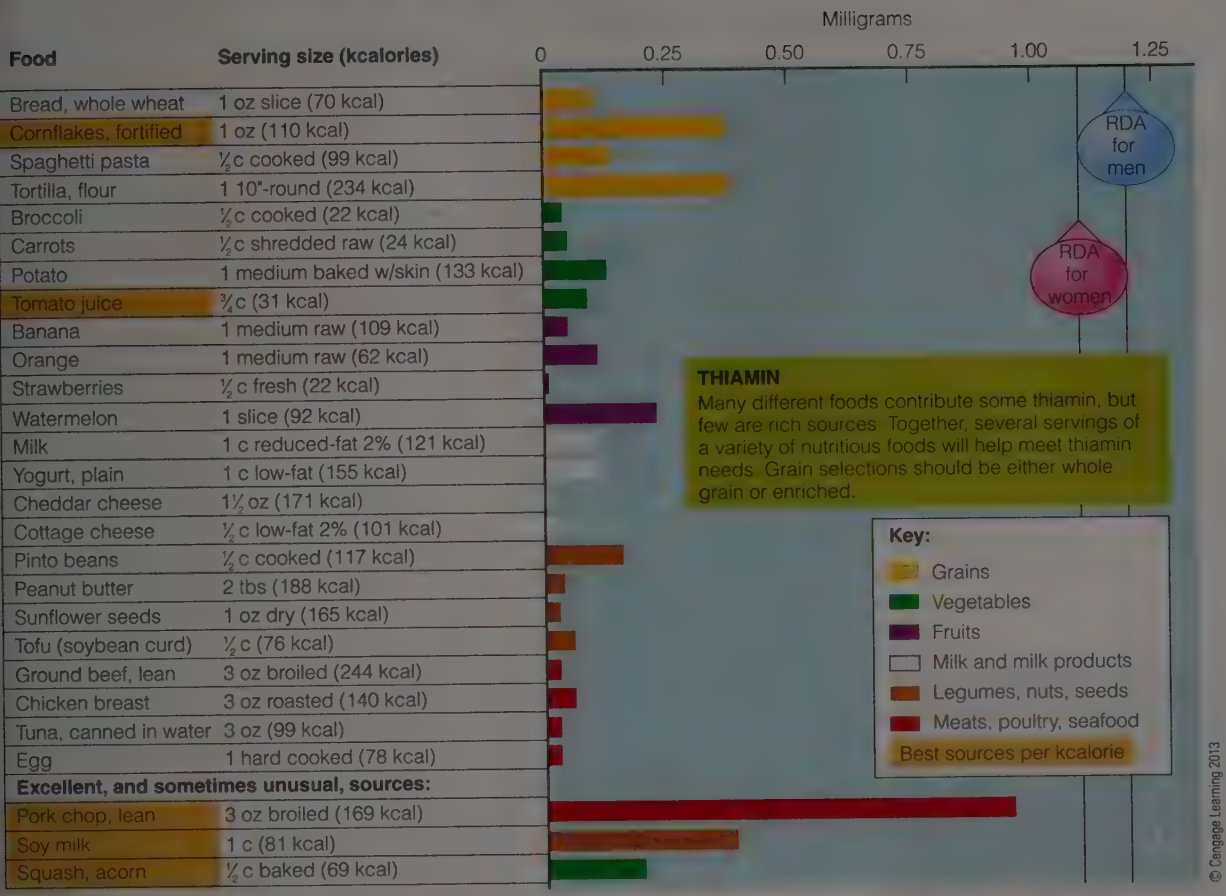
Another way to evaluate foods for their nutrient contributions is to consider their nutrient density (their thiamin *per 100 kcalories*, for example). Quite often, vegetables rank higher on a nutrient-per-kcalorie list than they do on a nutrient-per-serving list (see p. 37 to review how to evaluate foods based on nutrient density). The left column in the figure highlights about five foods that offer the best nutrient density. Notice how many of them are vegetables.

Realistically, people cannot eat for single nutrients. Fortunately, most foods deliver more than one nutrient, allowing people to combine foods into nourishing meals.

TRY IT Calculate which food provides more riboflavin per 1-ounce serving—a pork chop (3 oz, 291 kcal, 0.25 mg riboflavin) or cheddar cheese (1½ oz, 165 kcal, 0.11 mg riboflavin). Which food is more nutrient dense with respect to riboflavin?

FIGURE 10-4 Thiamin in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.



Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Pork chop, lean	3 oz broiled (169 kcal)
Soy milk	1 c (81 kcal)
Squash, acorn	½ c baked (69 kcal)

FAD picks up two hydrogens (with their electrons) from the TCA cycle and delivers them to the electron transport chain (described in Chapter 7).

Riboflavin Recommendations Like thiamin's RDA, riboflavin's RDA is based primarily on its role in enzyme activity. Most people in the United States and Canada meet or exceed riboflavin recommendations.

REVIEW IT Thiamin

Other Names	**Deficiency Disease**
Vitamin B_1	Beriberi (wet, with edema; dry, with muscle wasting)
RDA	**Deficiency Symptoms**[a]
Men: 1.2 mg/day	Enlarged heart, cardiac failure; muscular weakness; apathy, poor short-term memory, confusion, irritability; anorexia, weight loss
Women: 1.1 mg/day	
Chief Functions in the Body	**Toxicity Symptoms**
Part of coenzyme TPP (thiamin pyrophosphate) used in energy metabolism	None reported
Significant Sources	
Whole-grain, fortified, or enriched grain products; moderate amounts in all nutritious food; pork	
Easily destroyed by heat	

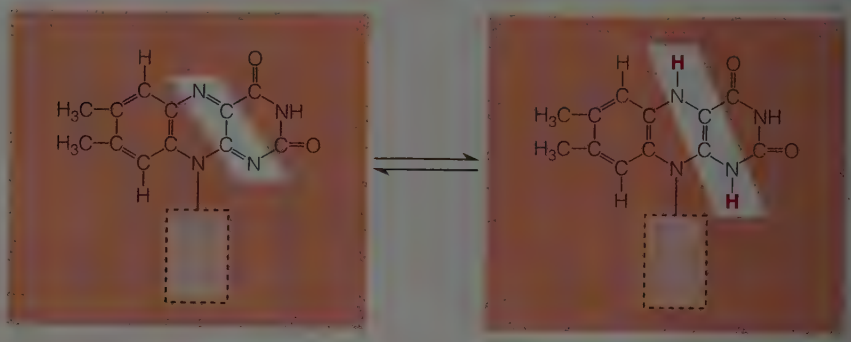
[a]Severe thiamin deficiency is often related to heavy alcohol consumption with limited food consumption (Wernicke-Korsakoff syndrome).


© Polara Studios, Inc.

Pork is the richest source of thiamin, but enriched or whole-grain products typically make the greatest contribution to a day's intake because of the quantities eaten. Legumes such as split peas are also valuable sources of thiamin.

FIGURE 10-5 Riboflavin Coenzyme, Accepting and Donating Hydrogens

This figure shows the chemical structure of the riboflavin portion of the coenzyme only; the remainder of the coenzyme structure is represented by dotted lines (see Appendix C for the complete chemical structures of FAD and FMN). The reactive sites that accept and donate hydrogens are highlighted in white.



FAD ⇌ $FADH_2$

During the TCA cycle, compounds release hydrogens, and the riboflavin coenzyme FAD picks up two of them. As it accepts two hydrogens, FAD becomes $FADH_2$.

$FADH_2$ carries the hydrogens to the electron transport chain. At the end of the electron transport chain, the hydrogens are accepted by oxygen, creating water, and $FADH_2$ becomes FAD again. For every $FADH_2$ that passes through the electron transport chain, two ATP are generated.

© Cengage Learning 2013



© Polara Studios, Inc.

All of these foods are rich in riboflavin, but milk and milk products provide much of the riboflavin in the diets of most people.

Riboflavin Deficiency and Toxicity Riboflavin deficiency most often accompanies other nutrient deficiencies.* Lack of the vitamin causes inflammation of the membranes of the mouth, skin, eyes, and GI tract. Excesses of riboflavin appear to cause no harm, and no UL has been established.

Riboflavin Food Sources The greatest contributions of riboflavin come from milk and milk products (see Figure 10-6). Whole-grain or enriched grains are also valuable sources because of the quantities typically consumed. When riboflavin sources are ranked by nutrient density (per kcalorie), many dark green, leafy vegetables (such as broccoli, turnip greens, asparagus, and spinach) appear high on the list. Vegans and others who don't use milk must rely on ample servings of dark greens and enriched grains for riboflavin. Nutritional yeast is another good source.

Ultraviolet light and irradiation destroy riboflavin. For these reasons, milk is sold in cardboard or opaque plastic containers, instead of clear glass bottles. In contrast, riboflavin is stable to heat, so cooking does not destroy it. The accompanying table provides a summary of riboflavin.

REVIEW IT Riboflavin

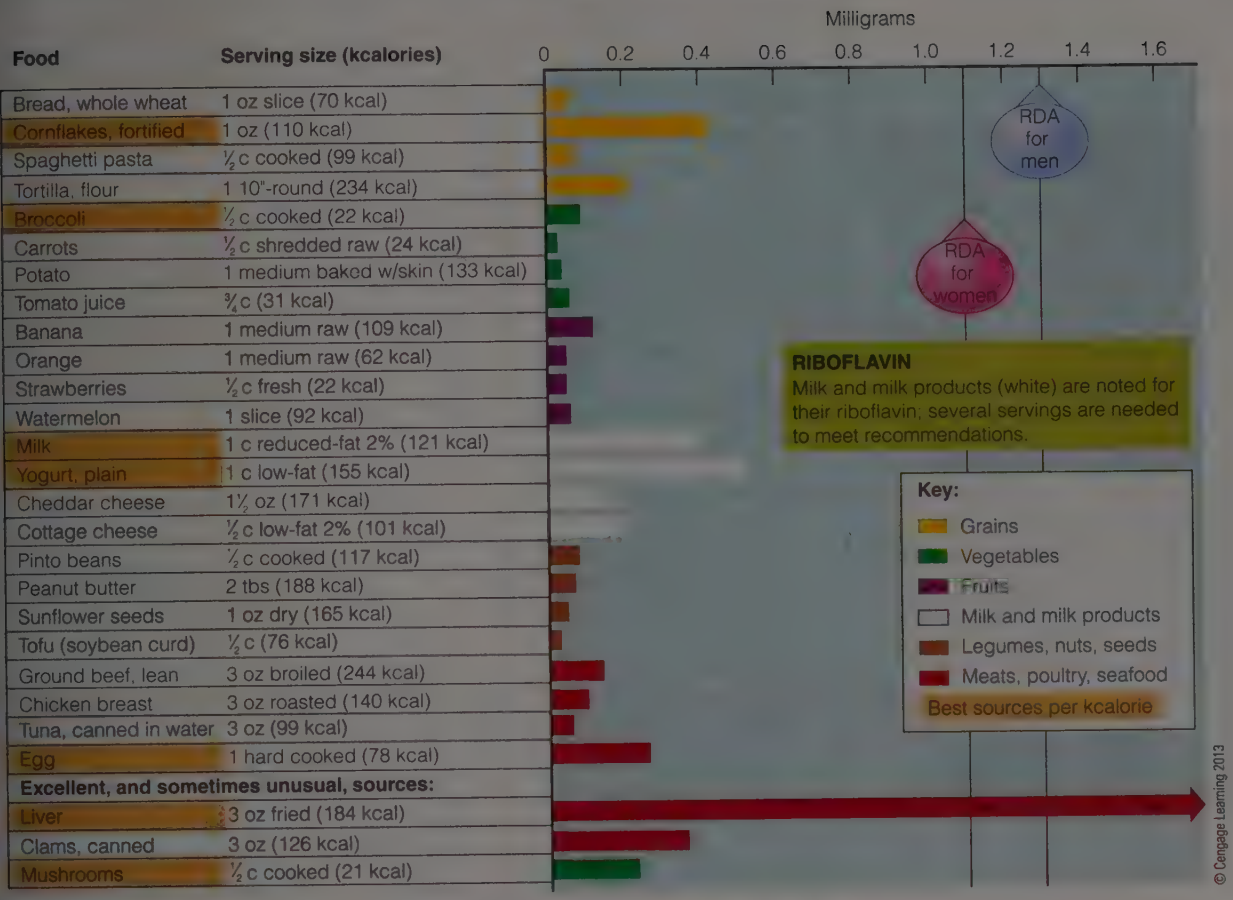
Other Names	
Vitamin B_2	
RDA	
Men: 1.3 mg/day	
Women: 1.1 mg/day	
Chief Functions in the Body	
Part of coenzymes FMN (flavin mononucleotide) and FAD (flavin adenine dinucleotide) used in energy metabolism	
Significant Sources	
Milk products (yogurt, cheese); whole-grain, fortified, or enriched grain products; liver	
	Easily destroyed by ultraviolet light and irradiation
	Deficiency Disease
	Ariboflavinosis (ay-RYE-boh-FLAY-vin-oh-sis)
	Deficiency Symptoms
	Sore throat; cracks and redness at corners of mouth;[a] painful, smooth, purplish red tongue;[b] inflammation characterized by skin lesions covered with greasy scales
	Toxicity Symptoms
	None reported

[a]Cracks at the corners of the mouth are called *angular stomatitis* or *cheilosis* (kye-LOH-sis or kee-LOH-sis).
[b]Smoothness of the tongue is caused by loss of its surface structures and is termed *glossitis* (gloss-EYE-tis).

*Riboflavin deficiency is called *ariboflavinosis* (ay-RYE-boh-FLAY-vin-oh-sis).

FIGURE 10-6 Riboflavin in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.



Niacin The name **niacin** describes two chemical structures: nicotinic acid and nicotinamide (also known as niacinamide). The body can easily convert nicotinic acid to nicotinamide, which is the major form of niacin in the blood.

The two coenzyme forms of niacin, NAD (nicotinamide adenine dinucleotide) and NADP (the phosphate form), participate in numerous metabolic reactions. They are central in energy-transfer reactions, especially the metabolism of glucose, fat, and alcohol. NAD is similar to the riboflavin coenzymes in that it carries hydrogens (and their electrons) during metabolic reactions, including the pathway from the TCA cycle to the electron transport chain. NAD also protects against neurological degeneration.[5]

Niacin Recommendations Niacin is unique among the B vitamins in that the body can make it from the amino acid tryptophan. This use of tryptophan occurs only after protein synthesis needs have been met.[6] Approximately 60 milligrams of dietary tryptophan is needed to make 1 milligram of niacin. For this reason, recommended intakes are stated in **niacin equivalents (NE)**. ♦ A food containing 1 milligram of niacin and 60 milligrams of tryptophan provides the equivalent of 2 milligrams of niacin, or 2 niacin equivalents. The RDA for niacin allows for this conversion and is stated in niacin equivalents; average niacin intakes in the United States and Canada exceed recommendations. The "How To" feature on p. 306 shows how to estimate niacin equivalents from both tryptophan and preformed niacin in the diet.

Niacin Deficiency The niacin-deficiency disease, **pellagra**, produces the symptoms of diarrhea, dermatitis, dementia, and eventually death (often called "the four Ds"). Figure 10-7 (p. 306) illustrates the dermatitis of pellagra.

In the early 1900s, pellagra caused widespread misery and some 87,000 deaths in the US South, where many people subsisted on a low-protein diet centered on

♦ 1 NE = 1 mg niacin or 60 mg tryptophan

niacin a B vitamin. The coenzyme forms are NAD (*nicotinamide adenine dinucleotide*) and NADP (*the phosphate form of NAD*). Niacin can be eaten preformed or made in the body from its precursor, tryptophan, an essential amino acid.

niacin equivalents (NE): the amount of niacin present in food, including the niacin that can theoretically be made from its precursor, tryptophan, present in the food.

pellagra the niacin-deficiency disease.

- **pellis** = skin
- **agra** = rough

FIGURE 10-7 Niacin-Deficiency Symptom—The Dermatitis of Pellagra

In the dermatitis of pellagra, the skin darkens and flakes away as if it were sunburned. Skin lesions typically develop only on those parts of the body exposed to the sun.



© Dr. A. M. Ansary/Photo Researchers, Inc.

How To

Estimate Niacin Equivalents

Niacin recommendations are expressed as niacin equivalents (NE), but diet analysis programs and food composition tables report only preformed niacin. To estimate niacin equivalents from the tryptophan in dietary protein:

- Assume that most dietary proteins contain about 1 percent tryptophan. To determine the amount of tryptophan in protein, divide grams of protein by 100.
- Multiply by 1000 to convert grams of tryptophan to milligrams.
- Because it takes 60 milligrams of tryptophan to make 1 milligram of niacin, divide milligrams of tryptophan by 60 to get niacin equivalents.
- Add the amount of preformed niacin obtained in the diet.

Consider, for example, a person who consumes 80 grams of protein and 5 milligrams of preformed niacin.

- Estimate the amount of tryptophan in 80 grams of protein and convert to milligrams:

  80 g protein ÷ 100 = 0.8 g tryptophan

  0.8 g tryptophan × 1000 = 800 mg tryptophan

- Convert milligrams of tryptophan to niacin equivalents:

  800 mg tryptophan ÷ 60 = 13 mg NE

To determine the total amount of niacin available from the diet, add the amount available from tryptophan to the amount preformed in the diet.

13 mg NE + 5 mg preformed niacin = 18 mg NE

TRY IT Calculate how many niacin equivalents a person receives from a diet that delivers 60 grams protein and 6 milligrams niacin.

corn. This diet supplied neither enough niacin nor enough tryptophan. At least 70 percent of the niacin in corn is bound to complex carbohydrates and small peptides, making it unavailable for absorption. Furthermore, corn is high in the amino acid leucine, which interferes with the tryptophan-to-niacin conversion, thus further contributing to the development of pellagra.

Pellagra was originally believed to be caused by an infection. Medical researchers spent many years and much effort searching for infectious microbes until they realized that the problem was not what was *present* in the food but what was *absent* from it. That a disease such as pellagra could be caused by diet—and not by pathogens—was a groundbreaking discovery. It contradicted commonly held medical opinions that diseases were caused only by infectious agents. By carefully following the scientific method (as described in Chapter 1), researchers advanced the science of nutrition dramatically.

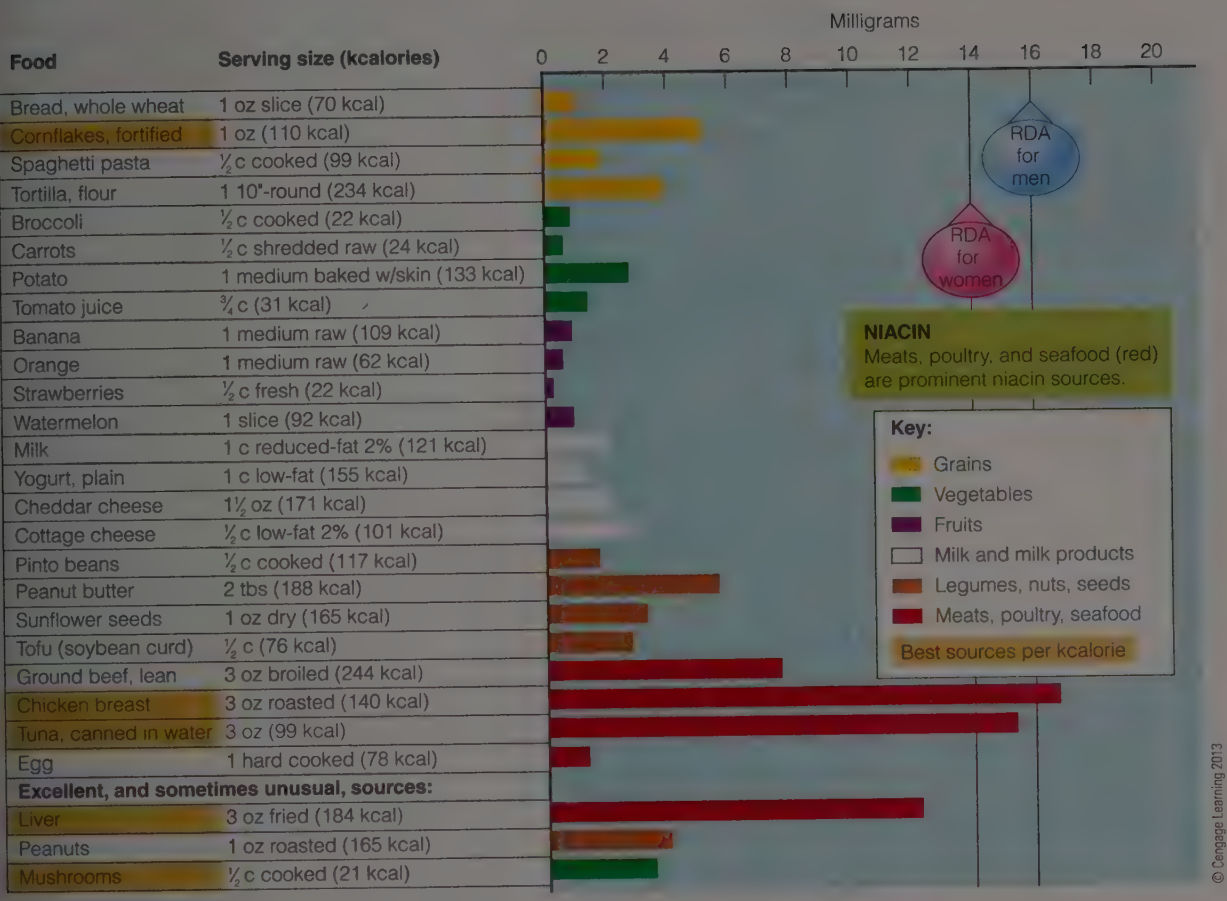
Niacin Toxicity When a normal dose of a nutrient (levels commonly found in foods) provides a normal blood concentration, the nutrient is having a *physiological* effect. When a large dose (levels commonly available only from supplements) overwhelms the body and raises blood concentrations to abnormally high levels, the nutrient is acting like a drug and having a *pharmacological* effect. Naturally occurring niacin from foods has a physiological effect that causes no harm. Large doses of nicotinic acid from supplements or drugs, however, produce a variety of pharmacological effects, most notably **"niacin flush."** Niacin flush occurs when nicotinic acid is taken in doses only three to four times the RDA. It dilates the capillaries and causes a tingling sensation that can be painful. The nicotinamide form does not produce this effect.

Large doses of nicotinic acid have been used to lower LDL cholesterol, raise HDL cholesterol, and increase adiponectin levels—all factors that help to protect against heart disease.[7] Such therapy must be closely monitored. People with the following conditions may be particularly susceptible to the toxic effects of niacin: liver disease, diabetes, peptic ulcers, gout, irregular heartbeats, inflammatory

niacin flush: a temporary burning, tingling, and itching sensation that occurs when a person takes a large dose of nicotinic acid; often accompanied by a headache and reddened face, arms, and chest.

> FIGURE 10-8 Niacin in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.



Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Liver	3 oz fried (184 kcal)
Peanuts	1 oz roasted (165 kcal)
Mushrooms	½ c cooked (21 kcal)

bowel disease, migraine headaches, and alcoholism. The nicotinamide form does not improve blood cholesterol levels.

Niacin Food Sources Tables of food composition typically list preformed niacin only, but as mentioned, niacin can also be made in the body from the amino acid tryptophan. Dietary tryptophan could meet about half the daily niacin need for most people, but the average diet easily supplies enough preformed niacin.

Figure 10-8 presents niacin in selected foods. Meat, poultry, fish, legumes, and enriched and whole grains contribute about half the niacin people consume. Mushrooms, potatoes, and tomatoes are among the richest vegetable sources, and they can provide abundant niacin when eaten in generous amounts.

Niacin is less vulnerable to losses during food preparation and storage than other water-soluble vitamins. Being fairly heat resistant, niacin can withstand reasonable cooking times, but like other water-soluble vitamins, it will leach into cooking water. The table on p. 308 provides a summary of niacin.


© Polara Studios, Inc

Protein-rich foods such as meat, fish, poultry, and peanut butter contribute much of the niacin in people's diets. Enriched breads and cereals and a few vegetables are also rich in niacin.

Biotin **Biotin** plays an important role in metabolism as a coenzyme that carries activated carbon dioxide. This role is critical in the TCA cycle: biotin delivers a carbon to 3-carbon pyruvate, thus replenishing oxaloacetate, the 4-carbon compound needed to combine with acetyl CoA to keep the TCA cycle turning (review Figure 7-15 on p. 211). The biotin coenzyme also participates in gluconeogenesis, fatty acid synthesis, and the breakdown of certain fatty acids and amino acids.

biotin (BY-oh-tin): a B vitamin that functions as a coenzyme in metabolism.

REVIEW IT Niacin

Other Names	Significant Sources
Nicotinic acid, nicotinamide, niacinamide, vitamin B_3; precursor is dietary tryptophan (an amino acid)	Milk, eggs, meat, poultry, fish; whole-grain, fortified, and enriched grain products; nuts and all protein-containing foods
RDA	**Deficiency Disease**
Men: 16 mg NE/day Women: 14 mg NE/day	Pellagra
UL[a]	**Deficiency Symptoms**
Adults: 35 mg/day	Diarrhea, abdominal pain, vomiting; inflamed, swollen, smooth, bright red tongue;[b] depression, apathy, fatigue, loss of memory, headache; bilateral symmetrical rash on areas exposed to sunlight
Chief Functions in the Body	**Toxicity Symptoms**
Part of coenzymes NAD (nicotinamide adenine dinucleotide) and NADP (its phosphate form) used in energy metabolism	Painful flush, hives, and rash ("niacin flush"); nausea and vomiting; liver damage, impaired glucose tolerance

[a]The UL applies to synthetic forms obtained from supplements, fortified foods, or a combination.
[b]Smoothness of the tongue is caused by loss of its surface structures and is termed *glossitis* (gloss-EYE-tis).

Biotin Recommendations Biotin is needed in very small amounts. Because there is insufficient research on biotin requirements, an Adequate Intake (AI) has been determined, instead of an RDA.

Biotin Deficiency and Toxicity Biotin deficiencies rarely occur. Researchers can induce a biotin deficiency in animals or human beings by feeding them raw egg whites, which contain a protein that binds biotin and thus prevents its absorption.* Biotin-deficiency symptoms include skin rash, hair loss, and neurological impairment. More than two dozen raw egg whites must be consumed daily for several months to produce these effects; cooking eggs denatures the binding protein. Because no adverse effects have been reported from high biotin intakes, a UL has not been set.

Biotin Food Sources Biotin is widespread in foods (including egg yolks), so eating a variety of foods protects against deficiencies. Some biotin is also synthesized by GI tract bacteria, but this amount does not contribute much to the biotin absorbed. The accompanying table provides a summary of biotin.

REVIEW IT Biotin

Adequate Intake (AI)	Deficiency Symptoms
Adults: 30 µg/day	Depression, lethargy, hallucinations, numb or tingling sensation in the arms and legs; red, scaly rash around the eyes, nose, and mouth; hair loss
Chief Functions in the Body	**Toxicity Symptoms**
Part of a coenzyme used in energy metabolism, fat synthesis, amino acid metabolism, and glycogen synthesis	None reported
Significant Sources	
Widespread in foods; liver, egg yolks, soybeans, fish, whole grains; also produced by GI bacteria	

Pantothenic Acid

Pantothenic acid is part of the chemical structure of coenzyme A—the same CoA that forms acetyl CoA, the "crossroads" compound in several metabolic pathways, including the TCA cycle. (Appendix C presents the chemical structures of these two molecules and shows that coenzyme A is made up in part of pantothenic acid.) As such, it is involved in more than 100 different steps in the synthesis of lipids, neurotransmitters, steroid hormones, and hemoglobin.

pantothenic (PAN-toe-THEN-ick) **acid:** a B vitamin. The principal active form is part of coenzyme A, called "CoA" throughout Chapter 7.

• **pantos** = everywhere

*The protein *avidin* (AV-eh-din) in egg whites binds biotin.

Pantothenic Acid Recommendations An Adequate Intake (AI) for pantothenic acid has been set. It reflects the amount needed to replace daily losses.

Pantothenic Acid Deficiency and Toxicity Pantothenic acid deficiency is rare. Its symptoms involve a general failure of all the body's systems and include fatigue, GI distress, and neurological disturbances. The "burning feet" syndrome that affected prisoners of war in Asia during World War II is thought to have been caused by pantothenic acid deficiency. No toxic effects have been reported, and no UL has been established.

Pantothenic Acid Food Sources Pantothenic acid is widespread in foods, and typical diets seem to provide adequate intakes. Beef, poultry, whole grains, potatoes, tomatoes, and broccoli are particularly good sources. Losses of pantothenic acid during food production can be substantial because it is readily destroyed by the freezing, canning, and refining processes. The accompanying table provides a summary of pantothenic acid.

REVIEW IT Pantothenic Acid

Adequate Intake (AI)	Deficiency Symptoms
Adults: 5 mg/day	Vomiting, nausea, stomach cramps; insomnia, fatigue, depression, irritability, restlessness, apathy; hypoglycemia, increased sensitivity to insulin; numbness, muscle cramps, inability to walk
Chief Functions in the Body	**Toxicity Symptoms**
Part of coenzyme A, used in energy metabolism	None reported
Significant Sources	
Widespread in foods; chicken, beef, potatoes, oats, tomatoes, liver, egg yolk, broccoli, whole grains	
Easily destroyed by food processing	

Vitamin B_6

Vitamin B_6 occurs in three forms—pyridoxal, pyridoxine, and pyridoxamine. All three can be converted to the coenzyme PLP (pyridoxal phosphate), which is active in amino acid metabolism. Because PLP can transfer amino groups (NH_2) from an amino acid to a keto acid, the body can make nonessential amino acids (review Figure 6-12 on p. 179). The ability to add and remove amino groups makes PLP valuable in protein and urea metabolism as well. The conversions of the amino acid tryptophan to niacin or to the neurotransmitter serotonin also depend on PLP. In addition, PLP participates in the synthesis of heme (the nonprotein portion of hemoglobin), nucleic acids (such as DNA and RNA), and lecithin (a phospholipid).

Vitamin B_6 Recommendations The RDA for vitamin B_6 is based on the amounts needed to maintain adequate levels of its coenzymes. Unlike other water-soluble vitamins, vitamin B_6 is stored extensively in muscle tissue. Research does not support claims, however, that large doses of vitamin B_6 enhance muscle strength or physical endurance.

Vitamin B_6 Deficiency Without adequate vitamin B_6, synthesis of key neurotransmitters diminishes, and abnormal compounds produced during tryptophan metabolism accumulate in the brain. Early symptoms of vitamin B_6 deficiency include depression and confusion; advanced symptoms include abnormal brain wave patterns and convulsions. Low levels of vitamin B_6 are associated with increased risks of some cancers and cardiovascular disease.[8]

Alcohol contributes to the destruction and loss of vitamin B_6 from the body. As Highlight 7 describes, when the body breaks down alcohol, it produces acetaldehyde. If allowed to accumulate, acetaldehyde dislodges the PLP coenzyme from its enzymes; once loose, PLP breaks down and is excreted.

Another drug that acts as a vitamin B_6 **antagonist** is isoniazid, a medication that inhibits the growth of the tuberculosis bacterium.* This drug has saved countless lives, but because isoniazid binds and inactivates vitamin B_6, it can induce a deficiency. Whenever isoniazid is used to treat tuberculosis, vitamin B_6 supplements must be given to protect against deficiency.

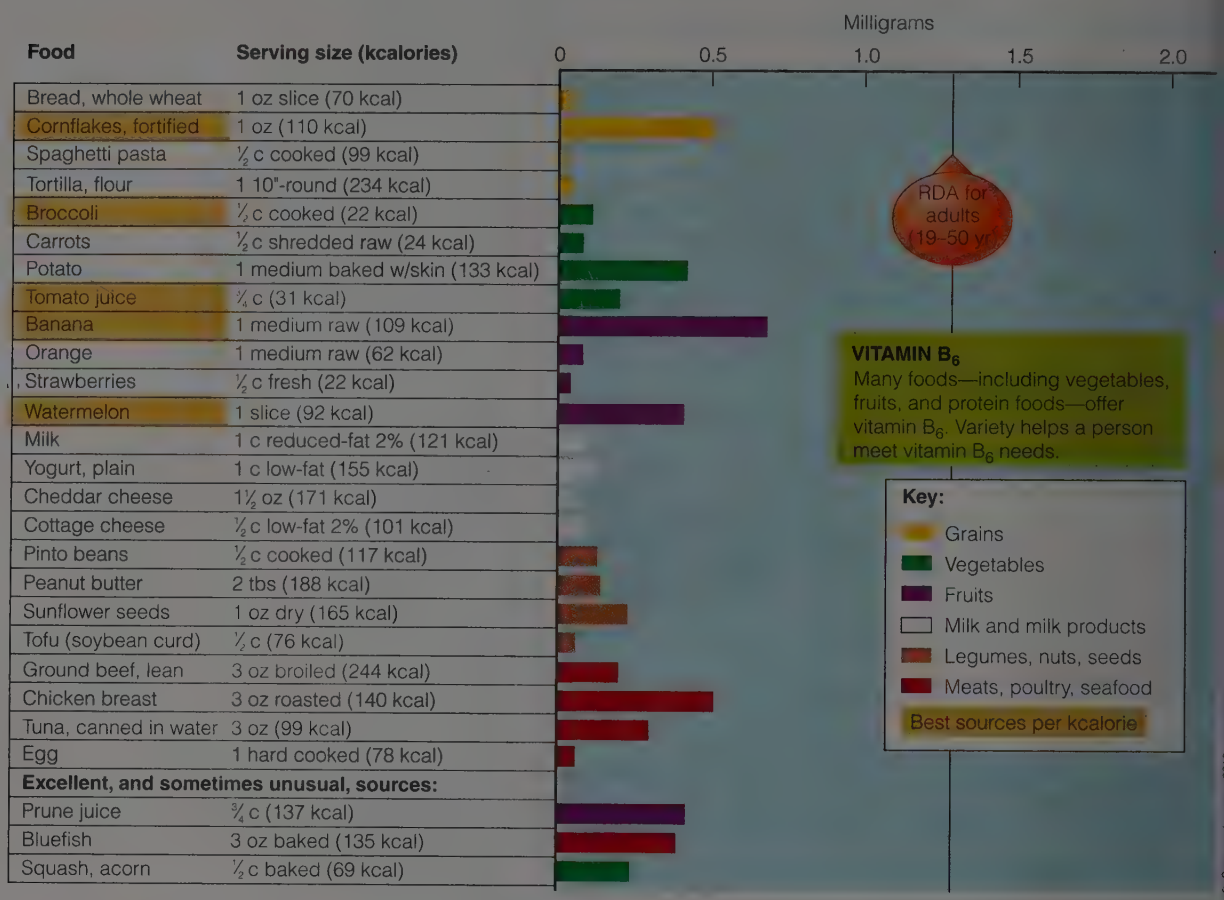
vitamin B_6: a family of compounds—pyridoxal, pyridoxine, and pyridoxamine. The primary active coenzyme form is *PLP* (*pyridoxal phosphate*).

antagonist: a competing factor that counteracts the action of another factor. When a drug displaces a vitamin from its site of action, the drug renders the vitamin ineffective and thus acts as a vitamin antagonist.

*Isoniazid (eye-so-NYE-uh-zid) is also known as INH (isonicotinic acid hydrazide).

> FIGURE 10-9 Vitamin B_6 in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.



Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Prune juice	¾ c (137 kcal)
Bluefish	3 oz baked (135 kcal)
Squash, acorn	½ c baked (69 kcal)



© Polara Studios, Inc.

Most protein-rich foods such as meat, fish, and poultry provide ample vitamin B_6; some vegetables and fruits are good sources too.

folate (FOLE-ate): a B vitamin; also known as folic acid, folacin, or pteroylglutamic (tare-o-EEL-glue-TAM-ick) acid (PGA). The coenzyme forms are *DHF (dihydrofolate)* and *THF (tetrahydrofolate)*.

Vitamin B_6 Toxicity The first major report of vitamin B_6 toxicity appeared in the early 1980s. Until that time, most researchers and dietitians believed that, like the other water-soluble vitamins, vitamin B_6 could not reach toxic concentrations in the body. The report described neurological damage in people who had been taking more than 2 *grams* of vitamin B_6 daily (20 times the current UL of 100 *milligrams* per day) for 2 months or more.

Vitamin B_6 Food Sources As you can see from the colors in Figure 10-9, meats, fish, and poultry (red bars), potatoes and a few other vegetables (green bars), and fruits (purple bars) offer vitamin B_6. As is true of most of the other vitamins, fruits and vegetables rank considerably higher when foods are judged by nutrient density (vitamin B_6 per kcalorie). Several servings of vitamin B_6–rich foods are needed to meet recommended intakes.

Foods lose vitamin B_6 when heated. Information is limited, but vitamin B_6 bioavailability from plant-derived foods seems to be lower than from animal-derived foods. Fiber does not appear to interfere with vitamin B_6 absorption. The accompanying table provides a summary of vitamin B_6.

Folate

Folate, also known as folacin or folic acid, has a chemical name that would fit a flying dinosaur: pteroylglutamic acid (PGA for short). Its primary coenzyme form, THF (tetrahydrofolate), serves as part of an enzyme complex that transfers 1-carbon compounds that arise during metabolism.[9] This action converts vitamin B_{12} to one of its coenzyme forms, synthesizes the DNA required for all rapidly growing cells, and regenerates the amino acid methionine from homocysteine.

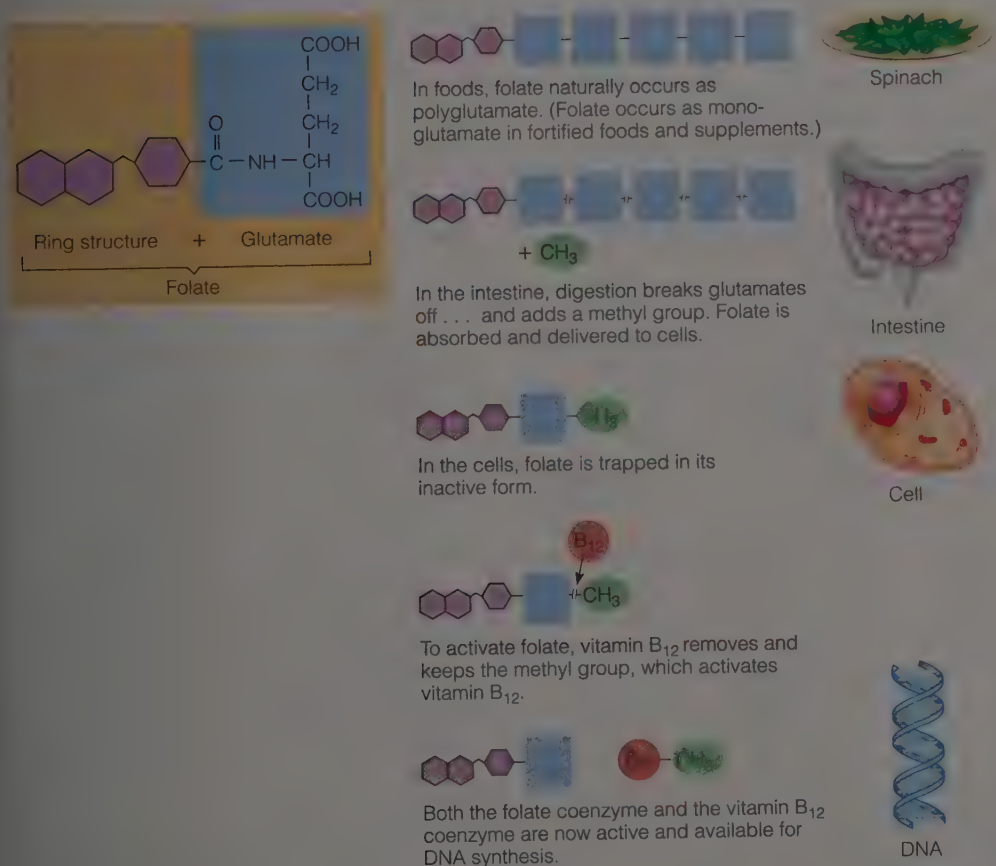
REVIEW IT Vitamin B_6

Other Names	Significant Sources
Pyridoxine, pyridoxal, pyridoxamine	Meats, fish, poultry, potatoes and other starchy vegetables, legumes, noncitrus fruits, fortified cereals, liver, soy products
RDA	Easily destroyed by heat
Adults (19–50 yr): 1.3 mg/day	**Deficiency Symptoms**
UL	Scaly dermatitis; anemia (small-cell type);[a] depression, confusion, convulsions
Adults: 100 mg/day	**Toxicity Symptoms**
Chief Functions in the Body	Depression, fatigue, irritability, headaches, nerve damage causing numbness and muscle weakness leading to an inability to walk and convulsions; skin lesions
Part of coenzymes PLP (pyridoxal phosphate) and PMP (pyridoxamine phosphate) used in amino acid and fatty acid metabolism; helps to convert tryptophan to niacin and to serotonin; helps to make red blood cells	

[a]Small-cell-type anemia is called *microcytic anemia.*

Figure 10-10 summarizes folate's absorption, activation, and relationship with vitamin B_{12}. It explains that foods deliver folate mostly in the "bound" form—that is, combined with a string of amino acids (all glutamate), known as polyglutamate. (See Appendix C for the chemical structure.) Enzymes on the intestinal cell surfaces hydrolyze the polyglutamate to monoglutamate—folate with only one glutamate attached—and several single glutamates. The monoglutamate is then attached to a methyl group (CH_3) and delivered to the liver and

FIGURE 10-10 Folate's Absorption and Activation



© Cengage Learning 2013

other body cells. To activate folate, the methyl group must be removed by an enzyme that requires the help of vitamin B_{12}. Without that help, folate becomes trapped inside cells in its methyl form, unavailable to support DNA synthesis and cell growth.

The liver incorporates excess folate into bile that is then sent to the gallbladder and GI tract. Thus folate travels in the same enterohepatic circulation as bile (review Figure 5-14 on p. 141).

This complicated system for handling folate is vulnerable to GI tract injuries. Because folate is actively secreted back into the GI tract with bile, it can be reabsorbed repeatedly. If the GI tract cells are damaged, then folate is lost. Such is the case in alcohol abuse; folate deficiency rapidly develops and, ironically, further damages the GI tract. Remember, folate is active in cell multiplication—and the cells lining the GI tract are among the most rapidly replaced cells in the body. When unable to make new cells, the GI tract deteriorates and not only loses folate, but fails to absorb other nutrients as well.

Folate Recommendations The bioavailability of folate ranges from 50 percent for foods to 100 percent for supplements taken on an empty stomach. These differences in bioavailability must be considered when establishing folate recommendations.[10] The DRI committee gives naturally occurring folate from foods full credit. Synthetic folate from fortified foods and supplements is given extra credit because, on average, it is 1.7 times more available than naturally occurring food folate. Thus a person consuming 100 micrograms of folate from foods and 100 micrograms from a supplement receives 270 **dietary folate equivalents (DFE).** ♦ (The "How To" feature below describes how to estimate dietary folate equivalents.) The need for folate rises considerably during pregnancy and whenever cells are multiplying, so the recommendations for pregnant women are considerably higher than for other adults.

♦ To calculate DFE:
DFE = µg food folate + (1.7 × µg synthetic folate)
Using the example in the text:

100 µg food
+ 170 µg supplement (1.7 × 100 µg)
270 µg DFE

dietary folate equivalents (DFE): the amount of folate available to the body from naturally occurring sources, fortified foods, and supplements, accounting for differences in the bioavailability from each source.

neural tube: the embryonic tissue that forms the brain and spinal cord. The two main types of neural tube defects are *spina bifida* (literally "split spine") and *anencephaly* ("no brain").

Folate and Neural Tube Defects The brain and spinal cord develop from the **neural tube**, and defects in its orderly formation during the early weeks of pregnancy may result in various central nervous system disorders and death. (Chapter 15 includes an illustration of a neural tube defect.)

>How To

Estimate Dietary Folate Equivalents

Folate is expressed in terms of DFE (dietary folate equivalents) because synthetic folate from supplements and fortified foods is absorbed at almost twice (1.7 times) the rate of naturally occurring folate from other foods. Use the following equation to calculate:

DFE = µg food folate + (1.7 × µg synthetic folate)

Consider, for example, a pregnant woman who takes a supplement and eats a bowl of fortified cornflakes, 2 slices of fortified bread, and a cup of fortified pasta. From the supplement and fortified foods, she obtains synthetic folate:

Supplement	100 µg folate
Fortified cornflakes	100 µg folate
Fortified bread	40 µg folate
Fortified pasta	60 µg folate
	300 µg folate

To calculate the DFE, multiply the amount of synthetic folate by 1.7:

300 µg × 1.7 = 510 µg DFE

Now add the naturally occurring folate from the other foods in her diet—in this example, another 90 µg of folate.

510 µg DFE + 90 µg = 600 µg DFE

Notice that if we had not converted synthetic folate from supplements and fortified foods to DFE, then this woman's intake would appear to fall short of the 600 µg recommendation for pregnancy (300 µg + 90 µg = 390 µg). But as our example shows, her intake does meet the recommendation. At this time, supplement and fortified food labels list folate in µg only, not µg DFE, making such calculations necessary.

TRY IT Calculate how many dietary folate equivalents a person receives from 200 µg folate from a supplement, 75 µg folate from fortified cereal, and 120 µg folate from other foods.

Folate supplements taken 1 month before conception and continued throughout the first trimester of pregnancy can help prevent **neural tube defects**. For this reason, all women of childbearing age ♦ who are capable of becoming pregnant should consume 0.4 milligram (400 micrograms) of folate daily. Because half of the pregnancies each year are unplanned and because neural tube defects occur early in development before most women realize they are pregnant, the Food and Drug Administration (FDA) has mandated that grain products be fortified to deliver folate to the US population.* Labels on fortified products may claim that "adequate intake of folate has been shown to reduce the risk of neural tube defects." Fortification has improved folate status in women of childbearing age and lowered the prevalence rate of neural tube defects, as Figure 10-11 shows.

Some research suggests that folate may also prevent other congenital birth defects, such as cleft lip and cleft palate.[11] Such findings strengthen recommendations for women to pay attention to their folate needs.

Folate fortification raises safety concerns as well. Because high intakes of folate can mask a vitamin B_{12} deficiency, folate consumption should not exceed 1 milligram daily without close medical supervision.[12] The risks and benefits of folate fortification continue to be a topic of current debate.[13]

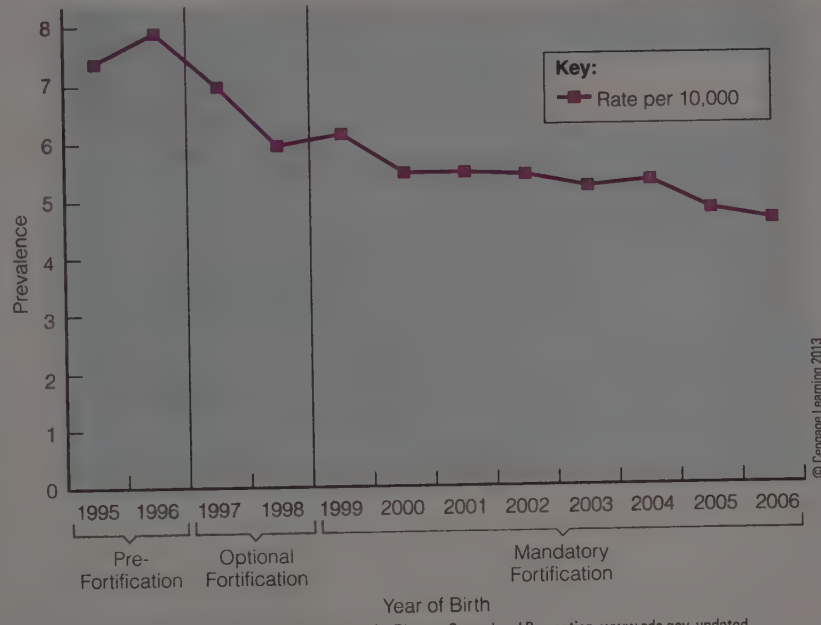
Folate and Heart Disease The FDA's decision to fortify grain products with folate was strengthened by research suggesting a role for folate in protecting against heart disease.[14] One of folate's key roles in the body is to break down the amino acid homocysteine. Without folate, homocysteine accumulates, which seems to enhance formation of blood clots and atherosclerotic lesions. Fortified foods and folate supplements raise blood folate and reduce blood homocysteine, but do not seem to reduce the risk of heart attacks, strokes, or death from cardiovascular causes.[15]



© Wellcome Trust Library/Custom Medical Stock Photo

Folate helps to protect against spina bifida, a neural tube defect characterized by the incomplete closure of the spinal cord and its bony encasement.

FIGURE 10-11 Decreasing Prevalence of Neural Tube Defects since Folate Fortification



SOURCE: National Center for Health Statistics, Centers for Disease Control and Prevention, www.cdc.gov, updated January 2010.

Folate and Cancer Because the synthesis of DNA and the transfer of methyl groups depend on folate, its relationships with cancer are complex, depending on the type of cancer and the timing of folate supplementation.[16] Some research suggests that sufficient folate may protect against the initiation of cancer, whereas other studies report that high intakes may enhance progression once cancer has begun.[17] In general, foods containing folate probably reduce the risk of pancreatic cancer.[18] Limited evidence suggests folate may also reduce the risk of esophageal and colorectal cancer.[19]

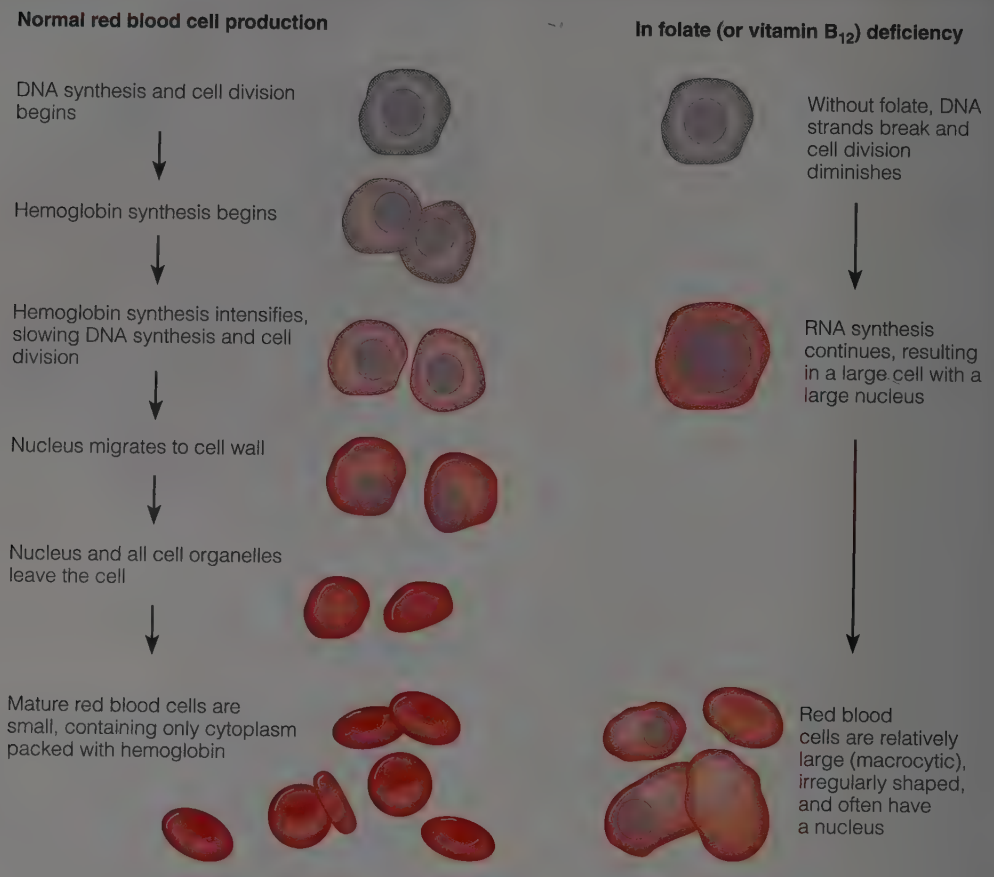
♦ Women of childbearing age (15 to 45 yr) should:

- Eat folate-rich foods
- Eat folate-fortified foods
- Take a multivitamin daily (most provide 400 µg folate)

*Bread products, flour, corn grits, cornmeal, farina, rice, macaroni, and noodles must be fortified with 140 micrograms of folate per 100 grams of grain. For perspective, 100 grams is roughly 3 slices of bread; 1 cup of flour; ½ cup of corn grits, cornmeal, farina, or rice; or ¾ cup of macaroni or noodles.

neural tube defects: malformations of the brain, spinal cord, or both during embryonic development that often result in lifelong disability or death.

FIGURE 10-12 Normal Blood Cells and Blood Cells in Macrocytic Anemia Compared



© Cengage Learning 2013

Folate Deficiency Folate deficiency impairs cell division and protein synthesis—processes critical to growing tissues. In a folate deficiency, the replacement of red blood cells and GI tract cells falters. Not surprisingly, then, two of the first symptoms of a folate deficiency are **anemia** and GI tract deterioration.

The anemia of folate deficiency is known as *macrocytic* or *megaloblastic anemia* and is characterized by large, immature red blood cells (see Figure 10-12). Without folate, DNA damage destroys many of the red blood cells as they attempt to divide and mature. The result is fewer, but larger, red blood cells that cannot carry oxygen or travel through the capillaries as efficiently as normal red blood cells. Since the implementation of folate fortification in the United States, the prevalence of macrocytic anemia has decreased.[20]

Primary folate deficiencies may develop from inadequate intake and have been reported in infants who were fed goat's milk, which is notoriously low in folate. Secondary folate deficiencies may result from impaired absorption or an unusual metabolic need for the vitamin. Metabolic needs increase in situations where cell multiplication must speed up, such as pregnancies involving twins and triplets; cancer; skin-destroying diseases such as chicken pox and measles; and burns, blood loss, GI tract damage, and the like.

Of all the vitamins, folate appears to be most vulnerable to interactions with drugs, which can also lead to a secondary deficiency. Some medications, notably anticancer drugs, have a chemical structure similar to folate's structure and can displace the vitamin from enzymes and interfere with normal metabolism. Like all cells, cancer cells need the real vitamin to multiply—without it, they die. Unfortunately, anticancer drugs affect both cancerous cells and healthy cells, creating a folate deficiency for all cells. (Highlight 17 discusses nutrient-drug interactions,

anemia (ah-NEE-me-ah): literally, "too little blood." Anemia is any condition in which too few red blood cells are present, or the red blood cells are immature (and therefore large) or too small or contain too little hemoglobin to carry the normal amount of oxygen to the tissues. Anemia is not a disease itself but can be a consequence of many different disease conditions, including many nutrient deficiencies, bleeding, excessive red blood cell destruction, and defective red blood cell formation.

- **an** = without
- **emia** = blood

and Figure H17-1 illustrates the similarities between the vitamin folate and the anticancer drug methotrexate.)

Aspirin and antacids also interfere with the body's folate status: aspirin inhibits the action of folate-requiring enzymes, and antacids limit the absorption of folate. Healthy adults who use these drugs to relieve an occasional headache or upset stomach need not be concerned, but people who rely heavily on aspirin or antacids should be aware of the nutrition consequences.

Folate Toxicity A UL has been established for folate from fortified foods or supplements (see the inside front cover). Commonly consumed amounts of folate from both natural sources and fortified foods appear to cause no harm. The small percentage of adults who also take high-dose folate supplements, however, can reach levels that are high enough to obscure a vitamin B_{12} deficiency and delay diagnosis of neurological damage.[21]

Folate Food Sources Figure 10-13 shows that folate is especially abundant in legumes, fruits, and vegetables. The vitamin's name suggests the word *foliage*, and indeed, dark green, leafy vegetables are outstanding sources. With fortification, grain products also contribute folate. The small red and white bars in Figure 10-13 indicate that meats and milk products are poor folate sources. Heat and oxidation during cooking and storage can destroy as much as half of the folate in foods. The accompanying table provides a summary of folate.



© Polara Studios, Inc

Dark green and leafy vegetables (such as spinach and broccoli), legumes (such as black beans, kidney beans, and black-eyed peas), liver, and some fruits (notably citrus fruits and juices) are naturally rich in folate.

REVIEW IT Folate

Other Names	Significant Sources
Folic acid, folacin, pteroylglutamic acid (PGA)	Fortified grains, leafy green vegetables, legumes, seeds, liver
RDA	Easily destroyed by heat and oxygen
Adults: 400 µg/day	**Deficiency Symptoms**
UL[a]	Anemia (large-cell type);[b] smooth, red tongue;[c] mental confusion, weakness, fatigue, irritability, headache; shortness of breath; elevated homocysteine
Adults: 1000 µg/day	**Toxicity Symptoms**
Chief Functions in the Body	Masks vitamin B_{12}–deficiency symptoms
Part of coenzymes THF (tetrahydrofolate) and DHF (dihydrofolate) used in DNA synthesis and therefore important in new cell formation	

[a]The UL applies to synthetic forms obtained from supplements, fortified foods, or a combination
[b]Large-cell-type anemia is known as either *macrocytic* or *megaloblastic anemia*
[c]Smoothness of the tongue is caused by loss of its surface structures and is termed *glossitis* (gloss-EYE-tis).

Vitamin B_{12} Vitamin B_{12} and folate are closely related: each depends on the other for activation. Recall that vitamin B_{12} removes a methyl group to activate the folate coenzyme. When folate gives up its methyl group, the vitamin B_{12} coenzyme becomes activated (review Figure 10-10 on p. 311).

The regeneration of the amino acid methionine and the synthesis of DNA and RNA depend on both folate and vitamin B_{12}.* In addition, without any help from folate, vitamin B_{12} maintains the sheath that surrounds and protects nerve fibers and promotes their normal growth. Bone cell activity and metabolism also depend on vitamin B_{12}.

The digestion and absorption of vitamin B_{12} depends on several steps. In the stomach, hydrochloric acid and the digestive enzyme pepsin release vitamin B_{12} from the proteins to which it is attached in foods. Then as vitamin B_{12} passes from the stomach to the small intestine, it binds with a stomach secretion called **intrinsic factor**. Bound together, intrinsic factor and vitamin B_{12} travel to the end of the small intestine, where receptors recognize the complex. Importantly, the receptors do not recognize vitamin B_{12} without intrinsic

vitamin B_{12}: a B vitamin characterized by the presence of cobalt (see Figure 13-2). The active forms of coenzyme B_{12} are methylcobalamin and deoxyadenosylcobalamin.

intrinsic factor: a glycoprotein (a protein with short polysaccharide chains attached) secreted by the stomach cells that binds with vitamin B_{12} in the small intestine to aid in the absorption of vitamin B_{12}.

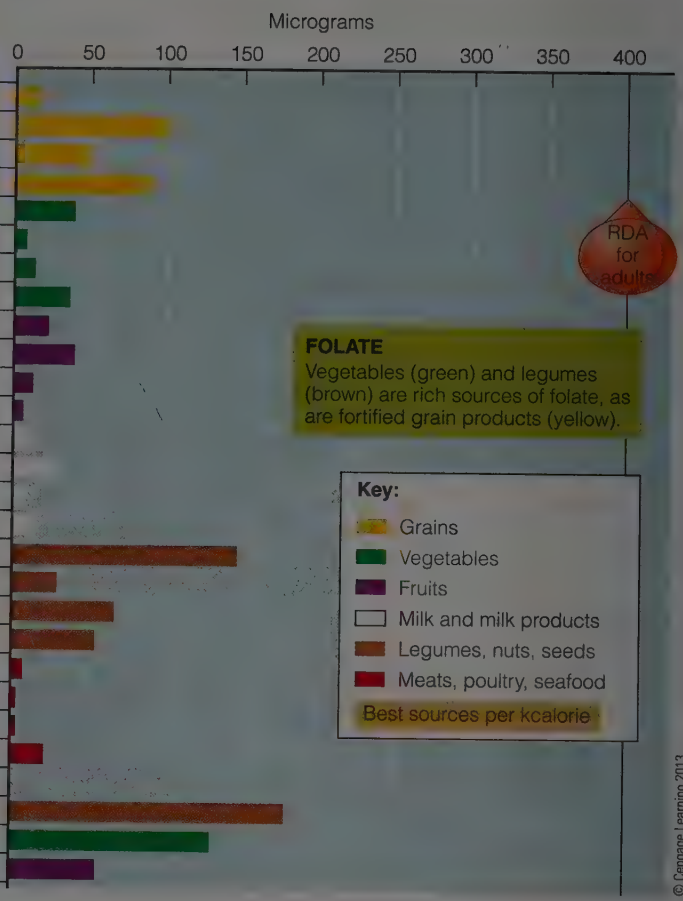
- **intrinsic** = on the inside

*In the body, methionine serves as a methyl (CH_3) donor. In doing so, methionine can be converted to other amino acids. Some of these amino acids can regenerate methionine, but methionine is still considered an essential amino acid that is needed in the diet.

> **FIGURE 10-13 Folate in Selected Foods**

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	½ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Lentils	½ c cooked (115 kcal)
Asparagus	½ c cooked (22 kcal)
Orange juice	¾ c fresh (84 kcal)



© Cengage Learning 2013

factor. The vitamin is gradually absorbed into the bloodstream as the intrinsic factor is degraded. Transport of vitamin B_{12} in the blood depends on specific binding proteins.

Like folate, vitamin B_{12} enters the enterohepatic circulation—continuously being secreted into bile and delivered to the intestine where it is reabsorbed. Because most vitamin B_{12} is reabsorbed, healthy people rarely develop a deficiency even when their intake is minimal.

Vitamin B_{12} Recommendations The RDA for adults is only 2.4 micrograms of vitamin B_{12} a day—just over two-millionths of a gram. The ink in the period at the end of this sentence may weigh about 2.4 micrograms. As tiny as this amount appears to the human eye, it contains billions of molecules of vitamin B_{12}, enough to provide coenzymes for all the enzymes that need its help.

Vitamin B_{12} Deficiency and Toxicity Most vitamin B_{12} deficiencies reflect inadequate absorption, not poor intake. Inadequate absorption typically occurs for one of two reasons: a lack of hydrochloric acid or a lack of intrinsic factor. Without hydrochloric acid, the vitamin is not released from the dietary proteins and so is not available for binding with the intrinsic factor. Without the intrinsic factor, the vitamin cannot be absorbed.

Vitamin B_{12} deficiency is common among the elderly.[22] Many older adults develop **atrophic gastritis,** a condition that damages the cells of the stomach. Atrophic gastritis may also develop in response to iron deficiency or infection with *Helicobacter pylori,* the bacterium implicated in ulcer formation. Without healthy stomach cells, production of hydrochloric acid and intrinsic factor diminishes. Even

atrophic (a-TRO-fik) **gastritis** (gas-TRY-tis) chronic inflammation of the stomach accompanied by a diminished size and functioning of the mucous membrane and glands. This condition is also characterized by inadequate hydrochloric acid and intrinsic factor—two substances needed for vitamin B_{12} absorption.

- **atrophy** = wasting
- **gastro** = stomach
- **itis** = inflammation

with an adequate intake from foods, vitamin B_{12} status suffers. The vitamin B_{12} deficiency caused by atrophic gastritis and a lack of intrinsic factor is known as **pernicious anemia.**

Some people inherit a defective gene for the intrinsic factor. In such cases, or when the stomach has been injured and cannot produce enough of the intrinsic factor, vitamin B_{12} must be given by injection to bypass the need for intestinal absorption. Alternatively, the vitamin may be delivered by nasal spray; absorption is rapid, high, and well tolerated.

Because vitamin B_{12} is found primarily in foods derived from animals, people who follow a vegan diet may develop a vitamin B_{12} deficiency. It may take several years for people who stop eating animal-derived foods to develop deficiency symptoms because the body recycles much of its vitamin B_{12}, reabsorbing it over and over again. Even when the body fails to absorb vitamin B_{12}, deficiency may take up to 3 years to develop because the body conserves its supply. Neurological degeneration, a sign of vitamin B_{12} deficiency, appears more rapidly in infants born to mothers with unsupplemented vegan diets or untreated pernicious anemia.[23]

Because vitamin B_{12} is required to convert folate to its active form, one of the most obvious vitamin B_{12}–deficiency symptoms is the anemia commonly seen in folate deficiency. This anemia is characterized by large, immature red blood cells, which indicate slow DNA synthesis and an inability to divide (see Figure 10-12, p. 314). When folate is trapped in its inactive (methyl folate) form due to vitamin B_{12} deficiency or is unavailable due to folate deficiency itself, DNA synthesis slows.

First to be affected in a vitamin B_{12} or folate deficiency are the rapidly growing blood cells. Either vitamin B_{12} or folate will clear up the anemia, but if folate is given when vitamin B_{12} is needed, the result is disastrous: devastating neurological symptoms. Remember that vitamin B_{12}, but not folate, maintains the sheath that surrounds and protects nerve fibers and promotes their normal growth. Folate "cures" the *blood* symptoms of a vitamin B_{12} deficiency, but cannot stop the *nerve* symptoms from progressing. By doing so, folate "masks" a vitamin B_{12} deficiency.[24]

Marginal vitamin B_{12} deficiency impairs cognition.[25] Advanced neurological symptoms include a creeping paralysis that begins at the extremities and works inward and up the spine. Early detection and correction are necessary to prevent permanent nerve damage and paralysis. With sufficient folate in the diet, the neurological symptoms of vitamin B_{12} deficiency can develop without evidence of anemia.[26] Such interactions between folate and vitamin B_{12} highlight some of the safety issues surrounding the use of supplements and the fortification of foods.[27] No adverse effects have been reported for excess vitamin B_{12}, and no UL has been set.

Vitamin B_{12} Food Sources Vitamin B_{12} is unique among the vitamins in being found almost exclusively in foods derived from animals. Its bioavailability is greatest from milk and fish.[28] Anyone who eats reasonable amounts of animal-derived foods is most likely to have an adequate intake, including vegetarians who use milk products or eggs. Vegans, who restrict all foods derived from animals, need a reliable source, such as vitamin B_{12}–fortified soy milk or vitamin B_{12} supplements. Yeast grown on a vitamin B_{12}–enriched medium and mixed with that medium provides some vitamin B_{12}, but yeast itself does not contain active vitamin B_{12}. Similarly, neither fermented soy products such as miso (a soybean paste) nor sea algae such as spirulina provide active vitamin B_{12}. Extensive research shows that the amounts listed on the labels of these plant products are inaccurate and misleading because the vitamin B_{12} is in an inactive, unavailable form.

As mentioned earlier, the water-soluble vitamins are particularly vulnerable to losses in cooking. For most of these nutrients, microwave heating minimizes losses as well as, or better than, traditional cooking methods. Such is not the case for vitamin B_{12}, however. Microwave heating inactivates vitamin B_{12}. To preserve this vitamin, use the oven or stovetop instead of a microwave to cook meats and milk products (major sources of vitamin B_{12}). The table on p. 318 provides a summary of vitamin B_{12}.

pernicious (per-NISH-us) **anemia**: a blood disorder that reflects a vitamin B_{12} deficiency caused by lack of intrinsic factor and characterized by abnormally large and immature red blood cells. Other symptoms include muscle weakness and irreversible neurological damage.

- **pernicious** = destructive

REVIEW IT Vitamin B_{12}

Other Names	Significant Sources
Cobalamin (and related forms)	Foods of animal origin (meat, fish, poultry, shellfish, milk, cheese, eggs), fortified cereals
RDA	Easily destroyed by microwave cooking
Adults: 2.4 µg/day	**Deficiency Disease**
Chief Functions in the Body	Pernicious anemia[a]
Part of coenzymes methylcobalamin and deoxyadenosylcobalamin used in new cell synthesis; helps to maintain nerve cells; reforms folate coenzyme; helps to break down some fatty acids and amino acids	**Deficiency Symptoms**
	Anemia (large-cell type);[b] fatigue, degeneration of peripheral nerves progressing to paralysis; sore tongue, loss of appetite, constipation
	Toxicity Symptoms
	None reported

[a]The name *pernicious anemia* refers to the vitamin B_{12} deficiency caused by atrophic gastritis and a lack of intrinsic factor, but not to that caused by inadequate dietary intake.
[b]Large-cell-type anemia is known as either *macrocytic* or *megaloblastic anemia.*

Choline Although not defined as a vitamin, choline is an essential nutrient that is commonly grouped with the B vitamins.[29] The body uses choline to make the neurotransmitter acetylcholine and the phospholipid lecithin. During fetal development, choline supports the structure and function of the brain and spinal cord, by supporting neural tube closure and enhancing learning performance.

Choline Recommendations The body can make choline from the amino acid methionine, but without dietary choline, synthesis alone appears to be insufficient to meet the body's needs. For this reason, the DRI Committee established an Adequate Intake (AI) for choline.

Choline Deficiency and Toxicity Average choline intakes fall below the AI, but the impact of deficiencies are not fully understood.[30] The UL for choline is based on its critical effect in lowering blood pressure.

Choline Food Sources Choline is found in a variety of common foods such as milk, eggs, and peanuts and as part of lecithin, a food additive commonly used as an emulsifying agent (review Figure 5-8 on p. 136). The accompanying table provides a summary of choline.

Nonvitamins Some substances have been mistaken for vitamins, but they are not essential nutrients. Among them are the compounds **inositol** and **carnitine,** which can be made by the body. Inositol is a part of cell membrane structures,

REVIEW IT Choline

Adequate Intake (AI)	Deficiency Symptoms
Men: 550 mg/day	Liver damage
Women: 425 mg/day	**Toxicity Symptoms**
UL	Body odor, sweating, salivation, reduced growth rate, low blood pressure, liver damage
Adults: 3500 mg/day	**Significant Sources**
Chief Functions in the Body	Milk, liver, eggs, peanuts
Needed for the synthesis of the neurotransmitter acetylcholine and the phospholipid lecithin	

inositol (in-OSS-ih-tall): a nonessential nutrient that can be made in the body from glucose. Inositol is a part of cell membrane structures.

carnitine (CAR-neh-teen): a nonessential, nonprotein amino acid made in the body from lysine that helps transport fatty acids across the mitochondrial membrane.

and carnitine transports long-chain fatty acids from the cytosol to the mitochondria for oxidation. Other nonvitamins include PABA (para-aminobenzoic acid, a component of folate's chemical structure), the bioflavonoids (vitamin P or hesperidin), pyrroloquinoline quinone (methoxatin), orotic acid, lipoic acid, and ubiquinone (coenzyme Q_{10}). Other names erroneously associated with vitamins are "vitamin O" (oxygenated saltwater), "vitamin B_5" (another name for pantothenic acid), "vitamin B_{15}" (also called "pangamic acid," a hoax), and "vitamin B_{17}" (laetrile, an alleged "cancer cure" and not a vitamin or a cure by any stretch of the imagination—in fact, laetrile is a potentially dangerous substance).

Interactions among the B Vitamins This chapter has described some of the impressive ways that vitamins work individually, as if their many actions in the body could easily be disentangled. In fact, it is often difficult to tell which vitamin is truly responsible for a given effect because the nutrients are interdependent; the presence or absence of one affects another's absorption, metabolism, and excretion. You have already seen this interdependence with folate and vitamin B_{12}.

Riboflavin and vitamin B_6 provide another example. One of the riboflavin coenzymes, FMN, assists the enzyme that converts vitamin B_6 to its coenzyme form PLP. Consequently, a severe riboflavin deficiency can impair vitamin B_6 activity. Thus a deficiency of one nutrient may alter the action of another. Furthermore, a deficiency of one nutrient may create a deficiency of another. For example, both riboflavin and vitamin B_6 (as well as iron) are required for the conversion of tryptophan to niacin. Consequently, an inadequate intake of either riboflavin or vitamin B_6 can diminish the body's niacin supply. These interdependent relationships are evident in many of the roles B vitamins play in the body.

B Vitamin Roles Figure 10-14 (p. 320) summarizes the metabolic pathways introduced in Chapter 7 and conveys an *impression* of the many ways B vitamins assist in metabolic pathways. Metabolism is the body's work, and the B vitamin coenzymes are indispensable to every step. In scanning the pathways of metabolism depicted in the figure, note the many abbreviations for the coenzymes that keep the processes going.

Look at the now-familiar pathway of glucose breakdown. To break down glucose to pyruvate, the cells must have certain enzymes. For the enzymes to work, they must have the niacin coenzyme NAD. Cells can make NAD, but only if they have enough niacin (or enough of the amino acid tryptophan to make niacin).

The next step is the breakdown of pyruvate to acetyl CoA. The enzymes involved in this step require both NAD and the thiamin and riboflavin coenzymes TPP and FAD, respectively. The cells can manufacture the enzymes they need from the vitamins, if the vitamins are in the diet.

Another coenzyme needed for this step is CoA. Predictably, the cells can make CoA except for an essential part that must be obtained in the diet—pantothenic acid. Another coenzyme requiring biotin serves the enzyme complex involved in converting pyruvate to oxaloacetate, the compound that combines with acetyl CoA to start the TCA cycle.

These and other coenzymes participate throughout all the metabolic pathways. Vitamin B_6 is an indispensable part of PLP—a coenzyme required for many amino acid conversions, for a crucial step in the making of the iron-containing portion of hemoglobin for red blood cells, and for many other reactions. Folate becomes THF—the coenzyme required for the synthesis of new genetic material and therefore new cells. The vitamin B_{12} coenzyme, in turn, regenerates THF to its active form; thus vitamin B_{12} is also necessary for the formation of new cells.

Thus each of the B vitamin coenzymes is involved, directly or indirectly, in energy metabolism. Some facilitate the energy-releasing reactions themselves; others help build new cells to deliver the oxygen and nutrients that allow the energy reactions to occur.

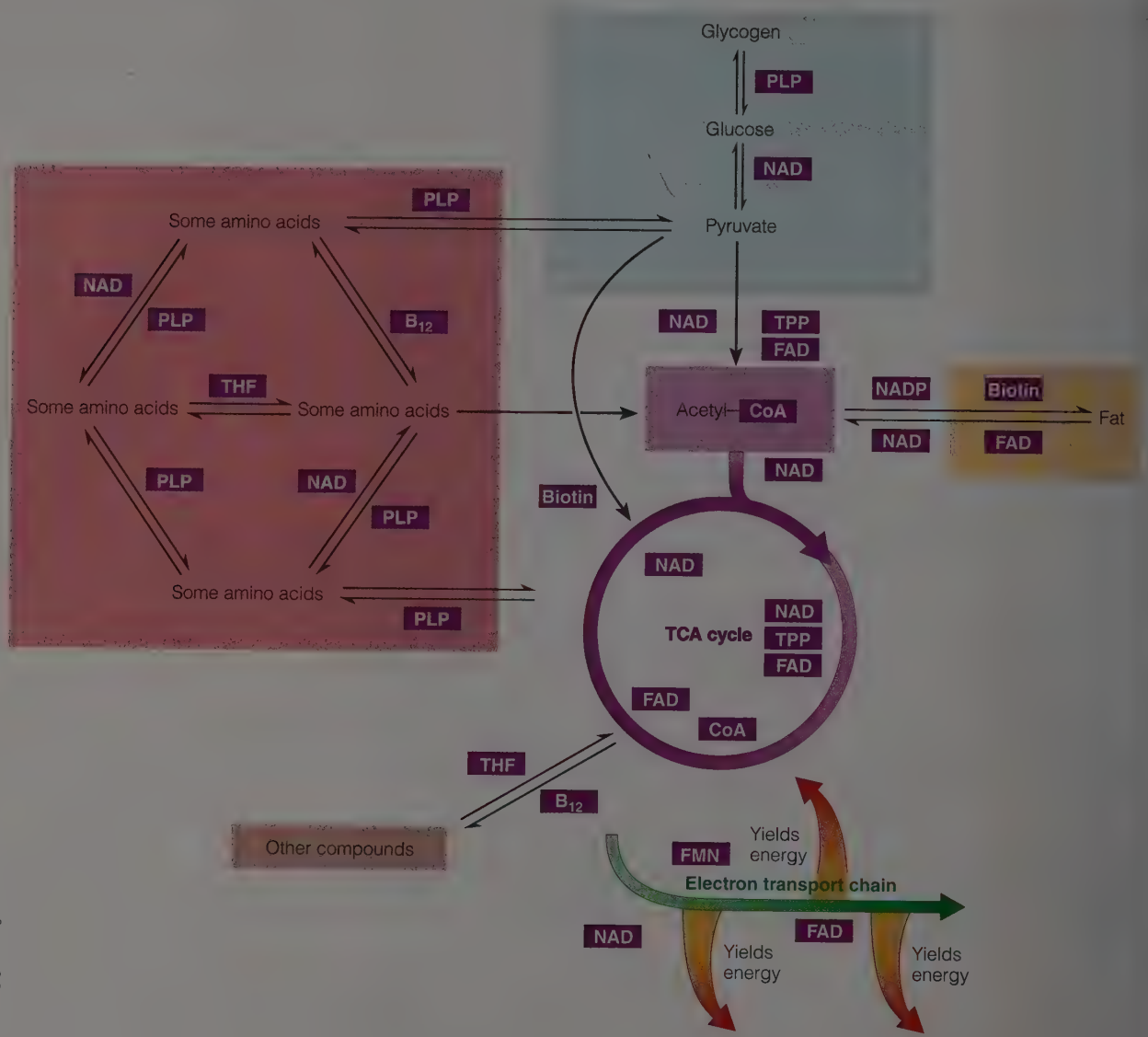
B Vitamin Deficiencies Now suppose the body's cells lack one of these B vitamins—niacin, for example. Without niacin, the cells cannot make NAD. Without NAD, the enzymes involved in every step of the glucose-to-energy pathway cannot function.

> FIGURE 10-14 Metabolic Pathways Involving B Vitamins

These metabolic pathways are introduced in Chapter 7 and are presented here to highlight the many coenzymes that facilitate the reactions. These coenzymes depend on the following vitamins:

- NAD and NADP: niacin
- TPP: thiamin
- CoA: pantothenic acid
- B_{12}: vitamin B_{12}
- FMN and FAD: riboflavin
- THF: folate
- PLP: vitamin B_6
- Biotin

Pathways leading toward acetyl CoA and the TCA cycle are catabolic, and those leading toward amino acids, glycogen, and fat are anabolic. For further details, see Appendix C.



© Cengage Learning 2013

Then, because all the body's activities require energy, literally everything begins to grind to a halt. This is no exaggeration. The deadly disease pellagra, caused by niacin deficiency, produces the "devastating four *D*s": dermatitis, which reflects a failure of the skin; dementia, a failure of the nervous system; diarrhea, a failure of digestion and absorption; and eventually, as would be the case for any severe nutrient deficiency, death. These symptoms are the obvious ones, but a niacin deficiency affects all other organs, too, because all are dependent on the energy pathways.

All the vitamins are as essential as niacin. With any B vitamin deficiency, many body systems become deranged, and similar symptoms may appear. A lack of any of them can have disastrous and far-reaching effects.

Deficiencies of single B vitamins seldom show up in isolation, however. After all, people do not eat nutrients singly; they eat foods, which contain mixtures of nutrients. Only in two cases described earlier—beriberi and pellagra—have dietary deficiencies associated with single B vitamins been observed on a large scale in human populations. Even in these cases, several vitamins were lacking even though one vitamin stood out above the rest. When foods containing the vitamin known to be needed were provided, the other vitamins that were in short supply came as part of the package.

Major deficiency diseases of epidemic proportions such as pellagra and beriberi are no longer seen in the United States and Canada, but lesser deficiencies of nutrients, including the B vitamins, sometimes occur in people whose food choices are poor because of poverty, ignorance, illness, or poor health habits like alcohol abuse. (Review Highlight 7 to fully appreciate how alcohol induces vitamin deficiencies and interferes with energy metabolism.) Remember from Chapter 1 that deficiencies can arise not only from deficient intakes (primary causes), but also for other (secondary) reasons.

In identifying nutrient deficiencies, it is important to realize that a particular sign or symptom may not always have the same cause. The skin and the tongue (shown in Figure 10-15) appear to be especially sensitive to B vitamin deficiencies, but focusing on these body parts gives them undue emphasis. Both the skin and the tongue are readily visible in a physical examination.* The physician sees and reports the deficiency's outward signs, but the full impact of a vitamin deficiency occurs inside the cells of the body. If the skin develops a rash or lesions, other tissues beneath it may be degenerating too. Similarly, the mouth and tongue are the visible part of the digestive system; if they are abnormal, most likely the rest of the GI tract is as well.

Keep in mind that the cause of a sign or symptom is not always apparent. The summary tables in this chapter show that deficiencies of riboflavin, niacin, biotin, and vitamin B_6 can all cause skin rashes. So can a deficiency of protein, linoleic acid, or vitamin A. Because skin is on the outside and easy to see, it is a useful indicator of "things going wrong inside cells." By itself, a skin condition says nothing about its possible cause.

The same is true of anemia. Anemia is often caused by iron deficiency, but it can also be caused by a folate or vitamin B_{12} deficiency; by digestive tract failure to absorb any of these nutrients; or by such nonnutritional causes as infections, parasites, cancer, or loss of blood. No single nutrient will always cure a given symptom.

A person who feels chronically tired may be tempted to self-diagnose iron-deficiency anemia and self-prescribe an iron supplement. But this will relieve tiredness

> FIGURE 10-15 B Vitamin–Deficiency Symptoms—The Smooth Tongue of Glossitis and the Skin Lesions of Cheilosis



© Custom Medical Stock Photo

A healthy tongue has a rough and somewhat bumpy surface.



© Science Photo Library/ Photo Researchers, Inc.

In a B vitamin deficiency, the tongue becomes smooth and swollen due to atrophy of the tissue (glossitis).



© 2004 Massachusetts Medical Society. All rights reserved

In a B vitamin deficiency, the corners of the mouth become irritated and inflamed (cheilosis).

*The two common signs of B vitamin deficiencies are *glossitis* (gloss-EYE-tis), an inflammation of the tongue, and *cheilosis* (kye-LOH-sis or kee-LOH-sis), a condition of reddened lips with cracks at the corners of the mouth.

only if the cause is indeed iron-deficiency anemia. If the cause is a folate deficiency, taking iron will only prolong the fatigue. A person who is better informed may decide to take a vitamin supplement with iron, covering the possibility of a vitamin deficiency. But the symptom may have a nonnutritional cause. If the cause of the tiredness is actually hidden blood loss due to cancer, the postponement of a diagnosis may be fatal. When fatigue is caused by a lack of sleep, of course, no nutrient or combination of nutrients can replace a good night's rest. A person who is chronically tired should see a physician rather than self-prescribe. If the condition is nutrition related, a registered dietitian should be consulted as well.

B Vitamin Toxicities Toxicities of the B vitamins from foods alone are unknown, but they can occur when people overuse dietary supplements. With supplements, the quantities can quickly overwhelm the cells. Consider that one small capsule can easily deliver 2 milligrams of vitamin B_6, but it would take more than 3000 bananas, 6600 cups of rice, or 3600 chicken breasts to supply an equivalent amount. When the cells become oversaturated with a vitamin, they must work to eliminate the excess. The cells dispatch water-soluble vitamins to the urine for excretion, but sometimes they cannot keep pace with the onslaught. Homeostasis becomes disturbed and symptoms of toxicity develop.

B Vitamin Food Sources Significantly, deficiency diseases, such as beriberi and pellagra, were eliminated by providing foods. Dietary supplements advertise that vitamins are indispensable to life, but human beings obtained their nourishment from foods for centuries before supplements existed. If the diet lacks a vitamin, the first solution is to adjust food intake to obtain that vitamin.

The bar graphs of selected foods in this chapter, taken together, sing the praises of a balanced diet. The grains deliver thiamin, riboflavin, niacin, and folate. The fruit and vegetable groups excel in folate. Protein foods serve thiamin, niacin, vitamin B_6, and vitamin B_{12} well. The milk group stands out for riboflavin and vitamin B_{12}. A diet that offers a variety of foods from each group, prepared with reasonable care, serves up ample B vitamins.

REVIEW IT Identify the main roles, deficiency symptoms, and food sources for each of the B vitamins.

The B vitamins serve as coenzymes that facilitate the work of every cell. They are active in carbohydrate, fat, and protein metabolism and in the making of DNA and thus new cells. Historically famous B vitamin–deficiency diseases are beriberi (thiamin), pellagra (niacin), and pernicious anemia (vitamin B_{12}). Pellagra can be prevented by adequate protein because the amino acid tryptophan can be converted to niacin in the body. A high intake of folate can mask the blood symptoms of a vitamin B_{12} deficiency, but it will not prevent the associated nerve damage. Vitamin B_6 participates in amino acid metabolism and can be harmful in excess. Biotin and pantothenic acid serve important roles in energy metabolism and are common in a variety of foods. Many substances that people claim as B vitamins are not. Fortunately, a variety of foods from each of the food groups provides an adequate supply of all of the B vitamins.

10.3 Vitamin C

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin C.

For many centuries, any man who joined the crew of a seagoing ship knew he had at best a 50–50 chance of returning alive—not because he might be slain by pirates or die in a storm, but because he might contract **scurvy.**[31] As many as two-thirds of a ship's crew could die of scurvy during a long voyage. Only men on short voyages, especially around the Mediterranean Sea, were free of scurvy. No one knew the reason: that on long ocean voyages, the ship's cook used up the fresh fruits and vegetables early and then served only cereals and meats until the return to port.

In the mid-1700s, James Lind, a British physician serving in the navy, devised an experiment to find a cure for scurvy. He divided 12 sailors with scurvy into 6 pairs. Each pair received a different supplemental ration: cider, vinegar, sulfuric acid, seawater, oranges and lemons, or a strong laxative. Those receiving the citrus fruits quickly

scurvy: the vitamin C–deficiency disease.

recovered, but sadly, it was almost 50 years before the British navy required all vessels to provide every sailor with lemon or lime juice daily. The tradition of providing British sailors with citrus juice daily to prevent scurvy gave them the nickname "limeys."

The antiscurvy "something" in citrus and other foods was dubbed the **antiscorbutic factor.** Nearly 200 years later, the factor was isolated and found to be a 6-carbon compound similar to glucose; it was named **ascorbic acid.**

Vitamin C Roles

Vitamin C parts company with the B vitamins in its mode of action. In some settings, vitamin C serves as a **cofactor** helping a specific enzyme perform its job, but in others, it acts as an antioxidant participating in more general ways.

As an Antioxidant

Vitamin C loses electrons easily, a characteristic that allows it to perform as an antioxidant. ♦ In the body, **antioxidants** defend against free radicals. Free radicals are discussed fully in Highlight 11, but for now, a simple definition will suffice. A **free radical** is a molecule with one or more unpaired electrons, which makes it unstable and highly reactive. Antioxidants can neutralize free radicals by donating an electron or two. In doing so, antioxidants protect other substances from free radical damage. Figure 10-16 illustrates how vitamin C can give up electrons and then accept them again to become reactivated. This recycling of vitamin C is key to limiting losses and maintaining a reserve of antioxidants in the body.

♦ Key antioxidant nutrients:
- Vitamin C, vitamin E, beta-carotene
- Selenium

Vitamin C is like a bodyguard for water-soluble substances; it stands ready to sacrifice its own life to save theirs. In the cells and body fluids, vitamin C protects tissues from the **oxidative stress** of free radicals and thus may play an important role in preventing diseases. In the intestines, vitamin C enhances iron absorption by protecting iron from oxidation. (Chapter 13 provides more details about the relationship between vitamin C and iron.)

As a Cofactor in Collagen Formation

Vitamin C helps to form the fibrous structural protein of connective tissues known as **collagen.** Collagen serves as the matrix on which bones and teeth are formed. When a person is wounded, collagen glues the separated tissues together, forming scars. Cells are held together largely by collagen; this is especially important in the walls of the blood vessels, which must withstand the pressure of blood surging with each beat of the heart.

Chapter 6 describes how the body makes proteins by stringing together chains of amino acids. During the synthesis of collagen, each time a proline or lysine is added to the growing protein chain, an enzyme hydroxylates it (adds an OH group), making the amino acid hydroxyproline or hydroxylysine, respectively. These two special amino acids facilitate the binding together of collagen fibers to make strong, rope-like structures. The conversion of proline to hydroxyproline requires both vitamin C and iron. Iron works as a cofactor in the reaction, and vitamin C protects iron from oxidation, thereby allowing iron to perform its duty. Without vitamin C and iron, the hydroxylation step does not occur.

As a Cofactor in Other Reactions

Vitamin C also serves as a cofactor in the synthesis of several other compounds. As in collagen formation, vitamin C helps in the

antiscorbutic (AN-tee-skor-BUE-tik) **factor:** the original name for vitamin C.
- **anti** = against
- **scorbutic** = causing scurvy

ascorbic acid: one of the two active forms of vitamin C (see Figure 10-16). Many people refer to vitamin C by this name.
- **a** = without
- **scorbic** = having scurvy

cofactor: a small, inorganic or organic substance that facilitates the action of an enzyme.

antioxidants: in the body, substances that significantly decrease the adverse effects of free radicals on normal physiological functions.

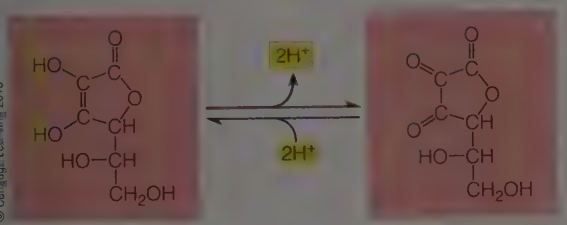
free radical: an unstable molecule with one or more unpaired electrons.

oxidative stress: a condition in which the production of oxidants and free radicals exceeds the body's ability to handle them and prevent damage.

collagen: the structural protein from which connective tissues such as scars, tendons, ligaments, and the foundations of bones and teeth are made.

> FIGURE 10-16 Active Forms of Vitamin C

The two hydrogens highlighted in yellow give vitamin C its acidity and its ability to act as an antioxidant.



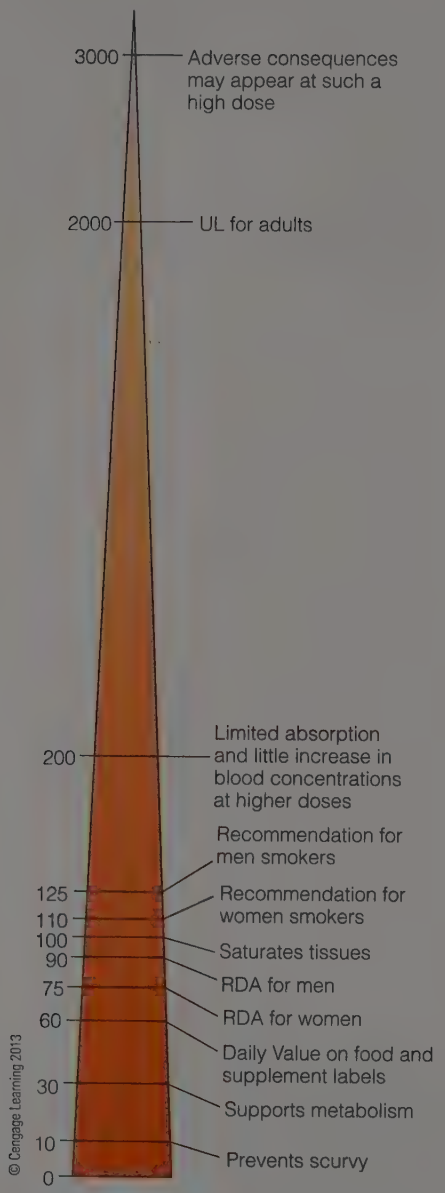
© Cengage Learning 2013

Ascorbic acid protects against oxidative damage by donating its two hydrogens with their electrons to free radicals (molecules with unpaired electrons). In doing so, ascorbic acid becomes dehydroascorbic acid.

Dehydroascorbic acid can readily accept hydrogens to become ascorbic acid. The reversibility of this reaction is key to vitamin C's role as an antioxidant.

> FIGURE 10-17 Vitamin C Intake (mg/day)

Recommendations for vitamin C are set generously above the minimum requirement and well below the toxicity level.



♦ Vitamin C is found in:

- High amounts: Adrenal glands, pituitary glands
- Medium amounts: Liver, spleen, heart, kidneys, lungs, pancreas, white blood cells
- Small amounts: Muscles, red blood cells

♦ For perspective, 1 c orange juice provides >100 mg vitamin C.

hydroxylation of carnitine, a compound that transports fatty acids, especially long-chain fatty acids, across the inner membrane of mitochondria in cells. It also participates in the conversions of the amino acids tryptophan and tyrosine to the neurotransmitters serotonin and norepinephrine, respectively. Vitamin C also assists in the making of hormones, including thyroxin, which regulates the metabolic rate; when metabolism speeds up in times of extreme physical stress, the body's use of vitamin C increases.

In Stress Among the stresses known to increase vitamin C needs are infections; burns; extremely high or low temperatures; intakes of toxic heavy metals such as lead, mercury, and cadmium; the chronic use of certain medications, including aspirin, barbiturates, and oral contraceptives; and cigarette smoking. During stress, the adrenal glands—which contain more vitamin C than any other organ in the body—release vitamin C ♦ and hormones into the blood.

When immune system cells are called into action, they use a great deal of oxygen and produce free radicals. In this case, free radicals are helpful. They act as ammunition in an "oxidative burst" that demolishes the offending viruses and bacteria and destroys the damaged cells. Vitamin C steps in as an antioxidant to control this oxidative activity.

In the Prevention and Treatment of the Common Cold Vitamin C has been a popular option for the prevention and treatment of the common cold for decades, but research supporting such claims has been conflicting and controversial. Some studies find no relationship between vitamin C and the occurrence of the common cold, whereas others report modest benefits—fewer colds, fewer days, and shorter duration of severe symptoms, especially for those exposed to physical and environmental stresses.[32] A review of the research on vitamin C in the treatment and prevention of the common cold reveals a slight, but consistent reduction (of 8 percent) in the duration of the common cold in favor of those taking a daily dose of at least 200 milligrams of vitamin C.[33] The question for consumers to consider is, "Is this enough to warrant routine daily supplementation?" Findings from one study show that consumers want their colds to be at least 25 percent less severe to justify the costs of taking vitamin C supplements regularly.[34]

Discoveries about how vitamin C works in the body provide possible links between the vitamin and the common cold. Anyone who has ever had a cold knows the discomfort of a runny or stuffed-up nose. Nasal congestion develops in response to elevated blood **histamine**, and people commonly take antihistamines for relief. Like an antihistamine, vitamin C comes to the rescue and deactivates histamine.

In Disease Prevention Whether vitamin C may help in preventing or treating cancer, heart disease, cataract, and other diseases is still being studied, and findings are presented in Highlight 11's discussion on antioxidants. Conducting research in the United States and Canada can be difficult, however, because diets typically contribute enough vitamin C to provide optimal health benefits.

Vitamin C Recommendations

For decades, vitamin C ranked at the top of dietary supplement sales. How much vitamin C does a person need? As is true of all the vitamins, recommendations are set generously above the minimum requirement to prevent deficiency disease and well below the toxicity level (see Figure 10-17).[35]

The requirement—the amount needed to prevent the overt symptoms of scurvy—is only 10 milligrams daily. Consuming 10 milligrams a day does not saturate all the body tissues, however; higher intakes will increase the body's total vitamin C. At about 100 milligrams ♦ per day, 95 percent of the population reaches tissue saturation. Recommendations are slightly lower, based on the amounts needed to provide antioxidant protection. At about 200 milligrams, absorption reaches a maximum, and there is little, if any, increase in blood concentrations at higher doses. Excess vitamin C is readily excreted.

As mentioned earlier, cigarette smoking increases the need for vitamin C. Cigarette smoke contains oxidants, which greedily deplete this potent antioxidant. Exposure to cigarette smoke, especially when accompanied by low dietary intakes of vitamin C, depletes the body's vitamin C in both active and passive

histamine (HISS-tah-mean or HISS-tah-men): a substance produced by cells of the immune system as part of a local immune reaction to an antigen.

smokers. People who chew tobacco also have low levels of vitamin C. Because people who smoke cigarettes regularly suffer significant oxidative stress, their requirement for vitamin C is increased an additional 35 milligrams; nonsmokers regularly exposed to cigarette smoke should also be sure to meet their RDA for vitamin C. Smokers are among those most likely to suffer vitamin C deficiency.[36]

Vitamin C Deficiency Early signs of nutrient deficiencies can be difficult to recognize.[37] Two of the most notable signs of a vitamin C deficiency reflect its role in maintaining the integrity of blood vessels. The gums bleed easily around the teeth, and capillaries under the skin break spontaneously, producing pinpoint hemorrhages (see Figure 10-18).

When vitamin C concentrations fall to about a fifth of optimal levels (this may take more than a month on a diet lacking vitamin C), scurvy symptoms begin to appear. Inadequate collagen synthesis causes further hemorrhaging. Muscles, including the heart muscle, degenerate. The skin becomes rough, brown, scaly, and dry. Wounds fail to heal because scar tissue will not form. Bone rebuilding falters; the ends of the long bones become softened, malformed, and painful, and fractures develop. The teeth become loose as the cartilage around them weakens. Anemia and infections are common. There are also characteristic psychological signs, including hysteria and depression. Sudden death is likely, caused by massive internal bleeding.

Once diagnosed, scurvy is readily resolved by vitamin C. Moderate doses in the neighborhood of 100 milligrams per day are sufficient, curing the scurvy within about 5 days. Such an intake is easily achieved by including vitamin C–rich foods in the diet.

Vitamin C Toxicity The availability of vitamin C supplements and the publication of books recommending vitamin C to prevent colds and cancer have led many people to take large doses of vitamin C. Not surprisingly, side effects of vitamin C supplementation such as gastrointestinal distress and diarrhea have been reported. The UL for vitamin C was established based on these symptoms.

Several instances of interference with medical regimens are also known. Large amounts of vitamin C excreted in the urine obscure the results of tests used to detect glucose or ketones in the diagnosis of diabetes. In some instances, excess vitamin C gives a **false positive** result; in others, a **false negative**. People taking anticlotting medications may unwittingly counteract the effect if they also take massive doses of vitamin C. Those with kidney disease, a tendency toward gout, or a genetic abnormality that alters vitamin C's breakdown to its excretion products are prone to forming kidney stones if they take large doses of vitamin C.* Vitamin C supplements may adversely affect people with iron overload. As Chapter 13 explains, vitamin C enhances iron absorption and releases iron from body stores; too much free iron causes the kind of cellular damage typical of free

> **FIGURE 10-18 Vitamin C–Deficiency Symptoms—Scorbutic Gums and Pinpoint Hemorrhages**



Biophoto Associates/Photo Researchers, Inc.

Scorbutic gums. Unlike other lesions of the mouth, scurvy presents a symmetrical appearance without infection.



© Dr. P. Marazzi/Photo Researchers, Inc.

Pinpoint hemorrhages. Small red spots appear in the skin, indicating spontaneous bleeding internally.

*Vitamin C is inactivated and degraded by several routes, and sometimes oxalate, which can form kidney stones, is produced along the way. People may also develop oxalate crystals in their kidneys regardless of vitamin C status.

false positive: a test result indicating that a condition is present (positive) when in fact it is not present (therefore false).

false negative: a test result indicating that a condition is not present (negative) when in fact it is present (therefore false).

radicals. These adverse consequences illustrate how vitamin C can act as a *pro*oxidant when quantities exceed the body's needs.

Vitamin C Food Sources Fruits and vegetables can easily provide a generous amount of vitamin C. A cup of orange juice at breakfast, a salad for lunch, and a stalk of broccoli and a potato for dinner alone provide more than 300 milligrams. (For perspective, review Figure 10-17, p. 324) Clearly, a person making such food choices does not need vitamin C supplements.

Figure 10-19 shows the amounts of vitamin C in various common foods. The overwhelming abundance of purple and green bars reveals not only that the citrus fruits are justly famous for being rich in vitamin C, but that other fruits and vegetables are in the same league. A half cup of broccoli, bell pepper, or strawberries provides more than 50 milligrams of the vitamin (and an array of other nutrients). Because vitamin C is vulnerable to heat, raw fruits and vegetables usually have a higher nutrient density than their cooked counterparts. Similarly, because vitamin C is readily destroyed by oxygen, foods and juices should be stored properly and consumed within a week of opening.

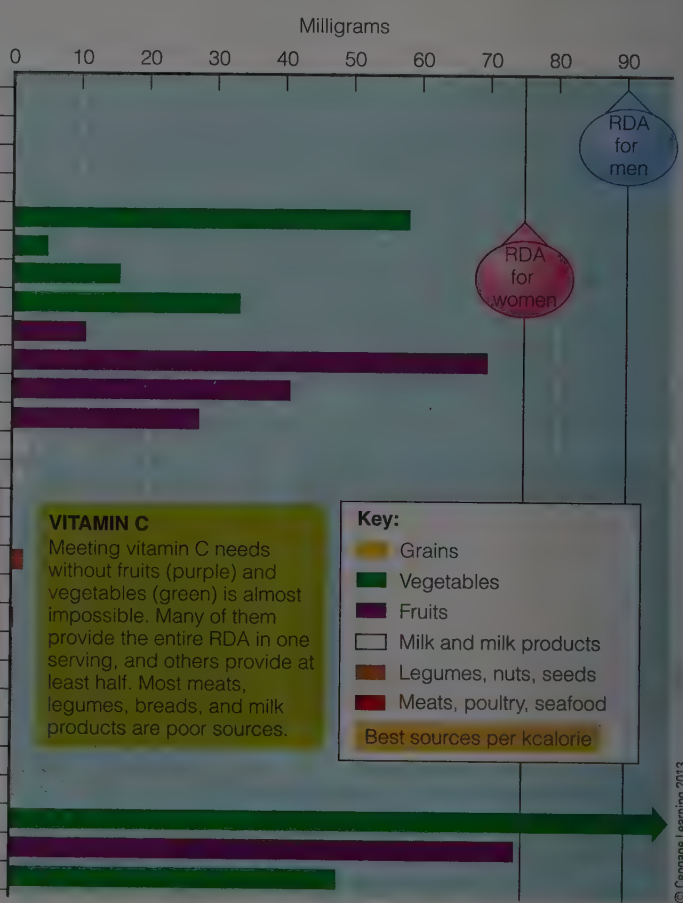
The potato is an important source of vitamin C, not because one potato by itself meets the daily need, but because potatoes are such a common staple that they make significant contributions. In fact, scurvy was unknown in Ireland until the potato blight of the mid-1840s when some 2 million people died of malnutrition and infection.

The lack of yellow, white, brown, and red bars in Figure 10-19 confirms that grains, milk and milk products (except breast milk), and most protein foods are notoriously poor sources of vitamin C. Organ meats (liver, kidneys, and others)

> FIGURE 10-19 Vitamin C in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Red bell pepper	½ c raw chopped (20 kcal)
Kiwi	1 (46 kcal)
Brussels sprouts	½ c cooked (30 kcal)

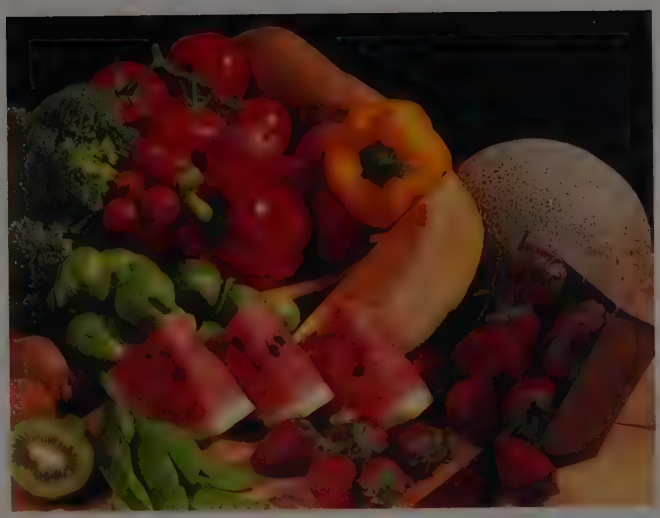


© Cengage Learning 2013



© Photodisc/ Getty Images

When dietitians say "vitamin C," people think "citrus fruits" . . .



© Polara Studios, Inc

. . . but these foods are also rich in vitamin C.

and raw meats contain some vitamin C, but most people don't eat large quantities of these foods. Raw meats and fish contribute enough vitamin C to be significant sources in parts of Alaska, Canada, and Japan, but elsewhere fruits and vegetables are necessary to supply sufficient vitamin C.

Because of vitamin C's antioxidant property, food manufacturers sometimes add a variation of vitamin C to some beverages and most cured meats, such as luncheon meats, to prevent oxidation and spoilage. This compound safely preserves these foods, but it does not have vitamin C activity in the body. Simply put, "Ham and bacon cannot replace fruits and vegetables."

REVIEW IT Identify the main roles, deficiency symptoms, and food sources for vitamin C.

Vitamin C acts primarily as an antioxidant and a cofactor. Recommendations are set well above the amount needed to prevent the deficiency disease scurvy. A variety of fruits and vegetables—most notably citrus fruits—provide generous amounts of vitamin C. The accompanying table provides a summary of vitamin C.

Vitamin C

Other Names	
Ascorbic acid	
RDA	
Men: 90 mg/day	
Women: 75 mg/day	
Smokers: +35 mg/day	
UL	
Adults: 2000 mg/day	
Chief Functions in the Body	
Collagen synthesis (strengthens blood vessel walls, forms scar tissue, provides matrix for bone growth), antioxidant, thyroxin synthesis, amino acid metabolism, strengthens resistance to infection, helps in absorption of iron	
	Significant Sources
	Citrus fruits, cabbage-type vegetables (such as brussels sprouts and cauliflower), dark green vegetables (such as bell peppers and broccoli), cantaloupe, strawberries, lettuce, tomatoes, potatoes, papayas, mangoes
	Easily destroyed by heat and oxygen
	Deficiency Disease
	Scurvy
	Deficiency Symptoms
	Anemia (small-cell type),[a] atherosclerotic plaques, pinpoint hemorrhages; bone fragility, joint pain; poor wound healing, frequent infections; bleeding gums, loosened teeth; muscle degeneration, pain, hysteria, depression; rough skin, blotchy bruises
	Toxicity Symptoms
	Nausea, abdominal cramps, diarrhea; headache, fatigue, insomnia; hot flashes; rashes; interference with medical tests, aggravation of gout symptoms, urinary tract problems, kidney stones[b]

[a]Small-cell-type anemia is *microcytic anemia.*

[b]People with kidney disease, a tendency toward gout, or a genetic abnormality that alters the breakdown of vitamin C are prone to forming kidney stones. Vitamin C is inactivated and degraded by several routes, sometimes producing oxalate, which can form stones in the kidneys.

REVIEW IT The Water-Soluble Vitamins

Vitamin and Chief Functions	Deficiency Symptoms	Toxicity Symptoms	Food Sources
Thiamin Part of coenzyme TPP in energy metabolism	Beriberi (edema or muscle wasting), anorexia and weight loss, neurological disturbances, muscular weakness, heart enlargement and failure	None reported	Enriched, fortified, or whole-grain products; pork
Riboflavin Part of coenzymes FAD and FMN in energy metabolism	Inflammation of the mouth, skin, and eyelids	None reported	Milk products; enriched, fortified, or whole-grain products; liver
Niacin Part of coenzymes NAD and NADP in energy metabolism	Pellagra (diarrhea, dermatitis, and dementia)	Niacin flush, liver damage, impaired glucose tolerance	Protein-rich foods
Biotin Part of coenzyme in energy metabolism	Skin rash, hair loss, neurological disturbances	None reported	Widespread in foods; GI bacteria synthesis
Pantothenic acid Part of coenzyme A in energy metabolism	Digestive and neurological disturbances	None reported	Widespread in foods
Vitamin B_6 Part of coenzymes used in amino acid and fatty acid metabolism	Scaly dermatitis, depression, confusion, convulsions, anemia	Nerve degeneration, skin lesions	Protein-rich foods
Folate Activates vitamin B_{12}; helps synthesize DNA for new cell growth	Anemia, glossitis, neurological disturbances, elevated homocysteine	Masks vitamin B_{12} deficiency	Legumes, vegetables, fortified grain products
Vitamin B_{12} Activates folate; helps synthesize DNA for new cell growth; protects nerve cells	Anemia; nerve damage and paralysis	None reported	Foods derived from animals
Vitamin C Synthesis of collagen, carnitine, hormones, neurotransmitters; antioxidant	Scurvy (bleeding gums, pinpoint hemorrhages, abnormal bone growth, and joint pain)	Diarrhea, GI distress	Fruits and vegetables

Vita means life. After this discourse on the vitamins, who could dispute that they deserve their name? Their regulation of metabolic processes makes them vital to the normal growth, development, and maintenance of the body. The accompanying table condenses the information provided in this chapter for a quick review. The remarkable roles of the vitamins continue in the next chapter.

Nutrition Portfolio

To obtain all the vitamins you need each day, be sure to select from a variety of foods from all the food groups. Go to Diet Analysis Plus and choose one of the days on which you have tracked your diet for the entire day. Go to the Intake vs. Goals report. Near the bottom of this report, you will see all of the vitamins grouped together; using this section of the report for reference, answer the following questions:

- How was your vitamin intake overall? Did you consume too much or too little of any vitamin? Which vitamins concerned you most?

Next go to the Intake Spreadsheet report, and looking at each of the vitamins, answer the following questions:

- Which of your foods provided high intakes of vitamins?
- Which of your foods provided few or no vitamins?
- Examine your daily choices of whole or enriched grains, dark green vegetables, citrus fruits, and legumes, then evaluate their contributions to your vitamin intakes.

- If you are a woman of childbearing age, calculate the dietary folate equivalents you receive from folate-rich foods, fortified foods, and supplements, then compare that to your RDA.
- Compare your vitamin intakes from supplements with their UL.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. A. Piro and coauthors, Casimir Funk: His discovery of the vitamins and their deficiency disorders, *Annals of Nutrition and Metabolism* 57 (2010): 85–88.
2. M. N. Riaz, M. Asif, and R. Ali, Stability of vitamins during extrusion, *Critical Reviews in Food Science and Nutrition* 49 (2009): 361–368.
3. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids* (Washington, D.C.: National Academies Press, 2000); Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline* (Washington, D.C.: National Academies Press, 1998).
4. K. J. Carpenter, *Beriberi, White Rice, and Vitamin B: A Disease, a Cause, and a Cure* (Berkeley: University of California Press, 2000).
5. K. L. Bogan and C. Brenner, Nicotinic acid, nicotinamide, and nicotinamide riboside: A molecular evaluation of NAD+ precursor vitamins in human nutrition, *Annual Review of Nutrition* 28 (2008): 115–130.
6. Committee on Dietary Reference Intakes, 1998, pp. 128–129.
7. J. M. Backes, R. J. Padley, and P. M. Moriarty, Important considerations for treatment with dietary supplement versus prescription niacin products, *Postgraduate Medicine* 123 (2011): 70–83.
8. S. C. Larsson, N. Orsini, and A. Wolk, Vitamin B_6 and risk of colorectal cancer: A meta-analysis of prospective studies, *Journal of the American Medical Association* 303 (2010): 1077–1083; J. Shen and coauthors, Association of vitamin B-6 status with inflammation, oxidative stress, and chronic inflammatory conditions: The Boston Puerto Rican Health Study, *American Journal of Clinical Nutrition* 91 (2010): 337–342; J. H. Page and coauthors, Plasma vitamin B(6) and risk of myocardial infarction in women, *Circulation* 120 (2009): 649–655.
9. A. S. Tibbetts and D. R. Appling, Compartmentalization of mammalian folate-mediated one-carbon metabolism, *Annual Review of Nutrition* 30 (2010): 57–81.
10. M. A. Caudill, Folate bioavailability: Implications for establishing dietary recommendations and optimizing status, *American Journal of Clinical Nutrition* 91 (2010): 1455S–1460S.
11. S. H. Blanton and coauthors, Folate pathway and nonsyndromic cleft lip and palate, *Birth Defects Research, Part A, Clinical and Molecular Teratology* 91 (2011): 50–60.
12. Committee on Dietary Reference Intakes, 1998.
13. O. Dary, Nutritional interpretation of folic acid interventions, *Nutrition Reviews* 67 (2009): 235–244; J. Selhub and coauthors, Folate-vitamin B-12 interaction in relation to cognitive impairment, anemia, and biochemical indicators of vitamin B-12 deficiency, *American Journal of Clinical Nutrition* 89 (2009): 702S–706S; M. D. Thompson, D. E. C. Cole, and J. G. Ray, Vitamin B-12 and neural tube defects: The Canadian experience, *American Journal of Clinical Nutrition* 89 (2009): 697S–701S; G. Varela-Moreiras, M. M. Murphy, and J. M. Scott, Cobalamin, folic acid, and homocysteine, *Nutrition Reviews* 67 (2009): S69–S72; A. D. Smith, Y. I. Kim, and H. Refsum, Is folic acid good for everyone? *American Journal of Clinical Nutrition* 87 (2008): 517–533.
14. R. Cui and coauthors, Dietary folate and vitamin B6 and B12 intake in relation to mortality from cardiovascular diseases: Japan collaborative cohort study, *Stroke* 41 (2010): 1285–1289; A. Imamura and coauthors, Low folate levels may be an atherogenic factor regardless of homocysteine levels in young healthy nonsmokers, *Metabolism* 59 (2010): 728–733; A. Mente and coauthors, A systematic review of the evidence supporting a causal link between dietary factors and coronary heart disease, *Archives of Internal Medicine* 169 (2009): 659–669.
15. J. M. Artmitage and the Study of Effectiveness of Additional Reductions in Cholesterol and Homocysteine (SEARCH) Collaborative Group, Effects of homocysteine-lowering with folic acid plus vitamin B_{12} vs placebo on mortality and major morbidity in myocardial infarction survivors: A randomized trial, *Journal of the American Medical Association* 303 (2010): 2486–2494; P. Tighe and coauthors, A dose-finding trial of the effect of the long-term folic acid intervention: Implications for food fortification policy, *American Journal of Clinical Nutrition* 93 (2011): 11–18; C. M. Albert and coauthors, Effect of folic acid and B vitamins on risk of cardiovascular events and total mortality among women at high risk for cardiovascular disease: A randomized trial, *Journal of the American Medical Association* 299 (2008): 2027–2036; M. Ebbing and coauthors, Mortality and cardiovascular events in patients treated with homocysteine-lowering B vitamins after coronary angiography, *Journal of the American Medical Association* 300 (2008): 795–801; E. Lonn, Homocysteine-lowering B vitamin therapy in cardiovascular prevention: Wrong again? *Journal of the American Medical Association* 299 (2008): 2086–2087.
16. J. W. Crott and coauthors, Moderate folate depletion modulates the expression of selected genes involved in cell cycle, intracellular signaling and folate uptake in human colonic epithelial cell lines, *Journal of Nutritional Biochemistry* 19 (2008): 328–335.
17. V. L. Stevens and coauthors, Folate and other one-carbon metabolism-related nutrients and risk of postmenopausal breast cancer in the Cancer Prevention Study II Nutrition Cohort, *American Journal of Clinical Nutrition* 91 (2010): 1708–1715; M. Ebbing and coauthors, Cancer incidence and mortality after treatment with folic acid and vitamin B_{12}, *Journal of the American Medical Association* 302 (2009): 2119–2126; U. C. Ericson and coauthors, Increased breast cancer risk at high plasma folate concentrations among women with the *MTHFR 677T* allele, *American Journal of Clinical Nutrition* 90 (2009): 1380–1389; S. S. Maruti, C. M. Ulrich, and E. White, Folate and one-carbon metabolism nutrients from supplements and diet in relation to breast cancer risk, *American Journal of Clinical Nutrition* 89 (2009): 624–633; J. B. Mason, Folate, cancer risk, and the Greek god, Proteus: A tale of two chameleons, *Nutrition Reviews* 67 (2009): 206–212; J. Sauer, J. B. Mason, and S. W. Choi, Too much folate: A risk factor for cancer and cardiovascular disease? *Current Opinion in Clinical Nutrition and Metabolic Care* 12 (2009): 30–36.
18. B. M. Oaks and coauthors, Folate intake, post-folic acid grain fortification, and pancreatic cancer risk in the Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial, *American Journal of Clinical Nutrition* 91 (2010): 449–455; A. R. Hart, H. Kennedy, and I. Harvey, Pancreatic

cancer: A review of the evidence on causation, *Clinical Gastroenterology Hepatology* 6 (2008): 275–282; World Cancer Research Fund and American Institute for Cancer Research, *Policy and Action for Cancer Prevention—Food, Nutrition, Physical Activity: A Global Perspective* (Washington, D.C.: AICR, 2009), p. 23.

19. Z. Liu and coauthors, Mild depletion of dietary folate combined with other B vitamins alters multiple components of the Wnt pathway in mouse colon, *Journal of Nutrition* 137 (2007): 2701–2708.
20. V. Ganji and M. R. Kafai, Hemoglobin and hematocrit values are higher and prevalence of anemia is lower in the post-folic acid fortification period than in the pre-folic acid fortification period in US adults, *American Journal of Clinical Nutrition* 89 (2009): 363–371.
21. R. L. Bailey and coauthors, Total folate and folic acid intake from foods and dietary supplements in the United States: 2003–2006, *American Journal of Clinical Nutrition* 91 (2010): 231–237; Q. Yang and coauthors, Folic acid source, usual intake, and folate and vitamin B-12 status in US adults: National Health and Nutrition Examination Survey (NHANES) 2003–2006, *American Journal of Clinical Nutrition* 91 (2010): 64–72.
22. L. H. Allen, How common is vitamin B-12 deficiency? *American Journal of Clinical Nutrition* 89 (2009): 693S–696S.
23. D. K. Dror and L. H. Allen, Effect of vitamin B_{12} deficiency on neurodevelopment in infants: Current knowledge and possible mechanisms, *Nutrition Reviews* 66 (2008): 250–255.
24. Varela-Moreiras, Murphy, and Scott, 2009.
25. L. Feng and coauthors, Vitamin B-12, apolipoprotein E genotype, and cognitive performance in community-living older adults: Evidence of a gene-micronutrient interaction, *American Journal of Clinical Nutrition* 89 (2009): 1263–1268.
26. Varela-Moreiras, Murphy, and Scott, 2009.
27. Allen, 2009; Dary, 2009; R. Green, Is it time for vitamin B-12 fortification? What are the questions? *American Journal of Clinical Nutrition* 89 (2009): 712S–716S; J. W. Miller and coauthors, Metabolic evidence of vitamin B-12 deficiency, including high homocysteine and methylmalonic acid and low holotranscobalamin, is more pronounced in older adults with elevated plasma folate, *American Journal of Clinical Nutrition* 90 (2009): 1586–1592; J. Selhub and coauthors, Folate-vitamin B-12 interaction in relation to cognitive impairment, anemia, and biochemical indicators of vitamin B-12 deficiency, *American Journal of Clinical Nutrition* 89 (2009): 702S–706S; Thompson, Cole, and Ray, 2009.
28. A. Vogiatzoglou and coauthors, Dietary sources of vitamin B-12 and their association with plasma vitamin B-12 concentrations in the general population: The Hordaland Homocysteine Study, *American Journal of Clinical Nutrition* 89 (2009): 1078–1087.
29. S. H. Zeisel and K. A. da Costa, Choline: An essential nutrient for public health, *Nutrition Reviews* 67 (2009): 615–623.
30. Zeisel and da Costa, 2009.
31. J. H. Baron, Sailors' scurvy before and after James Lind—A reassessment, *Nutrition Reviews* 67 (2009): 315–332.
32. M. Simasek and D. A. Blandino, Treatment of the common cold, *American Family Physician* 75 (2007): 515–520.
33. R. M. Douglas and coauthors, Vitamin C for preventing and treating the common cold, *Cochrane Database of Systematic Reviews* 3 (2007): CD000980.
34. B. Barrett and coauthors, Sufficiently important difference for common cold: Severity reduction, *Annals of Family Medicine* 5 (2007): 216–223.
35. Committee on Dietary Reference Intakes, 2000.
36. R. L. Schleicher and coauthors, Serum vitamin C and the prevalence of vitamin C deficiency in the United States: 2003–2004 National Health and Nutrition Examination Survey (NHANES), *American Journal of Clinical Nutrition* 90 (2009): 1252–1263.
37. D. Léger, Scurvy: Reemergence of nutritional deficiencies, *Canadian Family Physician* 54 (2008): 1403–1406.

LEARN IT Present arguments for and against the use of dietary supplements.



© Tanya Constantine/Jupiterimages

Vitamin and Mineral Supplements

An estimated 75,000 supplements are currently on the market. More than half of the adults in the United States take a **dietary supplement** regularly, spending almost $24 billion each year.[1] Many people take supplements as dietary insurance—in case they are not meeting their nutrient needs from foods alone. Others take supplements as health insurance—to protect against certain diseases.

One out of every three people takes multivitamin-mineral supplements daily. Others take large doses of single nutrients, most commonly, vitamin C, B vitamins, vitamin D, and calcium. In many cases, taking supplements is a costly but harmless practice; sometimes, it is both costly and harmful to health.[2]

For the most part, people self-prescribe supplements, taking them on the advice of friends, advertisements, websites, or books that may or may not be reliable. Sometimes, they take supplements on the recommendation of a physician. When such advice follows a valid nutrition assessment, supplementation may be warranted, but even then the preferred course of action is to improve food choices and eating habits.[3] Without an assessment, the advice to take supplements may be inappropriate. A registered dietitian can help with the decision.

When people think of dietary supplements, they often think of vitamins, but a diet that lacks vitamins probably lacks several minerals as well. This highlight asks several questions related to vitamin-mineral supplements. (The accompanying glossary defines dietary supplements and related terms.) What are the arguments *for* taking supplements? What are the arguments *against* taking them? Finally, if people do take supplements, how can they choose the appropriate ones? (Amino acid supplements and herbal supplements are discussed in Chapter 6 and Highlight 18, respectively.)

Arguments for Supplements

Vitamin-mineral supplements may be appropriate in some circumstances. In some cases, they can prevent or correct deficiencies; in others, they can reduce the risk of diseases. Consumers should discuss supplement use with their health-care professionals, who can help monitor for adverse effects or nutrient-drug interactions.

Correct Overt Deficiencies

In the United States and Canada, adults rarely suffer nutrient deficiency diseases such as scurvy, pellagra, and beriberi, but nutrient deficiencies do still occur. To correct an overt deficiency disease, a physician may prescribe therapeutic doses two to ten times the RDA (or AI) of a nutrient. At such high doses, the supplement is acting as a drug.

Support Increased Nutrient Needs

As Chapters 15 through 17 explain, nutrient needs increase during certain stages of life, making it difficult to meet some of those needs without supplementation. For example, women who lose a lot of blood and therefore a lot of iron during menstruation each month may need an iron supplement. Women of childbearing age need folate supplements to reduce the risks of neural tube defects. Similarly, pregnant women and women who are breastfeeding their infants have exceptionally high nutrient needs and so usually need special supplements. Newborns routinely receive a single dose of vitamin K at birth to prevent abnormal bleeding. Infants may need other supplements as well, depending on whether they are breastfed or receiving formula, and on whether their water contains fluoride.

Improve Nutrition Status

In contrast to the classical deficiencies, which present a multitude of symptoms and are relatively easy to recognize, subclinical deficiencies are subtle and easy to overlook—and they are also more likely to occur. People who do not eat enough food to deliver the needed amounts of nutrients, such as habitual dieters and the elderly, risk developing subclinical deficiencies. Similarly, vegetarians who restrict their use of entire food groups without appropriate substitutions may fail to fully meet their nutrient needs. If there is no way for these people to eat

GLOSSARY

dietary supplement: any pill, capsule, tablet, liquid, or powder that contains vitamins, minerals, herbs, or amino acids; intended to increase dietary intake of these substances.

FDA (Food and Drug Administration): a part of the Department of Health and Human Services' Public Health Service that is responsible for ensuring the safety and wholesomeness of all dietary supplements and food processed and sold in interstate commerce except meat, poultry, and eggs (which are under the jurisdiction of the USDA); inspecting food plants and imported foods; and setting standards for food composition and product labeling.

high potency: 100% or more of the Daily Value for the nutrient in a single supplement and for at least two-thirds of the nutrients in a multinutrient supplement.

nanotechnology: a manufacturing technology that manipulates atoms to change the structure of matter.

nanoceuticals: substances with extremely small particles that have been manufactured by nanotechnology.

enough nutritious foods to meet their needs, then vitamin-mineral supplements may be appropriate to help prevent nutrient deficiencies.

Improve the Body's Defenses

Health-care professionals may provide special supplementation to people being treated for addictions to alcohol or other drugs and to people with prolonged illnesses, extensive injuries, or other severe stresses such as surgery. Illnesses that interfere with appetite, eating, or nutrient absorption impair nutrition status. For example, the stomach condition atrophic gastritis often creates a vitamin B_{12} deficiency. In addition, nutrient needs are often heightened by diseases or medications. In all these cases, supplements are appropriate.

Reduce Disease Risks

Few people consume the optimal amounts of all the vitamins and minerals by diet alone. Inadequate intakes have been linked to chronic diseases such as heart disease, some cancers, and osteoporosis. For this reason, some physicians recommend that all adults take vitamin-mineral supplements. Such regular supplementation would provide an optimum intake to enhance metabolic harmony and prevent disease at relatively little cost. Others recognize the lack of conclusive evidence and the potential harm of supplementation and advise against such a recommendation. The most recent statement from the National Institutes of Health acknowledges that evidence is insufficient to recommend either for or against the use of supplements to prevent chronic diseases.

Highlight 11 reviews the relationships between supplement use and disease prevention. It describes some of the accumulating evidence suggesting that intakes of certain nutrients at levels much higher than can be attained from foods alone may be beneficial in reducing some disease risks. It also presents research confirming the associated risks. Clearly, consumers must be cautious in taking supplements to prevent disease.

Who Needs Supplements?

In summary, the following list acknowledges that in these specific conditions, these people may need to take supplements:

- People with specific nutrient deficiencies may need specific nutrient supplements.
- People whose energy intakes are particularly low (fewer than 1600 kcalories per day) may need multivitamin-mineral supplements.
- Vegetarians who eat all-plant diets (vegans) and older adults with atrophic gastritis may need vitamin B_{12}.
- People who have lactose intolerance or milk allergies or who otherwise do not consume enough milk products to forestall extensive bone loss may need calcium.
- People in certain stages of the life cycle who have increased nutrient requirements may need specific nutrient supplements. For example, infants may need vitamin D, iron, and fluoride; women of childbearing age and pregnant women may need folate and iron; and the elderly may need vitamin B_{12} and vitamin D.
- People who have inadequate intakes of milk or milk products, limited sun exposure, or heavily pigmented skin may need vitamin D.
- People who have diseases, infections, or injuries or who have undergone surgery that interferes with the intake, absorption, metabolism, or excretion of nutrients may need specific nutrient supplements.
- People taking medications that interfere with the body's use of specific nutrients may need specific nutrient supplements.

Except for people in these circumstances, most adults can get all the nutrients they need by eating a variety of nutrient-dense foods. Even athletes can meet their nutrient needs without the help of supplements, as Chapter 14 explains.

Arguments against Supplements

Foods rarely cause nutrient imbalances or toxicities, but supplements can. The higher the dose, the greater the risk of harm. People's tolerances for high doses of nutrients vary, just as their risks of deficiencies do. Amounts that some can tolerate may be harmful for others, and no one knows who falls where along the spectrum. It is difficult to determine just how much of a nutrient is enough—or too much. The Tolerable Upper Intake Levels of the DRI answer the question "How much is too much?" by defining the highest amount that appears safe for most healthy people. Table H10-1 presents Upper Levels and Daily Values for selected vitamins and minerals and the quantities typically found in supplements.

Who Should Not Take Supplements?

The following list recognizes that in certain circumstances, these people may need to avoid specific supplements:[4]

- Men and postmenopausal women should not take iron supplements given that excess iron is harmful and generally more likely than inadequacies.
- Smokers should not take beta-carotene supplements given that high doses have been associated with increased lung cancer and mortality.
- Postmenopausal women should not take vitamin A supplements given that excess retinol has been associated with increased risk of hip fractures and reduced bone density.
- Surgery patients should not take vitamin E supplements during the week before surgery because vitamin E acts as a blood thinner.

Toxicity

Supplement users are more likely to have excessive intakes of certain nutrients—notably iron, zinc, vitamin A, and niacin. The extent and severity of supplement toxicity remain unclear. Only a few alert health-care professionals can recognize toxicity, even when it is acute. When it is chronic, with the effects developing subtly and progressing slowly, it often goes unrecognized. In view of the potential hazards, some authorities believe supplements should bear warning labels, advising consumers that large doses may be toxic.

TABLE H10-1 Vitamin and Mineral Intakes for Adults

Nutrient	Tolerable Upper Intake Levels[a]	Daily Values	Typical Multivitamin-Mineral Supplement	Average Single-Nutrient Supplement
Vitamins				
Vitamin A	3000 µg (10,000 IU)	5000 IU	5000 IU	8000 to 10,000 IU
Vitamin D	100 µg (4000 IU)	400 IU	400 IU	1000 to 5,000 IU[b]
Vitamin E	1000 mg (1500 to 2200 IU)[c]	30 IU	30 IU	100 to 1000 IU
Vitamin K	—[d]	80 µg	40 µg	—[f]
Thiamin	—[d]	1.5 mg	1.5 mg	50 mg
Riboflavin	—[d]	1.7 mg	1.7 mg	25 mg
Niacin (as niacinamide)	35 mg[c]	20 mg	20 mg	100 to 500 mg
Vitamin B_6	100 mg	2 mg	2 mg	100 to 200 mg
Folate	1000 µg[c]	400 µg	400 µg	400 µg
Vitamin B_{12}	—[d]	6 µg	6 µg	100 to 1000 µg
Pantothenic acid	—[d]	10 mg	10 mg	100 to 500 mg
Biotin	—[d]	300 µg	30 µg	300 to 600 µg
Vitamin C	2000 mg	60 mg	10 mg	500 to 2000 mg
Choline	3500 mg	—	10 mg	250 mg
Minerals				
Calcium	2500 mg	1000 mg	160 mg	250 to 600 mg
Phosphorus	4000 mg	1000 mg	110 mg	—[f]
Magnesium	350 mg[e]	400 mg	100 mg	250 mg
Iron	45 mg	18 mg	18 mg	18 to 30 mg
Zinc	40 mg	15 mg	15 mg	10 to 100 mg
Iodine	1100 µg	150 µg	150 µg	—[f]
Selenium	400 µg	70 µg	10 µg	50 to 200 µg
Fluoride	10 mg	—	—	—[f]
Copper	10 mg	2 mg	0.5 mg	—[f]
Manganese	11 mg	2 mg	5 mg	—[f]
Chromium	—[d]	120 µg	25 µg	200 to 400 µg
Molybdenum	2000 µg	75 µg	25 µg	—[f]

[a]Unless otherwise noted, Upper Levels represent total intakes from food, water, and supplements.
[b]Most commonly, single supplements are of vitamin D_3 (cholecalciferol); single supplements of vitamin D_2 (ergocalciferol) may provide up to 50,000 IU per dose.
[c]Upper Levels represent intakes from supplements, fortified foods, or both.
[d]These nutrients have been evaluated by the DRI Committee for Tolerable Upper Intake Levels, but none were established because of insufficient data. No adverse effects have been reported with intakes of these nutrients at levels typical of supplements, but caution is still advised, given the potential for harm that accompanies excessive intakes.
[e]Upper Levels represent intakes from supplements only.
[f]Available as a single supplement by prescription.

© Cengage Learning 2013

Toxic overdoses of vitamins and minerals in children are more readily recognized and, unfortunately, fairly common. Fruit-flavored, chewable vitamins shaped like cartoon characters entice young children to eat them like candy in amounts that can cause poisoning. Iron supplements (30 milligrams of iron or more per tablet) are especially toxic and are the leading cause of accidental ingestion fatalities among children. Even mild overdoses cause GI distress, nausea, and black diarrhea, which reflects gastric bleeding. Severe overdoses result in bloody diarrhea, shock, liver damage, coma, and death.

Life-Threatening Misinformation

Another problem arises when people who are ill come to believe that high doses of vitamins or minerals can be therapeutic. Not only can high doses be toxic, but the person may take them instead of seeking medical help. Furthermore, there are no guarantees that the supplements will be effective. Taking vitamin supplements instead of medication may sound appealing, but they do not protect against the progression of heart disease or cancers.[5] In some cases, supplements may even be harmful.[6] Supplements of beta-carotene and vitamin A increased the risk of lung cancer and mortality, especially among smokers.[7] Similarly, supplements of vitamin E increased the risk of prostate cancer among healthy men.[8]

Marketing materials for supplements often make health statements that are required to be "truthful and not misleading," but they often fall far short of both. Highlight 18 revisits this topic and includes a discussion of herbal preparations and other alternative therapies.

Unknown Needs

Another argument against the use of supplements is that no one knows exactly how to formulate the "ideal" supplement. What nutrients should be included? Which, if any, of the phytochemicals should be included? How much of each? On whose needs should the choices be based? Surveys have repeatedly shown little relationship between the supplements people take and the nutrients they actually need.

False Sense of Security

Another argument against supplement use is that it may lull people into a false sense of security. A person might eat irresponsibly, thinking, "My supplement will ensure my needs are met." Or, experiencing a warning symptom of a disease, a person might postpone seeking a diagnosis, thinking, "I probably just need a supplement to make this go away." Such self-diagnosis is potentially dangerous.

Other Invalid Reasons

Other invalid reasons people might use for taking supplements include:

- The belief that the food supply or soil contains inadequate nutrients
- The belief that supplements can provide energy
- The belief that supplements can enhance athletic performance or build lean body tissues without physical work or faster than work alone (see Highlight 14)
- The belief that supplements will help a person cope with stress
- The belief that supplements can prevent, treat, or cure conditions ranging from the common cold to cancer

Ironically, people with health problems are more likely to take supplements than other people, yet today's health problems are more likely to be due to overnutrition and poor lifestyle choices than to nutrient deficiencies. The truth—that most people would benefit from improving their eating and activity patterns—is harder to swallow than a supplement pill.

Bioavailability and Antagonistic Actions

In general, the body absorbs nutrients best from foods in which the nutrients are diluted and dispersed among other substances that may facilitate their absorption. Taken in pure, concentrated form, nutrients are likely to interfere with one another's absorption or with the absorption of nutrients in foods eaten at the same time. Documentation of these effects is particularly extensive for minerals: zinc hinders copper and calcium absorption, iron hinders zinc absorption, calcium hinders magnesium and iron absorption, and magnesium hinders the absorption of calcium and iron. Similarly, binding agents in supplements limit mineral absorption.

Although minerals provide the most-familiar and best-documented examples, interference among vitamins is now being seen as supplement use increases. The vitamin A precursor beta-carotene, long thought to be nontoxic, interferes with vitamin E metabolism when taken over the long term as a dietary supplement. Vitamin E, on the other hand, antagonizes vitamin K activity and so should not be used by people being treated for blood-clotting disorders. Consumers who want the benefits of optimal absorption of nutrients should eat foods selected for nutrient density and variety.

Whenever the diet is inadequate, the person should first attempt to improve it so as to obtain the needed nutrients from foods. If that is truly impossible, then the person needs a multivitamin-mineral supplement that supplies between 50 and 150 percent of the Daily Value for each of the nutrients. These amounts reflect the ranges commonly found in foods and therefore are compatible with the body's normal handling of nutrients (its physiologic tolerance). The next section provides some pointers to assist in the selection of an appropriate supplement.

Selection of Supplements

Whenever a physician or registered dietitian recommends a supplement, follow the directions carefully. When selecting a supplement yourself, look for a single, balanced vitamin-mineral supplement. Supplements with a USP verification logo have been tested by the US Pharmacopeia (USP) to assure that the supplement:

- Contains the declared ingredients and amounts listed on the label
- Does not contain harmful levels of contaminants
- Will disintegrate and release ingredients in the body
- Was made under safe and sanitary conditions

If you decide to take a vitamin-mineral supplement, ignore the eye-catching art and meaningless claims. Pay attention to the form the supplements are in, the list of ingredients, and the price. Here's where the truth lies, and from it you can make a rational decision based on facts. You have two basic questions to answer.

Form

The first question: What form do you want—chewable, liquid, or pills? If you'd rather drink your supplements than chew them, fine. If you choose a chewable form, though, be aware that chewable vitamin C can dissolve tooth enamel. If you choose pills, look for statements about the disintegration time. The USP suggests that supplements should completely disintegrate within 30 to 45 minutes. Obviously, supplements that don't dissolve have little chance of entering the bloodstream, so look for a brand that claims to meet USP disintegration standards.

Contents

The second question: What vitamins and minerals do you need? Generally, an appropriate supplement provides vitamins and minerals in amounts that do not exceed recommended intakes. Avoid supplements that, in a daily dose, provide more than the Upper Level for *any* nutrient. Avoid preparations with more than 10 milligrams of iron per dose, except as prescribed by a physician. Iron is hard to get rid of once it's in the body, and an excess of iron can cause problems, just as a deficiency can (see Chapter 13).

Misleading Claims

Manufacturers of *organic* or natural vitamins boast that their pills are purified from real foods rather than synthesized in a laboratory. These supplements are no more effective than others and often cost more. The word *synthetic* may sound like "fake," but to synthesize just means to put together. Think back on the course of human evolution; it is not natural to take any kind of pill. In reality, the finest, most natural vitamin "supplements" available are whole grains, vegetables, fruits, meat, fish, poultry, eggs, legumes, nuts, and milk and milk products.

Avoid products that make **"high potency"** claims. More is not better (review Figure 10-1 on p. 299). Remember that foods are also providing these nutrients. Nutrients can build up and cause unexpected problems. For example, a man who takes vitamins and begins to lose his hair may think his hair loss means he needs *more* vitamins, when in fact it may be the early sign of a vitamin A overdose. (Of course, it may be completely unrelated to nutrition as well.)

Be aware that fake vitamins and preparations that contain items not needed in human nutrition, such as carnitine and inositol, reflect a marketing strategy aimed at your pocket, not at your health. The manufacturer wants you to believe that its pills contain the latest "new" nutrient that other brands omit, but in reality, these substances are not known to be needed by human beings.

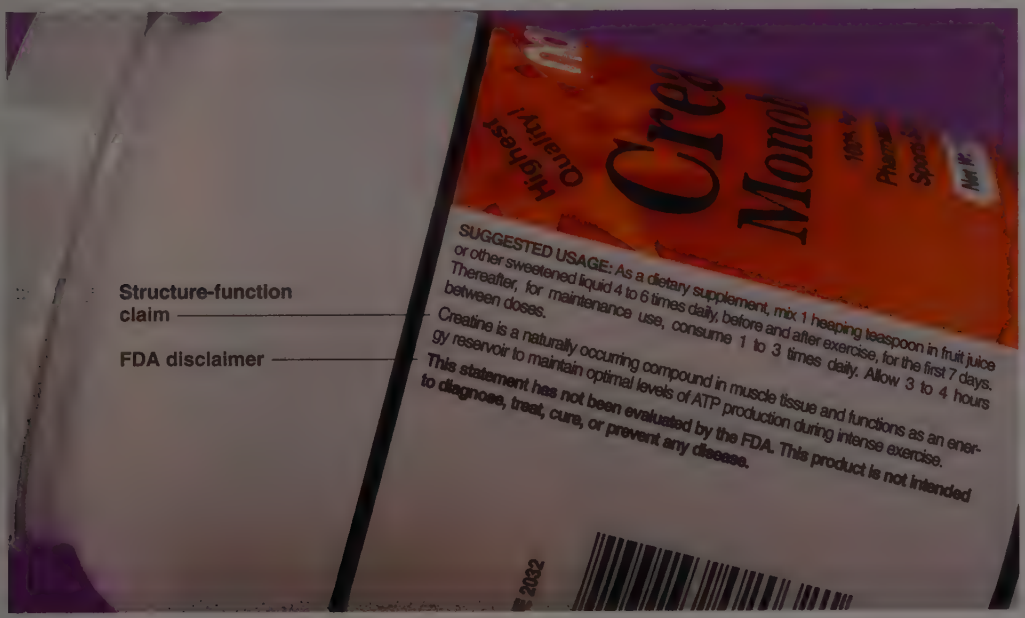
Realize that the claim that supplements "relieve stress" is another marketing ploy. If you give even passing thought to what people mean by "stress," you'll realize manufacturers could never design a supplement to meet everyone's needs. Is it stressful to take an exam? Well, yes. Is it stressful to survive a major car wreck with third-degree burns and multiple bone fractures? Definitely, yes. The body's responses to these stresses are different. The body does use vitamins and minerals in mounting a stress response, but a body fed a well-balanced diet can meet the needs of most minor stresses. For the major ones, medical intervention is needed. In any case, taking a dietary supplement won't make life any less stressful.

Other marketing tricks to sidestep are "green" pills that contain dehydrated, crushed parsley, alfalfa, and other fruit and vegetable extracts. The nutrients and phytochemicals advertised can be obtained from a serving of vegetables more easily and for less money. Such pills may also provide enzymes, but enzymes are inactivated in the stomach during protein digestion.

Recognize the latest nutrition buzzwords. Manufacturers were marketing "antioxidant" supplements before the print had time to dry on the first scientific reports of antioxidant vitamins' action in the body. Remember, too, that high doses can alter a nutrient's action in the body. An antioxidant in physiological quantities may be beneficial, but in pharmacological quantities, it may act as a prooxidant and cause harm. Highlight 11 explores antioxidants and supplement use in more detail.

Similarly, manufacturers began making dietary supplements using **nanotechnology** before the FDA had created guidelines defining their use in consumer products.[9] These **nanoceuticals** promise enhanced nutrient absorption and activity. Such claims may sound good, but again, more does not always mean better.

Finally, be aware that advertising on the Internet is cheap and not closely regulated. Promotional e-mails can be sent to millions of people in an instant. Internet messages can easily cite references and provide links to other sites, implying an endorsement when in fact none has been given. Be cautious when examining unsolicited information and search for a balanced perspective.



Structure-function claims do not need FDA authorization, but they must be accompanied by a disclaimer.

Cost

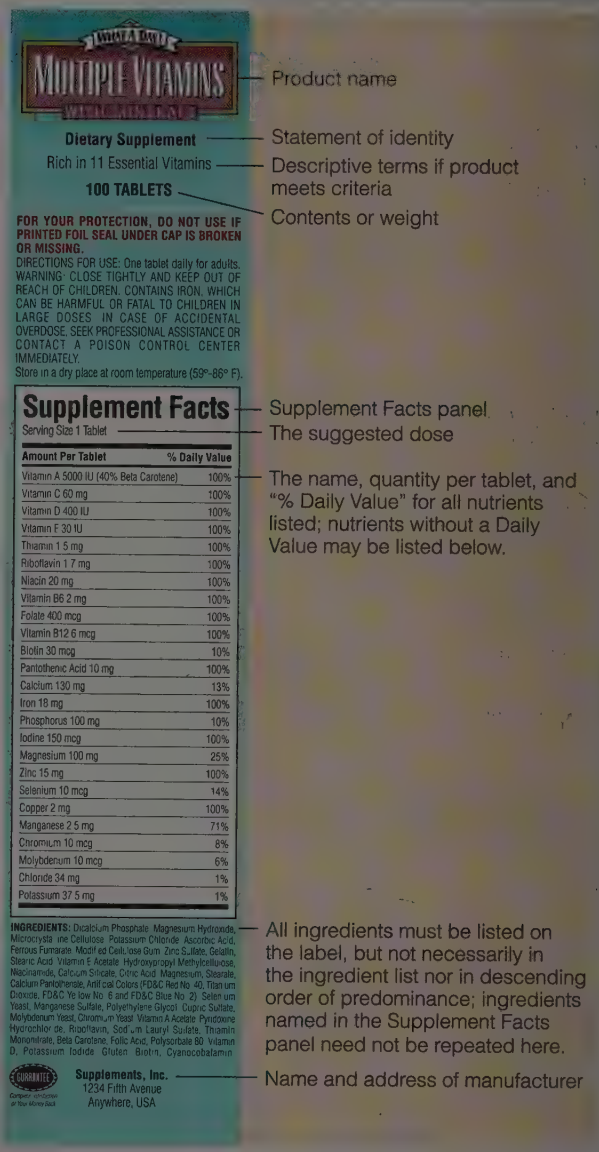
When shopping for supplements, remember that local or store brands may be just as good as nationally advertised brands. If they are less expensive, it may be because the price does not have to cover the cost of national advertising.

Regulation of Supplements

Dietary supplements are regulated by the **FDA (Food and Drug Administration)** as foods. Details of supplement regulation are defined in the Dietary Supplement Health and Education Act of 1994, which was intended to enable consumers to make informed choices about nutrient supplements. The act subjects supplements to the same general labeling requirements that apply to foods. Specifically:

- Nutrition labeling for dietary supplements is required.
- Labels may make nutrient claims (as "high" or "low") according to specific criteria (for example, "an excellent source of vitamin C").
- Labels may claim that the lack of a nutrient can cause a deficiency disease, but if they do, they must also include the prevalence of that deficiency disease in the United States.
- Labels may make health claims that are supported by significant scientific agreement and are not brand specific (for example, "folate protects against neural tube defects").
- Labels may claim to diagnose, treat, cure, or relieve common complaints such as menstrual cramps or memory loss, but may *not* make claims about specific diseases (except as noted previously).
- Labels may make structure-function claims about the role a nutrient plays in the body, how the nutrient performs its function, and how consuming the nutrient is associated with general well-being. The manufacturer is responsible for ensuring that the claims are truthful and not misleading. Claims must be accompanied by an FDA disclaimer statement: "This statement has not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure, or prevent any disease." Figure H10-1 provides an example of a supplement label that complies with the requirements.

> **FIGURE H10-1 An Example of a Supplement Label**



© Cengage Learning 2013

The multibillion-dollar-a-year supplement industry spends much money and effort influencing these regulations. The net effect of the Dietary Supplement Health and Education Act was a deregulation of the supplement industry. Unlike food additives or drugs, supplements do not need to be proved safe and effective, nor do they need the FDA's approval before being marketed. Furthermore, there are no standards for potency or dosage and no requirements for providing warnings of potential side effects. The FDA can only require good manufacturing practices: that dietary supplements be produced and packaged in a quality manner, do not contain contaminants or impurities, and are accurately labeled to reflect the actual contents.

Should a problem arise, the burden falls to the FDA to prove that the supplement poses a "significant or unreasonable risk of illness or injury." Only then would it be removed from the market. When asked, most Americans express support for greater regulation of dietary supplements. Health professionals agree.

If all the nutrients we need can come from food, why not just eat food? Foods have so much more to offer than supplements do. Nutrients in foods come in an infinite variety of combinations with a multitude of different carriers and absorption enhancers. They come with water, fiber, and an array of beneficial phytochemicals. Foods stimulate the GI tract to keep it healthy. They provide energy, and as long as you need energy each day, why not have nutritious foods deliver it? Foods offer pleasure, satiety, and opportunities for socializing while eating. Quite simply, foods meet human health needs far better than dietary supplements.[10] For further proof, read Highlight 11.

REFERENCES

1. J. Gahche and coauthors, Dietary supplement use among US adults has increased since NHANES III (1988–1994), *National Center for Health Statistics: Data Brief* 61 (2011): 1–8; Capitol health call: Dietary supplements, *Journal of the American Medical Association* 301 (2009): 1427.
2. D. B. McCormick, Vitamin/mineral supplements: Of questionable benefit for the general population, *Nutrition Reviews* 68 (2010): 207–213.
3. Position of the American Dietetic Association: Nutrient supplementation, *Journal of the American Dietetic Association* 109 (2009): 2073–2085.
4. Position of the American Dietetic Association, 2009.
5. M. G. O'Doherty and coauthors, Effect of supplementation with B vitamins and antioxidants on levels of asymmetric dimethylarginine (ADMA) and C-reactive protein (CRP): A double-blind, randomized, factorial design, placebo-controlled trial, *European Journal of Nutrition* 49 (2010): 483–492; G. J. Hankey and VITATOPS Trial Study Group, B vitamins in patients with recent transient ischaemic attack or stroke in the VITAmins TO Prevent Stroke (VITATOPS) trial: A randomized, double-blind, parallel, placebo-controlled trial, *The Lancet Neurology* 9 (2010): 855–865; S. Czernichow and coauthors, Effects of long-term antioxidant supplementation and association of serum antioxidant concentrations with risk of metabolic syndrome in adults, *American Journal of Clinical Nutrition* 90 (2009): 329–335; A. M. Hill, J. A. Fleming, and P. M. Kris-Etherton, The role of diet and nutritional supplements in preventing and treating cardiovascular disease, *Current Opinion in Cardiology* 24 (2009): 433–441; M. L. Neuhouser and coauthors, Multivitamin use and risk of cancer and cardiovascular disease in the Women's Health Initiative Cohorts, *Archives of Internal Medicine* 169 (2009): 294–304; G. Pocobelli and coauthors, Use of supplements of multivitamins, vitamin C, and vitamin E in relation to mortality, *American Journal of Epidemiology* 170 (2009): 472–483; H. D. Sesso and coauthors, Vitamins E and C in the prevention of cardiovascular disease in men, *Journal of the American Medical Association* 300 (2008): 2123–2133.
6. G. Bjelakovic and C. Gluud, Vitamin and mineral supplement use in relation to all-cause mortality in the Iowa Women's Health Study, *Archives of Internal Medicine* 171 (2011): 1633–1634.
7. G. Bjelakovic and coauthors, Antioxidant supplements for prevention of mortality in healthy participants and patients with various diseases, *Cochrane Database of Systematic Reviews* 16 (2008): CD007176; J. A. Satia and coauthors, Long-term use of beta-carotene, retinol, lycopene, and lutein supplements and lung cancer risk: Results from the VITamins And Lifestyle (VITAL) Study, *American Journal of Epidemiology* 169 (2009): 1409.
8. E. A. Klein and coauthors, Vitamin E and the risk of prostate cancer: The Selenium and Vitamin E Cancer Prevention Trial (SELECT), *Journal of the American Medical Association* 306 (2011): 1549–1556.
9. FDA opens dialogue on "nano" regulation, www.fda.gov/forconsumers/consumerupdates/ucm258462.html; B. E. Erickson, Dietary supplements made with little government oversight, accessed February 2009, http://pubs.acs.org/cen/government/87/8706gov3.html.
10. D. R. Jacobs Jr, M. D. Gross, and L. C. Tapsell, Food synergy: An operational concept for understanding nutrition, *American Journal of Clinical Nutrition* 89 (2009): 1543S–1548S.



CENGAGE LEARNING'S GLOBAL NUTRITION
GLOBAL NUTRITION RESOURCE CENTER

The fat-soluble vitamins are intricately bound through shared receptors. Learn more about their relationships and how scientists continue to debate appropriate recommendations for each by going to Nutrition Basics and Tools → Vitamins, Minerals, and Water.

11 The Fat-Soluble Vitamins: A, D, E, and K

Nutrition in Your Life

Realizing that vitamin A from vegetables participates in vision, a mom encourages her children to "eat your carrots" because "they're good for your eyes." A dad takes his children outside to "enjoy the fresh air and sunshine" because they need the vitamin D that is made with the help of the sun. A physician recommends that a patient use vitamin E to slow the progression of heart disease. Another physician gives a newborn a dose of vitamin K to protect against life-threatening blood loss. These common daily occurrences highlight some of the heroic work of the fat-soluble vitamins. In the Nutrition Portfolio at the end of this chapter, you can determine whether the foods you are eating are meeting your fat-soluble vitamin needs.

The fat-soluble vitamins A, D, E, and K differ from the water-soluble vitamins in several significant ways (review Table 10-2 on p. 300). Being insoluble in the watery juices of the GI tract, the fat-soluble vitamins require bile for their digestion and absorption. Upon absorption, fat-soluble vitamins travel through the lymphatic system within chylomicrons before entering the bloodstream, where many of them require protein carriers for transport. The fat-soluble vitamins participate in numerous activities throughout the body, but excesses are stored primarily in the liver and adipose tissue. The body maintains blood concentrations by retrieving these vitamins from storage as needed; thus people can eat less than their daily need for days, weeks, or even months or years without ill effects. They need only ensure that, over time, *average* daily intakes approximate recommendations. By the same token, because fat-soluble vitamins are not readily excreted, the risk of toxicity is greater than it is for the water-soluble vitamins.

LEARNING GPS

11.1 Vitamin A and Beta-Carotene 340

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin A.

- Roles in the Body 340
- Vitamin A Deficiency 342
- Vitamin A Toxicity 344
- Vitamin A Recommendations 345
- Vitamin A in Foods 345

11.2 Vitamin D 347

LEARN IT Identify the main roles, deficiency symptoms, and sources for vitamin D.

- Roles in the Body 347
- Vitamin D Deficiency 348
- Vitamin D Toxicity 350
- Vitamin D Recommendations and Sources 350

11.3 Vitamin E 353

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin E.

- Vitamin E as an Antioxidant 353
- Vitamin E Deficiency 353
- Vitamin E Toxicity 353
- Vitamin E Recommendations 353
- Vitamin E in Foods 354

11.4 Vitamin K 354

LEARN IT Identify the main roles, deficiency symptoms, and sources for vitamin K.

- Roles in the Body 354
- Vitamin K Deficiency 355
- Vitamin K Toxicity 355
- Vitamin K Recommendations and Sources 356

Highlight 11 Antioxidant Nutrients in Disease Prevention 360

LEARN IT Describe how antioxidants defend against free radicals that contribute to diseases.

11.1 Vitamin A and Beta-Carotene

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin A.

Vitamin A was the first fat-soluble vitamin to be recognized. More than a century later, vitamin A and its precursor, **beta-carotene**, continue to intrigue researchers with their diverse roles and profound effects on health.

Three different forms of vitamin A are active in the body: **retinol, retinal,** and **retinoic acid.** Collectively, these compounds are known as **retinoids.** Foods derived from animals provide compounds (retinyl esters) that are readily digested and absorbed as retinol in the intestine. Foods derived from plants provide **carotenoids,** some of which can be converted to vitamin A.* The most studied of the carotenoids with **vitamin A activity** is beta-carotene, which can be split to form retinol in the intestine and liver.[2] Beta-carotene's absorption and conversion are significantly less efficient than those of the retinoids. Figure 11-1 illustrates the structural similarities and differences of these vitamin A compounds and the cleavage of beta-carotene.

The cells can convert retinol and retinal to the other active forms of vitamin A as needed. The conversion of retinol to retinal is reversible, but the further conversion of retinal to retinoic acid is irreversible (see Figure 11-2). This irreversibility is significant because each form of vitamin A performs a function that the others cannot.

Several proteins participate in the digestion and absorption of vitamin A. After absorption via the lymph system, vitamin A eventually arrives at the liver, where it is stored. There, a special transport protein, **retinol-binding protein (RBP),** picks up vitamin A from the liver and carries it in the blood. Cells that use vitamin A have special protein receptors for it, and its action within each cell may differ depending on the receptor. For example, retinoic acid can stimulate cell growth in the skin and inhibit cell growth in tumors.[3]

vitamin A: all naturally occurring compounds with the biological activity of *retinol* (RET-ih-nol), the alcohol form of vitamin A.

beta-carotene (BAY-tah KARE-oh-teen): one of the carotenoids; an orange pigment and vitamin A precursor found in plants.

retinol (RET-ih-nol): the alcohol form of vitamin A.

retinal (RET-ih-nal): the aldehyde form of vitamin A.

retinoic (RET-ih-NO-ick) **acid:** the acid form of vitamin A.

retinoids (RET-ih-noyds): chemically related compounds with biological activity similar to that of retinol; metabolites of retinol.

carotenoids (kah-ROT-eh-noyds): pigments commonly found in plants and animals, some of which have vitamin A activity. The carotenoid with the greatest vitamin A activity is beta-carotene.

vitamin A activity: a term referring to both the active forms of vitamin A and the precursor forms in foods without distinguishing between them.

retinol-binding protein (RBP): the specific protein responsible for transporting retinol.

Roles in the Body

Vitamin A is a versatile vitamin, known to regulate the expression of several hundred genes. Its major roles include:

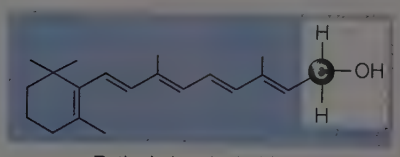
- Promoting vision
- Participating in protein synthesis and cell differentiation, thereby maintaining the health of epithelial tissues and skin
- Supporting reproduction and regulating growth

As mentioned, each form of vitamin A performs specific tasks. Retinol supports reproduction and is the major transport and storage form of the vitamin.

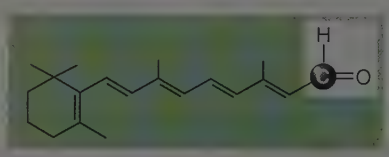
*Carotenoids with vitamin A activity include alpha-carotene, beta-carotene, and beta-cryptoxanthin; carotenoids with no vitamin A activity include lycopene, lutein, and zeaxanthin.

> FIGURE 11-1 Forms of Vitamin A

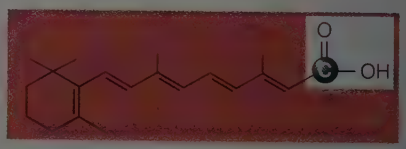
In this diagram, corners represent carbon atoms, as in all previous diagrams in this book. A further simplification here is that methyl groups (CH_3) are understood to be at the ends of the lines extending from corners. (See Appendix C for complete structures.)



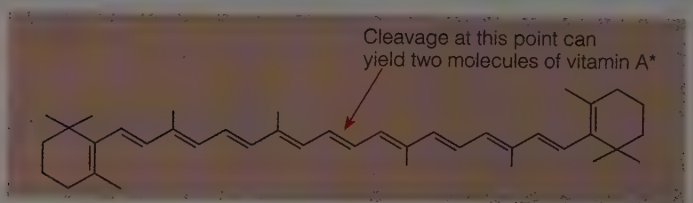
Retinol, the alcohol form



Retinal, the aldehyde form



Retinoic acid, the acid form



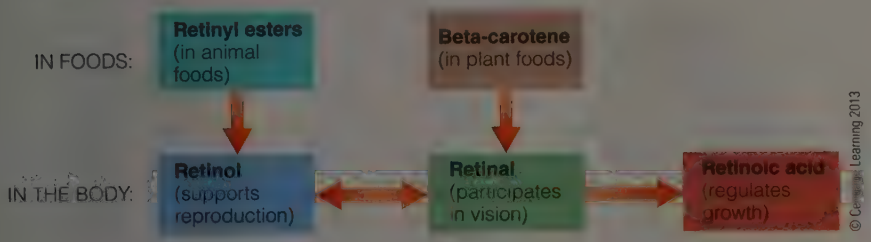
Beta-carotene, a precursor

*Sometimes cleavage occurs at other points as well, so that one molecule of beta-carotene may yield only one molecule of vitamin A. Furthermore, not all beta-carotene is converted to vitamin A, and absorption of beta-carotene is not as efficient as that of vitamin A. For these reasons, 12 µg of beta-carotene are equivalent to 1 µg of vitamin A. Conversion of other carotenoids to vitamin A is even less efficient.

© Cengage Learning 2013

> FIGURE 11-2 Conversion of Vitamin A Compounds

Notice that the conversion from retinol to retinal is reversible, whereas the pathway from retinal to retinoic acid is not.



Retinal is active in vision and is also an intermediate in the conversion of retinol to retinoic acid (review Figure 11-2). Retinoic acid acts like a hormone, regulating cell differentiation, growth, and embryonic development. Animals raised on retinoic acid as their sole source of vitamin A can grow normally, but they become blind because retinoic acid cannot be converted to retinal (review Figure 11-2).

Vitamin A in Vision Vitamin A plays two indispensable roles in the eye: it helps maintain a crystal-clear outer window, the **cornea**, and it participates in the conversion of light energy into nerve impulses at the **retina** (see Figure 11-3 for details). Some of the photosensitive cells of the retina contain **pigment** molecules called **rhodopsin**; each rhodopsin molecule is composed of a protein called **opsin** bonded to a molecule of retinal. When light passes through the cornea of the eye and strikes the retina, rhodopsin responds by changing shape and becoming bleached. As it does, the retinal shifts from a *cis* to a *trans* configuration, just as fatty acids do during hydrogenation (see pp. 134–135). The bleached *trans*-retinal cannot remain bonded to opsin. When retinal is released, opsin changes shape, thereby disturbing the membrane of the cell and generating an electrical impulse that travels along the cell's length. At the other end of the cell, the impulse is transmitted to a nerve cell, which conveys the message to the brain. Much of the retinal is then converted back to its active *cis* form and combined with the opsin protein to regenerate the pigment rhodopsin. Some retinal, however, may be oxidized to retinoic acid, a biochemical dead end for the visual process. Visual activity leads to repeated small losses of retinal, necessitating its constant replenishment either directly from foods or indirectly from retinol stores.

Vitamin A in Protein Synthesis and Cell Differentiation Despite its important role in vision, only one-thousandth of the body's vitamin A is in the retina. Much more is in the cells lining the body's surfaces. There, the vitamin participates in

cornea (KOR-nee-uh) the transparent membrane covering the outside of the eye.

retina (RET-in-uh) the innermost membrane of the eye, composed of several layers including one that contains the rods and cones.

pigment: a molecule capable of absorbing certain wavelengths of light so that it reflects only those that we perceive as a certain color.

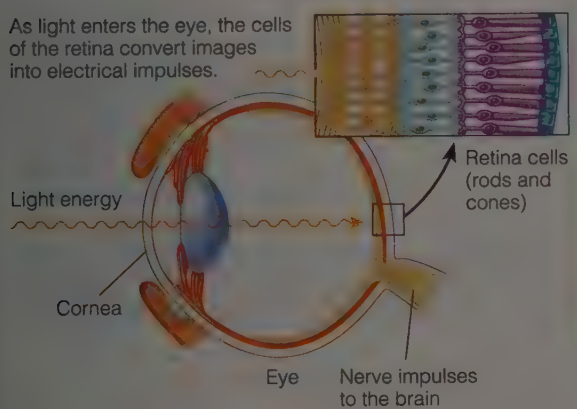
rhodopsin (ro-DOP-sin) a light-sensitive pigment of the retina that contains the retinal form of vitamin A and the protein opsin.

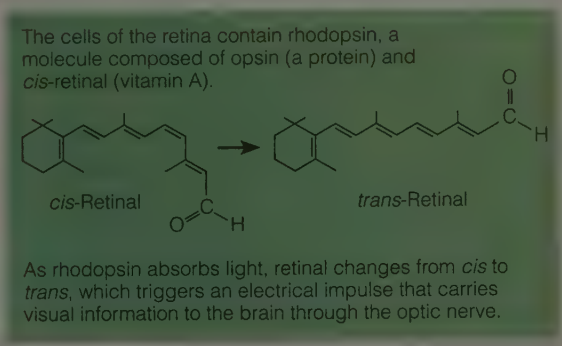
- **rhod** = red (pigment)
- **opsin** = visual protein

opsin (OP-sin) the protein portion of visual pigment molecules.

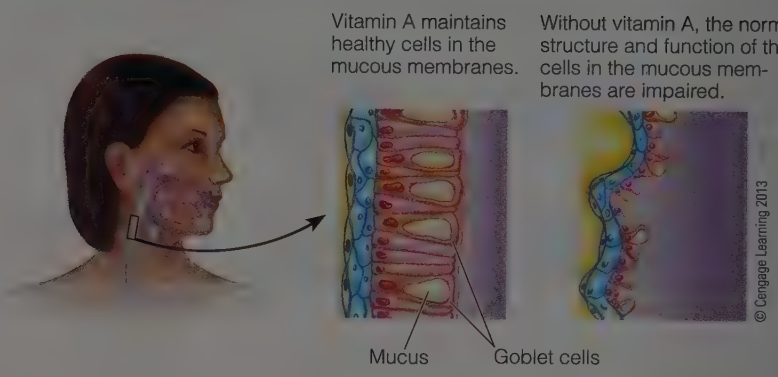
> FIGURE 11-3 *Animated* Vitamin A's Role in Vision

More than 100 million photosensitive cells reside in the retina, and each contains about 30 million molecules of vitamin A-containing visual pigments. The rods contain the rhodopsin pigment and respond to faint light; the cones contain the iodopsin pigment and function in color vision.





> FIGURE 11-4 Mucous Membrane Integrity



protein synthesis and **cell differentiation,** a process by which each type of cell develops to perform a specific function.

All body surfaces, both inside and out, are covered by layers of cells known as **epithelial cells.** The **epithelial tissue** on the outside of the body is, of course, the skin—and vitamin A helps to protect against skin damage from sunlight. The epithelial tissues that line the inside of the body are the **mucous membranes:** the linings of the mouth, stomach, and intestines; the linings of the lungs and the passages leading to them; the linings of the urinary bladder and urethra; the linings of the uterus and vagina; and the linings of the eyelids and sinus passageways. Within the body, the mucous membranes of the GI tract alone line an area larger than a quarter of a football field, and vitamin A helps to maintain their integrity (see Figure 11-4).

Vitamin A promotes differentiation of epithelial cells and goblet cells, one-celled glands that synthesize and secrete mucus. Mucus coats and protects the epithelial cells from invasive microorganisms and other potentially damaging substances, such as gastric juices.

Vitamin A in Reproduction and Growth As mentioned, vitamin A also supports reproduction and regulates growth.[4] In men, retinol participates in sperm development, and in women, vitamin A supports normal fetal development during pregnancy. Children lacking vitamin A fail to grow; given vitamin A supplements, these children gain weight and grow taller.

The growth of bones illustrates that growth is a complex phenomenon of **remodeling.** To convert a small bone into a large bone, the bone-remodeling cells must "undo" some parts of the bone as they go, and vitamin A participates in the dismantling.* The cells that break down bone contain sacs of degradative enzymes.** With the help of vitamin A, these enzymes destroy selected sites in the bone, removing the parts that are not needed.

♦ Key antioxidant nutrients:
- Vitamin C, vitamin E, beta-carotene
- Selenium

Beta-Carotene as an Antioxidant In the body, beta-carotene serves primarily as a vitamin A precursor.[5] Not all dietary beta-carotene is converted to active vitamin A, however. Some beta-carotene may act as an antioxidant ♦ capable of protecting the body against disease. (Highlight 11 provides details.)

Vitamin A Deficiency

Vitamin A status depends mostly on the adequacy of vitamin A stores, 90 percent of which are in the liver. Vitamin A status also depends on a person's protein status because retinol-binding protein serves as the vitamin's transport carrier inside the body.

If a person were to stop eating vitamin A–containing foods, deficiency symptoms would not begin to appear until after stores were depleted—1 to 2 years for a healthy adult but much sooner for a growing child. Then the consequences would

cell differentiation (DIF-er-EN-she-AY-shun): the process by which immature cells develop specific functions different from those of the original that are characteristic of their mature cell type.

epithelial (ep-i-THEE-lee-ul) **cells:** cells on the surface of the skin and mucous membranes.

epithelial tissue: the layer of the body that serves as a selective barrier between the body's interior and the environment. Examples are the cornea of the eyes, the skin, the respiratory lining of the lungs, and the lining of the digestive tract.

mucous (MYOO-kus) **membranes:** the membranes, composed of mucus-secreting cells, that line the surfaces of body tissues.

remodeling: the dismantling and re-formation of a structure.

*The cells that destroy bone during growth are *osteoclasts;* those that build bone are *osteoblasts.*
**The sacs of degradative enzymes are *lysosomes* (LYE-so-zomes).

be profound and severe.[6] Vitamin A deficiency is uncommon in the United States, but it is a major nutrition problem in many developing countries. An estimated 250 million children worldwide have some degree of vitamin A deficiency and thus are vulnerable to infectious diseases and blindness. About 1 to 2 percent of them become blind every year, half of them dying within a year of losing their sight. Routine vitamin A supplementation and food fortification can be a life-saving intervention.[7]

Infectious Diseases Vitamin A supports immune function and inhibits replication of the measles virus.[8] In developing countries around the world, measles is a devastating infectious disease, killing 450 children each day.[9] The severity of the illness often correlates with the degree of vitamin A deficiency; deaths are usually due to related infections such as pneumonia and severe diarrhea. Providing large doses of vitamin A reduces the risk of dying from these infections by half.

The World Health Organization (WHO) and UNICEF (the United Nations International Children's Emergency Fund) have made the control of vitamin A deficiency a major goal in their quest to improve child health and survival throughout the developing world. They recommend two doses of vitamin A supplements, given 24 hours apart, for all children with measles. In the United States, the American Academy of Pediatrics recommends vitamin A supplements for certain groups of measles-infected infants and children. Vitamin A supplements also protect against blindness and the complications of other life-threatening infections, including malaria, lung diseases, and HIV (human immunodeficiency virus, the virus that causes AIDS).

Night Blindness Night blindness is one of the first detectable signs of vitamin A deficiency and permits early diagnosis. In night blindness, the retina does not receive enough retinal to regenerate the visual pigments bleached by light. The person loses the ability to recover promptly from the temporary blinding that follows a flash of bright light at night or to see after dark. In many parts of the world, after the sun goes down, vitamin A–deficient people become night-blind. They often cling to others or sit still, afraid that they may trip and fall or lose their way if they try to walk alone. Figure 11-5 shows the eyes' slow recovery in response to a flash of bright light in night blindness.

Blindness (Xerophthalmia) Beyond night blindness is total blindness—failure to see at all. Night blindness is caused by a lack of vitamin A at the back of the eye, the retina; total blindness is caused by a lack of vitamin A at the front of the eye, the cornea. Severe vitamin A deficiency is the leading cause of preventable blindness in the world, causing half a million preschool children to lose their sight each year. Blindness due to vitamin A deficiency, known as **xerophthalmia**, develops in stages. At first, the cornea becomes dry and hard because of inadequate mucous

night blindness: slow recovery of vision after flashes of bright light at night or an inability to see in dim light; an early symptom of vitamin A deficiency.

xerophthalmia (zer-off-THAL-mee-uh). progressive blindness caused by inadequate mucus production due to severe vitamin A deficiency.

- **xero** = dry
- **ophthalm** = eye

> **FIGURE 11-5 Vitamin A–Deficiency Symptom—Night Blindness**

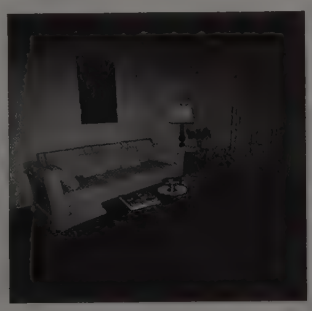
These photographs illustrate the eyes' slow recovery in response to a flash of bright light at night. In animal research studies, the response rate is measured with electrodes.



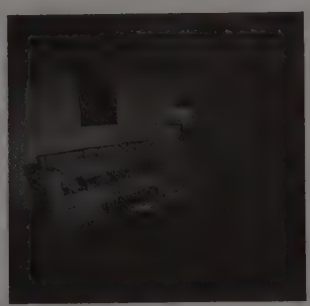
In dim light, you can make out the details in this room. You are using your rods for vision.



A flash of bright light momentarily blinds you as the pigment in the rods is bleached.



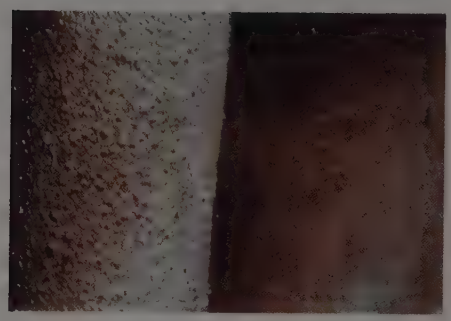
You quickly recover and can see the details again in a few seconds.



With inadequate vitamin A, you do not recover but remain blinded for many seconds.

© David Farr/Image Smythe (all)

> **FIGURE 11-6 Vitamin A–Deficiency Symptom—The Rough Skin of Keratinization**



© H. Sanstead/ U. of Texas/Galveston

In vitamin A deficiency, the epithelial cells secrete the protein keratin in a process known as *keratinization*. (Keratinization doesn't occur in the GI tract, but mucus-producing cells dwindle and mucus production declines.) The extreme of this condition is *hyperkeratinization* or *hyperkeratosis*. When keratin accumulates around hair follicles, the condition is known as *follicular hyperkeratosis*.

♦ Multivitamin supplements typically provide:
- 750 µg (2500 IU)
- 1500 µg (5000 IU)

For perspective, the RDA for vitamin A is 700 mg for women and 900 µg for men.

♦ For perspective, 10,000 IU ≈ 3000 µg vitamin A, roughly four times the RDA for women.

xerosis (zee-ROW-sis): abnormal drying of the skin and mucous membranes; a sign of vitamin A deficiency.

keratomalacia (KARE-ah-toe-ma-LAY-shuh): softening of the cornea that leads to irreversible blindness; a sign of severe vitamin A deficiency.

keratin (KARE-uh-tin): a water-insoluble protein; the normal protein of hair and nails.

keratinization: accumulation of keratin in a tissue; a sign of vitamin A deficiency.

preformed vitamin A: dietary vitamin A in its active form.

teratogen (ter-AT-oh-jen): a substance that causes abnormal fetal development and birth defects.

acne: a chronic inflammation of the skin's follicles and oil-producing glands, which leads to an accumulation of oils inside the ducts that surround hairs; usually associated with the maturation of young adults.

production—a condition known as **xerosis.** Then xerosis quickly progresses to **keratomalacia,** the softening of the cornea that leads to irreversible blindness.

Keratinization Elsewhere in the body, vitamin A deficiency affects other surfaces. On the body's outer surface, the epithelial cells change shape and begin to secrete the protein **keratin**—the hard, inflexible protein of hair and nails. As Figure 11-6 shows, the skin becomes dry, rough, and scaly as lumps of keratin accumulate **(keratinization).** Without vitamin A, the goblet cells in the GI tract diminish in number and activity, limiting the secretion of mucus. With less mucus, normal digestion and absorption of nutrients falter, and this, in turn, worsens malnutrition by limiting the absorption of whatever nutrients the diet may deliver. Similar changes in the cells of other epithelial tissues weaken defenses, making infections of the respiratory tract, the GI tract, the urinary tract, the vagina, and inner ear likely.

Vitamin A Toxicity

Just as a deficiency of vitamin A affects all body systems, so does a toxicity. Symptoms of toxicity begin to develop when all the binding proteins are loaded, and vitamin A is free to damage cells. Such effects are unlikely when a person depends on a balanced diet for nutrients, but toxicity is a real possibility when concentrated amounts of **preformed vitamin A** in foods derived from animals, fortified foods, or supplements is consumed.[10] Children are most vulnerable to toxicity because they need less vitamin A and are more sensitive to overdoses. An Upper Level (UL) has been set for preformed vitamin A (see inside front cover). Even multivitamin supplements ♦ provide more vitamin A than most people need.

Beta-carotene, which is found in a wide variety of fruits and vegetables, is not converted efficiently enough in the body to cause vitamin A toxicity; instead, it is stored in the fat just under the skin. Although overconsumption of beta-carotene from foods may turn the skin yellow, this is not harmful (see Figure 11-7). In contrast, overconsumption of beta-carotene from supplements may be quite harmful. In excess, this antioxidant may act as a prooxidant (as Highlight 11 explains). Adverse effects of beta-carotene supplements are most evident in people who drink alcohol and smoke cigarettes.

Bone Defects Excessive intake of vitamin A over the years may weaken the bones and contribute to fractures and osteoporosis.[11] Vitamin A suppresses bone-building activity, stimulates bone-dismantling activity, and interferes with vitamin D's ability to maintain normal blood calcium.

Birth Defects Excessive vitamin A during pregnancy leads to abnormal cell death in the spinal cord, which increases the risk of birth defects.[12] In such cases, vitamin A is considered a **teratogen.** High intakes (10,000 IU ♦ of supplemental vitamin A daily) before the seventh week of pregnancy appear to be the most damaging. For this reason, vitamin A is not given as a supplement in the first trimester of pregnancy without specific evidence of deficiency, which is rare.

Not for Acne Adolescents need to know that massive doses of vitamin A have no beneficial effect on **acne.** The prescription medicine Accutane is made from vitamin A but is chemically different.* Taken orally, Accutane is effective against the deep lesions of cystic acne. It is highly toxic, however, especially during growth, and has caused birth defects in infants when women have taken it during their pregnancies. For this reason, women taking Accutane must agree to pregnancy testing and to using contraception from at least 1 month before taking the drug through at least 1 month after discontinuing its use.[13] Should they become pregnant, they need to stop taking Accutane immediately and notify their physician.

Another vitamin A relative, Retin-A, fights acne, the wrinkles of aging, and other skin disorders.** Applied topically, this ointment smooths and softens skin; it also lightens skin that has become darkly pigmented after inflammation. During treatment, the skin becomes red and tender and peels.

*The generic name for Accutane is *isotretinoin*.
**The generic name for Retin-A is *tretinoin topical*.

>How To

Convert International Units (IU) to Weight Measurements

Supplement labels often list the amount of fat-soluble vitamins in International Units (IU), a universally accepted measure of a vitamin's biological effect. Such a measure allows scientists to compare the potency of substances and was most useful decades ago before chemicals could be purified and weighed accurately.

Because IU measures biological activity and not weight, the conversion factors differ for each fat-soluble vitamin:

For vitamin A (retinol):

- 1 IU = 0.3 µg
- 1 µg = 3.33 IU

For vitamin D (cholecalciferol):

- 1 IU = 0.025 µg
- 1 µg = 40 IU

For vitamin E (natural α-tocopherol):

- 1 IU = 0.67 mg
- 1 mg = 1.49 IU

To convert from IU to a weight measurement, multiply IU by the appropriate equivalent. For example, for a supplement listing 5000 IU vitamin A, 400 IU vitamin D, and 30 IU vitamin E:

5000 IU X 0.3 µg/IU = 1500 µg retinol

400 IU X 0.025 µg/IU = 10 µg cholecalciferol

30 IU X 0.67 mg/IU = 20 mg α-tocopherol

TRY IT Convert these values on a supplement label from IU to weight measurements: 4000 IU vitamin A, 600 IU vitamin D, and 12 IU vitamin E.

> **FIGURE 11-7 Symptom of Beta-Carotene Excess—Discoloration of the Skin**



© 2002 Massachusetts Medical Society

The hand on the right shows the skin discoloration that occurs when blood levels of beta-carotene rise in response to a low-kcalorie diet that features carrots, pumpkins, and orange juice. (The hand on the left belongs to someone else and is shown here for comparison.)

Vitamin A Recommendations Because the body can derive vitamin A from various retinoids and carotenoids, its content in foods and its recommendations are expressed as **retinol activity equivalents (RAE).** One microgram of retinol counts as 1 RAE, ♦ as does 12 micrograms of dietary beta-carotene. Most food and supplement labels report their vitamin A contents using International Units (IU), ♦ a measure of vitamin activity used before direct chemical analysis was possible. The accompanying "How To" feature explains how to convert IU to a weight measurement.

♦ 1 mg RAE
= 1 µg retinol
= 2 µg beta-carotene (supplement)
= 12 µg beta-carotene (dietary)
= 24 µg other vitamin A precursor carotenoids

♦ 1 IU retinol = 0.3 µg retinol or 0.3 µg RAE
1 IU beta-carotene (supplement) = 0.5 IU retinol or 0.15 µg RAE
1 IU beta-carotene (dietary) = 0.165 IU retinol or 0.05 µg RAE
1 IU other vitamin A precursor carotenoids = 0.025 µg RAE

Vitamin A in Foods The richest sources of the retinoids are foods derived from animals—liver, fish liver oils, milk and milk products, butter, and eggs. Because vitamin A is fat soluble, it is lost when milk is skimmed. To compensate, reduced-fat, low-fat, and fat-free milks are often fortified so as to supply 6 to 10 percent of the Daily Value per cup.* Margarine is usually fortified to provide the same amount of vitamin A as butter.

Plants contain no retinoids, but many vegetables and some fruits contain vitamin A precursors—the carotenoids. Only a few carotenoids have vitamin A activity; the carotenoid with the greatest vitamin A activity is beta-carotene. Beta-carotene is a rich, deep yellow, almost orange compound. The beta-carotene in dark green, leafy vegetables is abundant, but masked by large amounts of the green pigment **chlorophyll.** Attractive meals that include colorful fruits and vegetables are likely to provide vitamin A.

The Colors of Vitamin A Foods Dark leafy greens (like spinach—not celery or cabbage) and rich yellow or deep orange vegetables and fruits (such as cantaloupe, carrots, and sweet potatoes—not corn or bananas) help people meet their vitamin A needs (see Figure 11-8 on p. 346). A diet including several servings of such carotene-rich sources helps to ensure a sufficient intake.

Bright color is not always a sign of vitamin A activity, however. Beets and corn, for example, derive their colors from the red and yellow **xanthophylls,** which have no vitamin A activity. As for white plant foods such as potatoes, cauliflower,

*Vitamin A fortification of milk in the United States is required to a level found in whole milk (1200 IU per quart), but many manufacturers commonly fortify to a higher level (2000 IU per quart). Similarly, in Canada all milk that has had fat removed must be fortified with vitamin A.

retinol activity equivalents (RAE): a measure of vitamin A activity; the amount of retinol that the body will derive from a food containing preformed retinol or its precursor, beta-carotene.

chlorophyll (KLO-row-fil): the green pigment of plants, which absorbs light and transfers the energy to other molecules, thereby initiating photosynthesis.

xanthophylls (ZAN-tho-fills): pigments found in plants responsible for the color changes seen in autumn leaves.



© Polara Studios, Inc.

The carotenoids in foods bring colors to meals; the retinoids in our eyes allow us to see them.

pasta, and rice, they also offer little or no vitamin A. Similarly, fast foods often lack vitamin A. Anyone who dines frequently on hamburgers, french fries, and colas is wise to emphasize colorful vegetables and fruits at other meals.

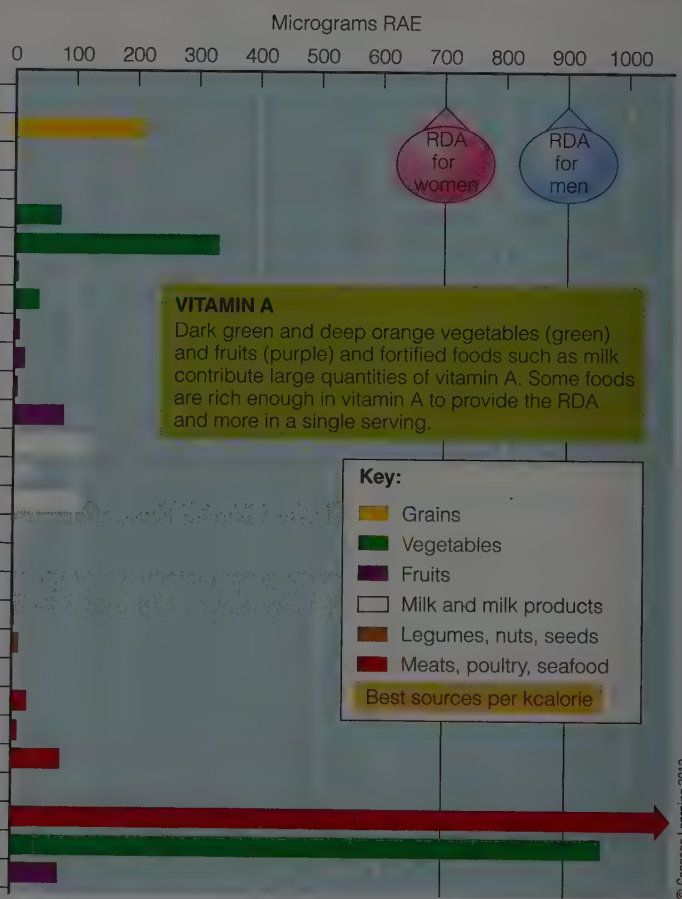
Vitamin A–Rich Liver People sometimes wonder if eating liver too frequently can cause vitamin A toxicity. Liver is a rich source because vitamin A is stored in the livers of animals, just as in humans.* Arctic explorers who have eaten large quantities of polar bear liver have become ill with symptoms suggesting vitamin A toxicity. Liver offers many nutrients, and eating it periodically may improve a person's nutrition status, but caution is warranted not to eat too much too often, especially for pregnant women. With 1 ounce of beef liver providing more than three times the RDA for vitamin A, intakes can rise quickly.

REVIEW IT Identify the main roles, deficiency symptoms, and food sources for vitamin A. Vitamin A is found in the body in three forms: retinol, retinal, and retinoic acid. Together, they are essential to vision, healthy epithelial tissues, and growth. Vitamin A deficiency is a major health problem worldwide, leading to infections, blindness, and keratinization. Toxicity can also cause problems and is most often associated with supplement abuse. Animal-derived foods such as liver and whole or fortified milk provide retinoids, whereas brightly colored plant-derived foods such as spinach, carrots, and pumpkins provide beta-carotene and other carotenoids. In addition to serving as a precursor for vitamin A, beta-carotene acts as an antioxidant in the body. The accompanying table provides a summary of vitamin A.

> FIGURE 11-8 Vitamin A in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk, fortified	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Beef liver	3 oz fried (184 kcal)
Sweet potatoes	½ c cooked (116 kcal)
Mango	1 (135 kcal)



© Cengage Learning 2013

*The liver is not the only organ that stores vitamin A. The kidneys, adrenal glands, and other organs do, too, but the liver stores the most and is the most commonly eaten organ meat.

REVIEW IT Vitamin A (*continued*)

Other Names
Retinol, retinal, retinoic acid; precursors are carotenoids such as beta-carotene
2001 RDA
Men: 900 µg RAE/day Women: 700 µg RAE/day
Upper Level
Adults: 3000 µg/day
Chief Functions in the Body
Vision; maintenance of cornea, epithelial cells, mucous membranes, skin; bone and tooth growth; reproduction; immunity
Significant Sources
Retinol: fortified milk, cheese, cream, butter, fortified margarine, eggs, liver
Beta-carotene: spinach and other dark green, leafy vegetables, broccoli, deep orange fruits (apricots, cantaloupe) and vegetables (squash, carrots, sweet potatoes, pumpkin)

Deficiency Disease
Hypovitaminosis A
Deficiency Symptoms
Night blindness, corneal drying (xerosis), triangular gray spots on eye (Bitot's spots), softening of the cornea (keratomalacia), and corneal degeneration and blindness (xerophthalmia); impaired immunity (infectious diseases); plugging of hair follicles with keratin, forming white lumps (hyperkeratosis)
Toxicity Disease
Hypervitaminosis A[a]
Chronic Toxicity Symptoms
Increased activity of osteoclasts[b] causing reduced bone density; liver abnormalities; birth defects
Acute Toxicity Symptoms
Blurred vision, nausea, vomiting, vertigo; increase of pressure inside skull, mimicking brain tumor; headaches; muscle incoordination

[a]A related condition, *hypercarotenemia*, is caused by the accumulation of too much of the vitamin A precursor beta-carotene in the blood, which turns the skin noticeably yellow. Hypercarotenemia is not, strictly speaking, a toxicity symptom.
[b]*Osteoclasts* are the cells that destroy bone during its growth. Those that build bone are *osteoblasts*

11.2 Vitamin D

LEARN IT Identify the main roles, deficiency symptoms, and sources for vitamin D.

Vitamin D differs from the other nutrients in that the body can synthesize it, with the help of sunlight, from a precursor that the body makes from cholesterol. Therefore, vitamin D is not an essential nutrient; given enough time in the sun, people need no vitamin D from foods.

Also known as **calciferol**, vitamin D comes in two major forms. **Vitamin D_2** (or **ergocalciferol**) derives primarily from plant foods in the diet. **Vitamin D_3** (or **cholecalciferol**) derives from animal foods in the diet and from synthesis in the skin. These two forms of vitamin D are similar and both must be activated before they can fully function.

Figure 11-9 (p. 348) diagrams the pathway for making and activating vitamin D in the body. To make vitamin D, ultraviolet rays from the sun hit a precursor in the skin and convert it to previtamin D_3, which is converted to vitamin D_3 with the help of the body's heat. To activate vitamin D—whether made in the body or consumed from the diet—two hydroxylation reactions must occur. First, the liver adds an OH group, and then the kidneys add another OH group to produce the active vitamin. As you might expect, diseases affecting either the liver or the kidneys can interfere with the activation of vitamin D and produce symptoms of deficiency.

Roles in the Body

Though called a vitamin, the active form of vitamin D is actually a hormone—a compound manufactured by one part of the body that travels through the blood and causes another body part to respond.[14] Like vitamin A, vitamin D has a binding protein that carries it to the target organs—most notably, the intestines, the kidneys, and the bones. All respond to vitamin D by making the minerals needed for bone growth and maintenance available.

Vitamin D in Bone Growth

Vitamin D is a member of a large and cooperative bone-making and maintenance team ♦ composed of nutrients and other compounds, including vitamins A and K; the hormones parathyroid hormone and

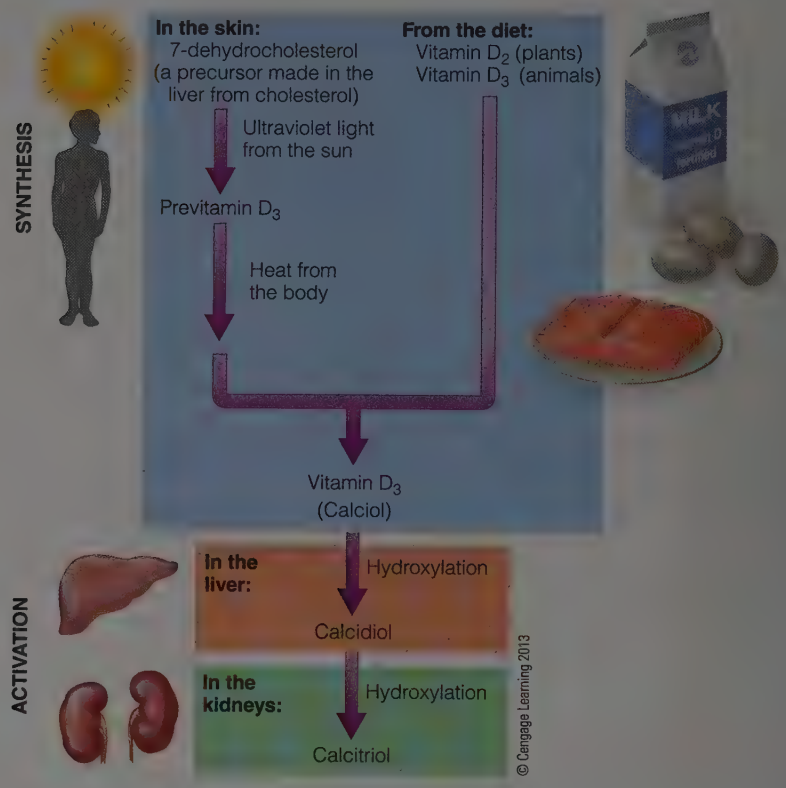
♦ Key bone nutrients:
- Vitamin D, vitamin K, vitamin A
- Calcium, phosphorus, magnesium, fluoride

calciferol (kal-SIF-er-ol): vitamin D.

vitamin D_2 or **ergocalciferol** (ER-go-kal-SIF-er-ol): vitamin D derived from plants in the diet.

vitamin D_3 or **cholecalciferol** (KO-lee-kal-SIF-er-ol) vitamin D derived from animals in the diet or made in the skin from 7-dehydrocholesterol, a precursor of cholesterol, with the help of sunlight.

> **FIGURE 11-9 Vitamin D Synthesis and Activation**
The final activation step in the kidneys is tightly regulated by hormones.



calcitonin; the protein collagen; and the minerals calcium, phosphorus, magnesium, and fluoride. Vitamin D's special role in bone health is to assist in the absorption of calcium and phosphorus, thus helping to maintain blood concentrations of these minerals.[15] The bones grow denser and stronger as they absorb and deposit these minerals. Details of calcium balance and mineral deposition appear in Chapter 12.

Vitamin D raises blood concentrations of bone minerals in three ways. When the diet is sufficient, vitamin D enhances their absorption from the GI tract. When the diet is insufficient, vitamin D provides the needed minerals from other sources: reabsorption by the kidneys and mobilization from the bones into the blood.[16] The vitamin may work alone, as it does in the GI tract, or in combination with parathyroid hormone, as it does in the bones and kidneys.[17]

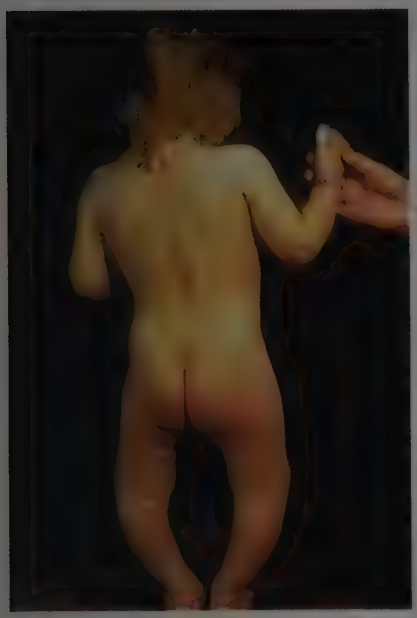
Vitamin D in Other Roles Scientists have discovered many other tissues that respond to vitamin D, including cells of the immune system, brain and nervous system, pancreas, skin, muscles and cartilage, and reproductive organs. In many cases, vitamin D enhances or suppresses the activity of genes that regulate cell growth.[18] As such, it may be valuable in treating a number of diseases.[19] Recent research suggests that vitamin D may protect against tuberculosis, inflammation, multiple sclerosis, macular degeneration, hypertension, and some cancers.[20] Even so, evidence does not support vitamin D supplementation to improve health beyond correcting deficiencies.[21]

Vitamin D Deficiency

Overt signs of vitamin D deficiency are relatively rare, but vitamin D insufficiency is remarkably common.[22] Almost 10 percent of the US population is deficient and another 25 percent are marginal.[23] Factors that contribute to vitamin D deficiency include dark skin, breastfeeding without supplementation, lack of sunlight, and not using fortified milk. In vitamin D deficiency, production of **calbindin,** a protein that binds calcium in the intestinal

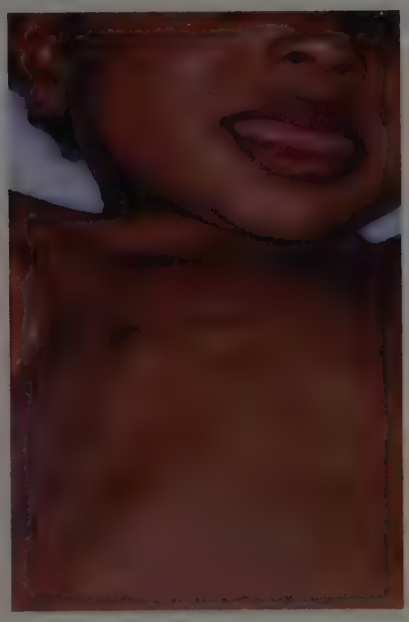
calbindin: a calcium-binding transport protein that requires vitamin D for its synthesis.

> **FIGURE 11-10 Vitamin D–Deficiency Symptoms—Bowed Legs and Beaded Ribs of Rickets**



© Biophoto Associates/Photo Researchers, Inc.

Bowed legs. In rickets, the poorly formed long bones of the legs bend outward as weight-bearing activities such as walking begin.



© Photo Courtesy of Dr. Norman Carvalho at Childrens Healthcare of Atlanta

Beaded ribs. In rickets, a series of "beads" develop where the cartilages and bones attach.

cells, slows. Thus, even when calcium in the diet is adequate, it passes through the GI tract unabsorbed, leaving the bones undersupplied. Consequently, a vitamin D deficiency creates a calcium deficiency and increases the risks of several chronic diseases and osteoporosis.[24] Vitamin D–deficient adolescents do not reach their peak bone mass.[25]

Rickets Worldwide, the prevalence of the vitamin D–deficiency disease **rickets** is extremely high, affecting more than half of the children in countries such as Mongolia, Tibet, and the Netherlands.[26] In the United States, rickets is not common, but when it occurs, black children and adolescents—especially females and overweight teens—are the ones most likely to be affected.[27] To prevent rickets, the American Academy of Pediatrics recommends a supplement for all infants, children, and adolescents who do not receive enough vitamin D.[28]

In rickets, the bones fail to calcify normally, causing growth retardation and skeletal abnormalities. The bones become so weak that they bend when they have to support the body's weight (see Figure 11-10). A child with rickets who is old enough to walk characteristically develops bowed legs, often the most obvious sign of the disease. Another sign is the beaded ribs that result from the poorly formed attachments of the bones to the cartilage.*

Osteomalacia In adults, the poor mineralization of bone results in the painful bone disease **osteomalacia.** The bones become increasingly soft, flexible, brittle, and deformed.

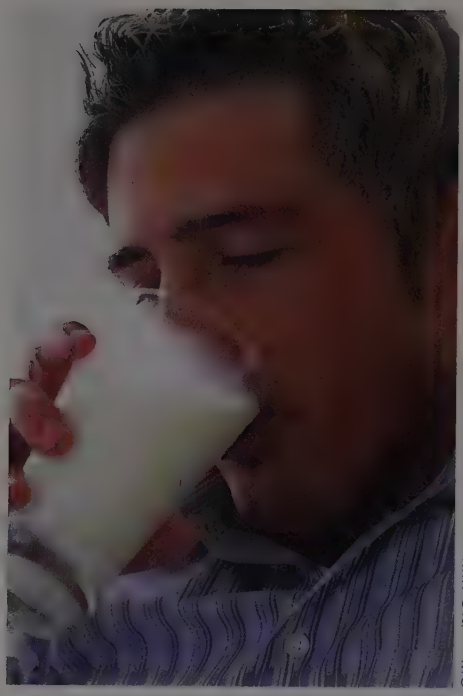
Osteoporosis Any failure to synthesize adequate vitamin D or obtain enough from foods sets the stage for a loss of calcium from the bones, which can result in fractures.[29] Highlight 12 describes the many factors that lead to osteoporosis, a condition of reduced bone density.

rickets: the vitamin D–deficiency disease in children characterized by inadequate mineralization of bone (manifested in bowed legs or knock-knees, outward-bowed chest, and "beads" on ribs). A rare type of rickets, not caused by vitamin D deficiency, is known as *vitamin D–refractory rickets.*

osteomalacia (OS-tee-oh-ma-LAY-shuh) a bone disease characterized by softening of the bones. Symptoms include bending of the spine and bowing of the legs. The disease occurs most often in adult women.

- **osteo** = bone
- **malacia** = softening

*Because the poorly formed rib attachments resemble rosary beads, this symptom is commonly known as *rachitic* (ra-KIT-ik) *rosary* ("the rosary of rickets").



© Westend61 GmbH/Alamy

A cold glass of milk refreshes as it replenishes vitamin D and other bone-building nutrients.

The Elderly Vitamin D deficiency is especially likely in older adults for several reasons. For one, the skin, liver, and kidneys lose their capacity to make and activate vitamin D with advancing age. For another, older adults typically drink little or no milk—the main dietary source of vitamin D. And finally, older adults typically spend much of the day indoors, and when they do venture outside, many of them cautiously wear protective clothing or apply sunscreen to all sun-exposed areas of their skin. Dark-skinned adults living in northern regions are particularly vulnerable. All of these factors increase the likelihood of vitamin D deficiency and its consequences: bone losses and fractures. Vitamin D supplementation helps to raise blood levels, reduce bone loss, improve muscle performance, and lower the risks of falls and fractures in elderly persons.[30]

Vitamin D Toxicity

Vitamin D clearly illustrates how nutrients in optimal amounts support health, but both inadequacies and excesses create harm. Vitamin D is among the most likely of the vitamins to have toxic effects when consumed in excessive amounts. The amounts of vitamin D made by the skin and found in foods are well within the safe limits set by the UL, but supplements containing the vitamin in concentrated form should be kept out of the reach of children and used cautiously, if at all, by adults.

Excess vitamin D raises the concentration of blood calcium.[31]* Excess blood calcium tends to precipitate in the soft tissue, forming stones, especially in the kidneys where calcium is concentrated in an effort to excrete it. Calcification may also harden the blood vessels and is especially dangerous in the major arteries of the brain, heart, and lungs, where it can cause death.

Vitamin D Recommendations and Sources

Only a few foods contain vitamin D naturally. Fortunately, the body can make vitamin D with the help of a little sunshine. In setting dietary recommendations, however, the DRI Committee assumed that no vitamin D was available from skin synthesis. In order to reach sufficient levels of vitamin D in the blood without contributions from the sun, dietary recommendations were recently increased.[32] ♦ Some research suggests that vitamin D recommendations should be higher still.[33]

♦ Vitamin D RDA for adults <71: 15 µg/day (600 IU/day)

Vitamin D in Foods Most adults, especially in sunny regions, need not make special efforts to obtain vitamin D from food. People who are not outdoors much or who live in northern or predominantly cloudy or smoggy areas are advised to drink at least 2 cups of vitamin D–fortified milk a day. The fortification of milk and other foods with vitamin D is the best guarantee that people will meet their needs.[34]** Despite vitamin D fortification, the average intake in the United States falls short of recommendations. Egg yolks and oily fish such as salmon, mackerel, and sardines are the best natural sources of vitamin D.

Meeting vitamin D needs is difficult without adequate sunshine, fortification, or supplementation. Vegetarians who do not include milk in their diets may use vitamin D–fortified soy milk and cereals. Importantly, feeding infants and young children nonfortified "health beverages" instead of milk or infant formula can create severe nutrient deficiencies, including rickets.

Vitamin D from the Sun Most of the world's population relies on natural exposure to sunlight to maintain adequate vitamin D nutrition. The sun imposes no risk of vitamin D toxicity; prolonged exposure to sunlight degrades the vitamin D precursor in the skin, preventing its conversion to the active vitamin.

Prolonged exposure to sunlight can, however, prematurely wrinkle the skin and cause skin cancer. Sunscreens help reduce these risks, but sunscreens with a sun protection factor (SPF) of 8 and higher can also reduce vitamin D synthesis.

*High blood calcium is known as *hypercalcemia* and may develop from a variety of disorders, including vitamin D toxicity. It does *not* develop from a high calcium intake.

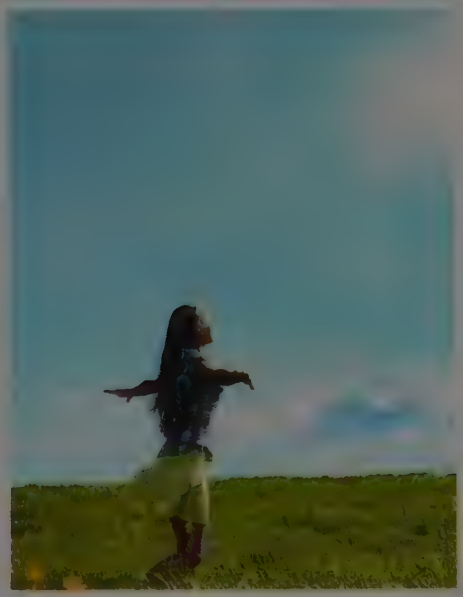
**Vitamin D fortification of milk in the United States is 400 IU per quart; in Canada, 350 to 450 IU per liter.

> FIGURE 11-11 Vitamin D Synthesis and Latitude

Above 40° north latitude (and below 40° south latitude in the southern hemisphere), vitamin D synthesis essentially ceases for the 4 months of winter. Synthesis increases as spring approaches, peaks in summer, and declines again in the fall. People living in regions of extreme northern (or extreme southern) latitudes may miss as much as 6 months of vitamin D production.



© Cengage Learning 2013



© Yellowj/Shutterstock.com

The sunshine vitamin—vitamin D.

Still, even with an SPF 15 to 30 sunscreen, sufficient vitamin D synthesis can be obtained in 10 to 20 minutes of sun exposure.[35] Alternatively, a person could apply sunscreen after enough time has elapsed to provide sufficient vitamin D synthesis. For most people, exposing hands, face, and arms on a clear summer day for 5 to 10 minutes two or three times a week should be sufficient to maintain vitamin D nutrition.

The pigments of dark skin provide some protection from the sun's damage, but they also reduce vitamin D synthesis. Dark-skinned people require longer sunlight exposure than light-skinned people: heavily pigmented skin achieves the same amount of vitamin D synthesis in 3 hours as fair skin in a half hour. Latitude, season, and time of day ♦ also have dramatic effects on vitamin D synthesis and status (see Figure 11-11). Heavy clouds, smoke, or smog block the ultraviolet (UV) rays of the sun that promote vitamin D synthesis. Differences in skin pigmentation, latitude, and smog may account for the finding that African American people, especially those in northern, smoggy cities, are most likely to be vitamin D deficient. Vitamin D deficiency is especially prevalent in the winter and in the Arctic and Antarctic regions of the world.[36] To ensure an adequate vitamin D status, supplements may be needed. The body's vitamin D supplies from summer synthesis alone are insufficient to meet winter needs.[37]

♦ Factors that may limit sun exposure and, therefore, vitamin D synthesis:

- Geographic location (latitude)
- Season of the year
- Time of day
- Air pollution and cloud cover
- Clothing
- Tall buildings
- Indoor living
- Sunscreens



> DIETARY GUIDELINES FOR AMERICANS 2010

Choose foods that provide more vitamin D, a nutrient of concern in American diets. Most dietary vitamin D derives from fortified foods such as milk, yogurt, and breakfast cereals; natural dietary sources of vitamin D include oily fish and egg yolks.

Depending on the radiation used, the UV rays from tanning lamps and tanning beds may also stimulate vitamin D synthesis and increase bone density. The potential hazards of skin damage, however, may outweigh any possible benefits.* The Food and Drug Administration (FDA) warns that if the lamps are not properly filtered, people using tanning booths risk burns, damage to the eyes and blood vessels, and skin cancer.

*The best wavelengths for vitamin D synthesis are UV-B rays between 290 and 310 nanometers. Some tanning parlors advertise "UV-A rays only, for a tan without the burn," but UV-A rays can damage the skin.

Vitamin D from Supplements As mentioned, some people may benefit from taking vitamin D supplements. Vitamin D can be found in multivitamin-mineral supplements as well as a high-dose single supplement. As a single supplement, vitamin D_3 is less expensive, more commonly available, and more potent than vitamin D_2.[38] Taking vitamin D supplements with the largest meal of the day improves absorption, resulting in a 50 percent increase in blood levels.[39]

REVIEW IT Identify the main roles, deficiency symptoms, and sources for vitamin D.

Vitamin D can be synthesized in the body with the help of sunlight or obtained from some foods, most notably fortified milk. Vitamin D sends signals to three primary target sites: the GI tract to absorb more calcium and phosphorus, the bones to release more, and the kidneys to retain more. These actions maintain blood calcium concentrations and support bone formation. A deficiency causes rickets in childhood and osteomalacia in later life. The accompanying table provides a summary of vitamin D.

Vitamin D

Other Names

calciferol (vitamin D)

ergocalciferol (vitamin D_2): vitamin D derived from plants in the diet and made from the yeast and plant sterol ergosterol.

cholecalciferol (vitamin D_3 or calciol): vitamin D derived from animals in the diet or made in the skin from 7-dehydrocholesterol, a precursor of cholesterol, with the help of sunlight.

calcidiol (25-hydroxyvitamin D): vitamin D found in the blood that is made from the hydroxylation of calciol in the liver.

calcitriol (1,25-dihydroxyvitamin D): vitamin D that is made from the hydroxylation of calcidiol in the kidneys; the biologically active hormone, sometimes called *active vitamin D*.

2011 RDA

Adults: 15 µg/day or 600 IU/day (19–70 yr)
20 µg/day or 800 IU/day (>70 yr)

Upper Level

Adults: 100 µg/day or 4000 IU/day

Chief Functions in the Body

Mineralization of bones (raises blood calcium and phosphorus by increasing absorption from digestive tract, withdrawing calcium from bones, stimulating retention by kidneys)

Significant Sources

Synthesized in the body with the help of sunlight; fortified milk, margarine, butter, juices, cereals, and chocolate mixes; veal, beef, egg yolks, liver, fatty fish (herring, salmon, sardines) and their oils

Deficiency Diseases

Rickets, osteomalacia

Deficiency Symptoms

Rickets in children:

Inadequate calcification, resulting in misshapen bones (bowing of legs); enlargement of ends of long bones (knees, wrists); deformities of ribs (bowed, with beads or knobs);[a] delayed closing of fontanel, resulting in rapid enlargement of head (see figure below); lax muscles resulting in protrusion of abdomen; muscle spasms

Osteomalacia or osteoporosis in adults:

Loss of calcium, resulting in soft, flexible, brittle, and deformed bones; progressive weakness; pain in pelvis, lower back, and legs

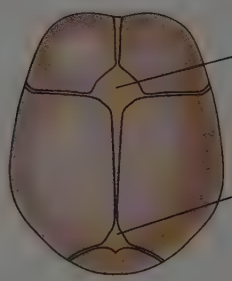
Toxicity Disease

Hypervitaminosis D

Toxicity Symptoms

Elevated blood calcium; calcification of soft tissues (blood vessels, kidneys, heart, lungs, tissues around joints)

Fontanel
A fontanel is an open space in the top of a baby's skull before the bones have grown together. In rickets, closing of the fontanel is delayed.



[a]Bowing of the ribs causes the symptoms known as *pigeon breast*. The beads that form on the ribs resemble rosary beads; thus this symptom is known as *rachitic* (ra-KIT-ik) *rosary* ("the rosary of rickets").

11.3 Vitamin E

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin E.

Researchers discovered a component of vegetable oils necessary for reproduction in rats and named this antisterility factor **tocopherol,** which means "to bring forth offspring." When chemists first isolated tocopherol compounds, they designated them by letters of the Greek alphabet: alpha, beta, gamma, and delta. All tocopherols consist of a complex ring structure and a long saturated side chain. (Appendix C provides the chemical structures.) The positions of methyl groups (CH_3) on the side chain and their chemical rotations distinguish one tocopherol from another. **Alpha-tocopherol** is currently the only one recognized as having vitamin E activity in the human body.[40] The other tocopherols are not readily converted to alpha-tocopherol in the body, nor do they perform the same roles. Whether these other tocopherols might be beneficial in other ways is the subject of current research. Gamma-tocopherol, for example, appears to be most effective in inhibiting inflammation and cancer growth.[41]

Vitamin E as an Antioxidant

Vitamin E is a fat-soluble antioxidant ♦ and one of the body's primary defenders against the adverse effects of free radicals. Its main action is to stop the chain reaction of free radicals from producing more free radicals (see Highlight 11). In doing so, vitamin E protects the vulnerable components of the cells and their membranes from destruction. Most notably, vitamin E prevents the oxidation of the polyunsaturated fatty acids, but it protects other lipids and related compounds (for example, vitamin A) as well.

Accumulating evidence suggests that vitamin E may reduce the risk of heart disease by protecting low-density lipoproteins (LDL) against oxidation and reducing inflammation. The oxidation of LDL and inflammation have been implicated as key factors in the development of heart disease. Highlight 11 explains how vitamin E and other antioxidants might protect against chronic diseases, such as heart disease and cancer, and explores whether foods or supplements might be most helpful—or harmful.

♦ Key antioxidant nutrients:
- Vitamin C, vitamin E, beta-carotene
- Selenium

Vitamin E Deficiency

A primary deficiency of vitamin E (from poor dietary intake) is rare; deficiency is usually associated with diseases of fat malabsorption such as cystic fibrosis. Without vitamin E, the red blood cells break and spill their contents, probably due to oxidation of the polyunsaturated fatty acids in their membranes. This classic sign of vitamin E deficiency, known as **erythrocyte hemolysis,** is seen in premature infants born before the transfer of vitamin E from the mother to the infant that takes place in the last weeks of pregnancy. Vitamin E treatment corrects **hemolytic anemia.**

Prolonged vitamin E deficiency also causes neuromuscular dysfunction involving the spinal cord and retina of the eye. Common symptoms include loss of muscle coordination and reflexes and impaired vision and speech. Vitamin E treatment corrects these neurological symptoms of vitamin E deficiency.

Two other conditions seem to respond to vitamin E treatment, although results are inconsistent. One is **fibrocystic breast disease,** a nonmalignant breast disease. The other is **intermittent claudication,** an abnormality of blood flow that causes cramping in the legs.

tocopherol (tuh-KOFF-er-ol): a general term for several chemically related compounds, one of which has vitamin E activity. (See Appendix C for chemical structures.)

alpha-tocopherol: the active vitamin E compound.

erythrocyte [illegible] **hemolysis** (HE-moh-LY-sis): the breaking open of red blood cells (erythrocytes); a symptom of vitamin E–deficiency disease in human beings.
- **erythro** = red
- **cyte** = cell
- **hemo** = blood
- **lysis** = breaking

hemolytic (HE-moh-LIT-ick) **anemia:** the condition of having too few red blood cells as a result of erythrocyte hemolysis.

fibrocystic (FYE-bro-SIS-tik) **breast disease:** a harmless condition in which the breasts develop lumps, sometimes associated with caffeine consumption. In some, it responds to abstinence from caffeine; in others, it can be treated with vitamin E.
- **fibro** = fibrous tissue
- **cyst** = closed sac

intermittent claudication (klaw-dih-KAY-shun): severe calf pain caused by inadequate blood supply. It occurs when walking and subsides during rest.
- **intermittent** = at intervals
- **claudicare** = to limp

Vitamin E Toxicity

Vitamin E supplement use has risen in recent years as its protective actions against chronic diseases have been recognized. Fortunately, the liver carefully regulates vitamin E concentrations. Toxicity is rare, and vitamin E appears safe across a broad range of intakes. The UL for vitamin E (1000 milligrams) is more than 65 times greater than the recommended intake for adults (15 milligrams). Extremely high doses of vitamin E may interfere with the blood-clotting action of vitamin K and enhance the effects of drugs used to oppose blood clotting, causing hemorrhage. Additional research is needed to determine whether vitamin E supplements increase the risk of hemorrhagic stroke.

Vitamin E Recommendations

The RDA for vitamin E is based on the alpha-tocopherol form only. As mentioned earlier, the other tocopherols cannot be converted to alpha-tocopherol, nor can they perform the same metabolic roles



© Craig M. Moore

Fat-soluble vitamin E is found predominantly in vegetable oils, seeds, and nuts.

in the body. A person who consumes large quantities of polyunsaturated fatty acids needs more vitamin E. Fortunately, vitamin E and polyunsaturated fatty acids tend to occur together in the same foods.

Vitamin E in Foods Vitamin E is widespread in foods. Much of the vitamin E in the diet comes from vegetable oils and products made from them, such as margarine and salad dressings. Wheat germ oil is especially rich in vitamin E.

Because vitamin E is readily destroyed by heat processing (such as deep-fat frying) and oxidation, fresh or lightly processed foods are preferable sources. Most processed and convenience foods do not contribute enough vitamin E to ensure an adequate intake.

Prior to 2000, values of the vitamin E in foods reflected all of the tocopherols and were expressed in "milligrams of tocopherol equivalents."* These measures overestimated the amount of alpha-tocopherol. To estimate the alpha-tocopherol content of foods stated in tocopherol equivalents, multiply by 0.8.[42]

REVIEW IT Identify the main roles, deficiency symptoms, and foods sources for vitamin E.

Vitamin E acts as an antioxidant, defending lipids and other components of the cells against oxidative damage. Deficiencies are rare, but they do occur in premature infants, the primary symptom being erythrocyte hemolysis. Vitamin E is found predominantly in vegetable oils and appears to be one of the least toxic of the fat-soluble vitamins. The accompanying table provides a summary of vitamin E.

Vitamin E

Other Names	Significant Sources
Alpha-tocopherol	Polyunsaturated plant oils (margarine, salad dressings), dark green, leafy vegetables (spinach, turnip greens, collard greens, broccoli), wheat germ, whole grains, liver, egg yolks, nuts, seeds, fatty meats
2000 RDA	Easily destroyed by heat and oxygen
Adults: 15 mg/day	**Deficiency Symptoms**
Upper Level	Red blood cell breakage,[a] nerve damage
Adults: 1000 mg/day	**Toxicity Symptoms**
Chief Functions in the Body	Augments the effects of anticlotting medication
Antioxidant (stabilization of cell membranes, regulation of oxidation reactions, protection of polyunsaturated fatty acids [PUFA] and vitamin A)	

[a]The breaking of red blood cells is called *erythrocyte hemolysis*.

11.4 Vitamin K

LEARN IT Identify the main roles, deficiency symptoms, and sources for vitamin K.

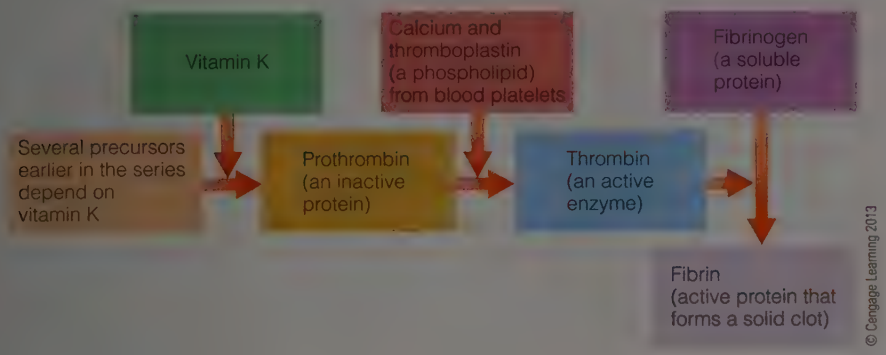
Like vitamin D, vitamin K can be obtained both from foods and from a nonfood source. Bacteria in the GI tract synthesize vitamin K that the body can absorb. Vitamin K appropriately gets its name from the Danish word *koagulation* ("coagulation" or "clotting"). Its primary action is blood clotting, where its presence can make the difference between life and death.[43] Blood has a remarkable ability to remain liquid, but it can clot within seconds when the integrity of that system is disturbed.

Roles in the Body More than a dozen different proteins and the mineral calcium are involved in making a blood clot. Vitamin K is essential for the activation of several of these proteins, among them prothrombin, made by the

*Appendix H accurately presents vitamin E data in milligrams of alpha-tocopherol.

> FIGURE 11-12 Blood-Clotting Process

Vitamin K is essential for the synthesis of prothrombin and several other clotting factors. Blood clots are formed by a cascade of reactions, with each step creating a compound that activates the next step.



liver as a precursor of the protein thrombin (see Figure 11-12). When any of the blood-clotting factors is lacking, **hemorrhagic disease** results. If an artery or vein is cut or broken, bleeding goes unchecked. Of course, this is not to say that hemorrhaging is always caused by vitamin K deficiency. Another cause is the genetic disorder **hemophilia,** which is neither caused nor cured by vitamin K.

Vitamin K also participates in the metabolism of bone proteins, most notably **osteocalcin.** Without vitamin K, osteocalcin cannot bind to the minerals that normally form bones, resulting in low bone density.[44]* An adequate intake of vitamin K helps to decrease bone turnover and protect against fractures.[45] The effectiveness of vitamin K supplements on bone health is inconclusive.

Vitamin K is historically known for its role in blood clotting, and more recently for its participation in bone building, but researchers continue to discover proteins needing vitamin K's assistance.[46] These proteins have been identified in the plaques of atherosclerosis, the kidneys, and the nervous system.

hemorrhagic (hem-oh-RAJ-ik) **disease:** a disease characterized by excessive bleeding.

hemophilia (HE-moh-FEEL-ee-ah) a hereditary disease in which the blood is unable to clot because it lacks the ability to synthesize certain clotting factors.

osteocalcin (os-teo-KAL-sen) a calcium-binding protein in bones, essential for normal mineralization.

sterile: free of microorganisms, such as bacteria.

Vitamin K Deficiency Chapter 1 explains that a *primary deficiency* develops in response to an inadequate dietary intake whereas a *secondary deficiency* occurs for other reasons. A primary deficiency of vitamin K is rare, but a secondary deficiency may occur in two circumstances. First, whenever fat absorption falters, as occurs when bile production fails, vitamin K absorption diminishes. Second, some drugs disrupt vitamin K's synthesis and action in the body: antibiotics kill the vitamin K–producing bacteria in the intestine, and anticoagulant drugs interfere with vitamin K metabolism and activity. Excessive bleeding due to a vitamin K deficiency can be fatal.

Newborn infants present a unique case of vitamin K nutrition because they are born with a **sterile** intestinal tract, and the vitamin K–producing bacteria take weeks to establish themselves. At the same time, plasma prothrombin concentrations are low. This reduces the likelihood of fatal blood clotting during the stress of birth. To prevent hemorrhagic disease in the newborn, a single dose of vitamin K is given at birth by intramuscular injection.** Concerns that vitamin K given at birth raises the risks of childhood cancer are unproved and unlikely.



Soon after birth, newborn infants receive a dose of vitamin K to prevent hemorrhagic disease.

Vitamin K Toxicity Toxicity is not common, and no adverse effects have been reported with high intakes of vitamin K. Therefore, a UL has not been established. High doses of vitamin K can, however,

*Vitamin K is a cofactor for a carboxylase enzyme. When vitamin K is inadequate, osteocalcin is undercarboxylated and therefore less effective in binding calcium.

**Vitamin K is usually given in the naturally occurring form known as *phylloquinone* (FILL-oh-KWIN-own); the synthetic form of vitamin K is *menadione* (men-uh-DYE-own). See Appendix C for the chemistry of these structures.



© Matthew Farruggio

Notable food sources of vitamin K include green vegetables such as collards, spinach, bib lettuce, brussels sprouts, and cabbage and vegetable oils such as soybean oil and canola oil.

reduce the effectiveness of anticoagulant drugs used to prevent blood clotting. People taking these drugs can continue eating their usual diets. Their blood clotting times should be monitored closely and drug dosages adjusted accordingly.[47]

Vitamin K Recommendations and Sources As mentioned earlier, vitamin K is made in the GI tract by the billions of bacteria that normally reside there. Once synthesized, vitamin K is absorbed and stored in the liver. This source provides only about half of a person's needs. Vitamin K–rich foods such as green vegetables and vegetable oils can easily supply the rest.

REVIEW IT Identify the main roles, deficiency symptoms, and sources for vitamin K.

Vitamin K helps with blood clotting, and its deficiency causes hemorrhagic disease (uncontrolled bleeding). Bacteria in the GI tract can make the vitamin; people typically receive about half of their requirements from bacterial synthesis and half from foods such as green vegetables and vegetable oils. Because people depend on bacterial synthesis for vitamin K, deficiency is most likely in newborn infants and in people taking antibiotics. The accompanying table provides a summary of vitamin K.

Vitamin K

Other Names	Significant Sources
Phylloquinone, menaquinone, menadione, naphthoquinone	Bacterial synthesis in the digestive tract;[a] liver; dark green, leafy vegetables, cabbage-type vegetables; milk
2001 Adequate Intake (AI)	**Deficiency Symptoms**
Men: 120 µg/day Women: 90 µg/day	Hemorrhaging
Chief Functions in the Body	**Toxicity Symptoms**
Synthesis of blood-clotting proteins and bone proteins	None known

[a]Vitamin K needs cannot be met from bacterial synthesis alone; however, it is a potentially important source in the small intestine, where absorption efficiency ranges from 40 to 70 percent.

The four fat-soluble vitamins play many specific roles in the growth and maintenance of the body. Their presence affects the health and function of the eyes, skin, GI tract, lungs, bones, teeth, nervous system, and blood; their deficiencies become apparent in these same areas. Toxicities of the fat-soluble vitamins are possible, especially when people use supplements, because the body stores excesses.

As with the water-soluble vitamins, the function of one fat-soluble vitamin often depends on the presence of another. Recall that vitamin E protects vitamin A from oxidation. In vitamin E deficiency, vitamin A absorption and storage are impaired. Three of the four fat-soluble vitamins—A, D, and K—play important roles in bone growth and remodeling. As mentioned, vitamin K helps synthesize a specific bone protein, and vitamin D regulates that synthesis. Vitamin A, in turn, may control which bone-building genes respond to vitamin D. Vitamin E and vitamin K share some metabolic pathways, which can create problems, especially in blood clotting.[48]

Fat-soluble vitamins also interact with minerals. Vitamin D and calcium cooperate in bone formation, and zinc is required for the synthesis of vitamin A's transport protein, retinol-binding protein. Zinc also assists the enzyme that regenerates retinal from retinol in the eye. Vitamin A deficiency and iron deficiency often occur together and each seems to worsen the other's metabolism.[49]

The roles of the fat-soluble vitamins differ from those of the water-soluble vitamins, and they appear in different foods—yet they are just as essential to life. The need for them underlines the importance of eating a wide variety of nourishing foods daily. The accompanying table provides a summary of the fat-soluble vitamins.

REVIEW IT The Fat-Soluble Vitamins

Vitamin and Chief Functions	Deficiency Symptoms	Toxicity Symptoms	Significant Sources
Vitamin A			
Vision; maintenance of cornea, epithelial cells, mucous membranes, skin; bone and tooth growth; reproduction; immunity	Infectious diseases, night blindness, blindness (xerophthalmia), keratinization	Reduced bone mineral density, liver abnormalities, birth defects	Retinol: milk and milk products Beta-carotene: dark green, leafy and deep yellow/orange vegetables
Vitamin D			
Mineralization of bones (raises blood calcium and phosphorus by increasing absorption from digestive tract, withdrawing calcium from bones, stimulating retention by kidneys)	Rickets, osteomalacia	Calcium imbalance (calcification of soft tissues and formation of stones)	Synthesized in the body with the help of sunshine; fortified milk
Vitamin E			
Antioxidant (stabilization of cell membranes, regulation of oxidation reactions, protection of polyunsaturated fatty acids [PUFA] and vitamin A)	Erythrocyte hemolysis, nerve damage	Hemorrhagic effects	Vegetable oils
Vitamin K			
Synthesis of blood-clotting proteins and bone proteins	Hemorrhage	None known	Synthesized in the body by GI bacteria; dark green, leafy vegetables

Nutrition Portfolio

For the fat-soluble vitamins, select colorful fruits and vegetables, fortified milk or soy products, and vegetable oils; use supplements with caution, if at all. Go to Diet Analysis Plus and choose one of the days on which you tracked your diet for an entire day. Select the MyPlate report and then consider the following questions:

- How was your overall intake in the vegetable group? Do you need improvement in this area? If so, what are some changes you could make?

Now look at the report titled Intake Spreadsheet to answer the following questions:

- Examine your weekly choices of vegetables and evaluate whether you meet the recommendations for dark green or orange and deep yellow vegetables.
- Consider whether you drink enough vitamin D–fortified milk or go outside in the sunshine regularly.
- Describe the vegetable oils you use when you cook and their vitamin contributions.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. G. Tang, Bioconversion of dietary provitamin A carotenoids to vitamin A in humans, *American Journal of Clinical Nutrition* 91 (2010): 1468S–1473S.
2. J. von Lintig, Colors with functions: Elucidating the biochemical and molecular basis of carotenoid metabolism, *Annual Review of Nutrition* 30 (2010): 35–56.
3. G. Wolf, Retinoic acid as cause of cell proliferation or cell growth inhibition depending on activation of one of two different nuclear receptors, *Nutrition Reviews* 66 (2008): 55–59.
4. N. Noy, Between death and survival: Retinoic acid in regulation of apoptosis, *Annual Review of Nutrition* 30 (2010): 201–217.
5. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids* (Washington, D.C.: National Academies Press, 2000).
6. A. Sommer, Vitamin A deficiency and clinical disease: An historical overview, *Journal of Nutrition* 138 (2008): 1835–1839.
7. E. Mayo-Wilson and coauthors, Vitamin A supplements for preventing mortality, illness, and blindness in children aged under 5: Systematic review and meta-analysis, *British Medical Journal* 343 (2011): d5094; S. A. Abrams and D. C. Hilmers, Postnatal vitamin A supplementation in developing countries: An intervention whose time has come? *Pediatrics*

122 (2008): 180–181; K. Kraemer and coauthors, Are low tolerable upper intake levels for vitamin A undermining effective food fortification efforts? *Nutrition Reviews* 66 (2008): 517–525.

8. S. M. Ahmad and coauthors, Vitamin A status is associated with T-cell responses in Bangladeshi men, *British Journal of Nutrition* 102 (2009): 797–802; C. Trottier and coauthors, Retinoids inhibit measles virus through a type I IFN-dependent bystander effect, *The FASEB Journal* 23 (2009): 3203–3212.
9. www.who.int/mediacentre/factsheets, f286, updated December 2009.
10. A. Sheth, R. Khurana, and V. Khurana, Potential liver damage associated with over-the-counter vitamin supplements, *Journal of the American Dietetic Association* 108 (2008): 1536–1537.
11. S. L. Morgan, Nutrition and bone: It is more than calcium and vitamin D, *Women's Health* 5 (2009): 727–737.
12. J. Zhao and coauthors, Retinoic acid downregulates microRNAs to induce abnormal development of spinal cord in spina bifida rat model, *Child's Nervous System* 24 (2008): 485–492.
13. T. L. Schonfeld, N. J. Amoura, and C. J. Kratochvil, iPLEDGE allegiance to the pill: Evaluation of year 1 of a birth defect prevention and monitoring system, *Journal of Law, Medicine, and Ethics* 37 (2009): 104–117.
14. H. F. Deluca, Evolution of our understanding of vitamin D, *Nutrition Reviews* 66 (2008): S73–S87; A. W. Norman, From vitamin D to hormone D: Fundamentals of the vitamin D endocrine system essential for good health, *American Journal of Clinical Nutrition* 88 (2008): 491S–499S.
15. R. P. Heaney, Vitamin D and calcium interactions: Functional outcomes, *American Journal of Clinical Nutrition* 88 (2008): 541S–544S.
16. Deluca, 2008; M. R. Haussler and coauthors, Vitamin D receptor: Molecular signaling and actions of nutritional ligands in disease prevention, *Nutrition Reviews* 66 (2008): S98–S112.
17. R. C. Khanal and I. Nemere, Regulation of intestinal calcium transport, *Annual Review of Nutrition* 28 (2008): 179–196.
18. S. Samual and M. D. Sitrin, Vitamin D's role in cell proliferation and differentiation, *Nutrition Reviews* 66 (2008): S116–S124.
19. E. van Etten and coauthors, Regulation of vitamin D homeostasis: Implications for the immune system, *Nutrition Reviews* 66 (2008): S125–S134.
20. E. M. Mowry, Vitamin D: Evidence for its role as a prognostic factor in multiple sclerosis, *Journal of Neurological Science* 311 (2011): 19–22; M. H. Hopkins and coauthors, Effects of supplemental vitamin D and calcium on biomarkers of inflammation in colorectal adenoma patients: A randomized, controlled clinical trial, *Cancer Prevention Research* 4 (2011): 1645–1654; K. Luong and L. T. Nguyen, Impact of vitamin D in the treatment of tuberculosis, *American Journal of Medical Sciences* 341 (2011): 493–498; A. E. Millen and coauthors, Vitamin D status and early age-related macular degeneration in postmenopausal women, *Archives of Ophthalmology* 129 (2011): 481–489; N. Parekh, Protective role of vitamin D against age-related macular degeneration: A hypothesis, *Topics in Clinical Nutrition* 25 (2010): 290–301; A. G. Pittas and coauthors, Systematic review: Vitamin D and cardiometabolic outcomes, *Annals of Internal Medicine* 152 (2010): 307–314; C. D. Toner, C. D. Davis, and J. A. Milner, The vitamin D and cancer conundrum: Aiming at a moving target, *Journal of the American Dietetic Association* 110 (2010): 1492–1500; A. Zitterman and coauthors, Vitamin D supplementation enhances the beneficial effects of weight loss on cardiovascular disease risk markers, *American Journal of Clinical Nutrition* 89 (2009): 1321–1327; M. T. Cantorna, Vitamin D and multiple sclerosis: An update, *Nutrition Reviews* 66 (2008): S135–S138; M. F. Holick, Vitamin D: A d-lightful health perspective, *Nutrition Reviews* 66 (2008): S182–S194; S. E. Judd and coauthors, Optimal vitamin D status attenuates the age-associated increase in systolic blood pressure in white Americans: Results from the third National Health and Nutrition Examination Survey, *American Journal of Clinical Nutrition* 87 (2008): 136–141.
21. A. Grey and M. Bolland, Vitamin D: A place in the sun? *Archives of Internal Medicine* 170 (2010): 1099–1100.
22. C. J. Rosen, Vitamin D insufficiency, *New England Journal of Medicine* 364 (2011): 248–254; A. A. Ginde , M. C. Liu, and C. A. Camargo, Demographic differences and trends of vitamin D insufficiency in the US population, 1988–2004, *Archives of Internal Medicine* 169 (2009): 626–632; S. A. Bowden and coauthors, Prevalence of vitamin D deficiency and insufficiency in children with osteopenia or osteoporosis referred to a pediatric metabolic bone clinic, *Pediatrics* 121 (2008): e1585–e1590; M. L. Neuhouser and coauthors, Vitamin D insufficiency in a multiethnic cohort of breast cancer survivors, *American Journal of Clinical Nutrition* 88 (2008): 133–139.
23. A. C. Looker and coauthors, Vitamin D status: United States, 2001–2006, *NCHS Data Brief* 59 (2011): 1–8.
24. L. A. Martini and R. J. Wood, Vitamin D and blood pressure connection: Update on epidemiologic, clinical, and mechanistic evidence, *Nutrition Reviews* 66 (2008): 291–297.
25. K. D. Cashman and coauthors, Low vitamin D status adversely affects bone health parameters in adolescents, *American Journal of Clinical Nutrition* 87 (2008): 1039–1044.
26. A. Prentice, Vitamin D deficiency: A global perspective, *Nutrition Reviews* 66 (2008): S153–S164.
27. C. M. Lenders and coauthors, Relation of body fat indexes to vitamin D status and deficiency among obese adolescents, *American Journal of Clinical Nutrition* 90 (2009): 459–467; S. Saintonge, H. Bang, and L. M. Gerber, Implications of a new definition of vitamin D deficiency in a multiracial US adolescent population: The National Health and Nutrition Examination Survey III, *Pediatrics* 123 (2009): 797–803; F. R. Greer, 25-Hydroxyvitamin D: Functional outcome in infants and young children, *American Journal of Clinical Nutrition* 88 (2008): 529S–533S; S. Y. Huh and C. M. Gordon, Vitamin D deficiency in children and adolescents: Epidemiology, impact and treatment, *Reviews in Endocrine and Metabolic Disorders* 9 (2008): 161–170; M. Misra and coauthors, Vitamin D deficiency in children and its management: Review of current knowledge and recommendations, *Pediatrics* 122 (2008): 398–417.
28. C. L. Wagner, F. R. Greer, and the Section on Breastfeeding and Committee on Nutrition, Prevention of rickets and vitamin D deficiency in infants, children, and adolescents, *Pediatrics* 122 (2008): 1142–1152.
29. K. Ukine, Severe osteomalacia presenting with multiple vertebral fractures: A case report and review of the literature, *Endocrine* 36 (2009): 30–36.
30. P. Lips and coauthors, Once-weekly dose of 8400 IU vitamin D_3 compared with placebo: Effects on neuromuscular function and tolerability in older adults with vitamin D insufficiency, *American Journal of Clinical Nutrition* 91 (2010): 985–991; B. Dawson-Hughes, Serum 25-hydroxyvitamin D and functional outcomes in the elderly, *American Journal of Clinical Nutrition* 88 (2008): 537S–540S.
31. G. Jones, Pharmacokinetics of vitamin D toxicity, *American Journal of Clinical Nutrition* 88 (2008): 582S–586S.
32. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Calcium and Vitamin D*, (Washington, D.C.: National Academies Press, 2011), pp. 75–124.
33. L. M. Hall and coauthors, Vitamin D intake needed to maintain target serum 25-hydroxyvitamin D concentrations in participants with low sun exposure and dark skin pigmentation is substantially higher than current recommendations, *Journal of Nutrition* 140 (2010): 542–550; K. D. Cashman and coauthors, Estimation of the dietary requirement for vitamin D in healthy adults, *American Journal of Clinical Nutrition* 88 (2008): 1535–1542; J. F. Aloia and coauthors, Vitamin D intake to attain a desired serum 25-hydroxyvitamin D concentration, *American Journal of Clinical Nutrition* 87 (2008): 1952–1958.
34. R. M. Biancuzzo and coauthors, Fortification of orange juice with vitamin D_2 or vitamin D_3 is as effective as an oral supplement in maintaining vitamin D status in adults, *American Journal of Clinical Nutrition* 91 (2010): 1621–1626; V. Mocanu and coauthors, Long-term effects of giving nursing home residents bread fortified with 125 μg (5000 IU) vitamin D_3 per daily serving, *American Journal of Clinical Nutrition* 89 (2009): 1132–1137; S. O'Donnell and coauthors, Efficacy of food fortification on serum 25-hydroxyvitamin D concentrations: Systematic review, *American Journal of Clinical Nutrition* 88 (2008): 1528–1534.
35. B. A. Gilchrest, Sun exposure and vitamin D sufficiency, *American Journal of Clinical Nutrition* 88 (2008): 570S–577S.
36. S. Sharma and coauthors, Vitamin D deficiency and disease risk among aboriginal Arctic populations, *Nutrition Reviews* 69 (2011): 468–478; Hall and coauthors, 2010; S. M. Smith and coauthors, Vitamin D supplementation during Antarctic winter, *American Journal of Clinical Nutrition* 89 (2009): 1092–1098.

37. L. A. Houghton and coauthors, Predictors of vitamin D status and its association with parathyroid hormone in young New Zealand children, *American Journal of Clinical Nutrition* 92 (2010): 69–76.
38. R. P. Heaney and coauthors, Vitamin D(3) is more potent than vitamin D(2) in humans, *Journal of Clinical Endocrinology and Metabolism* 96 (2011): E447–E452.
39. G. B. Mulligan and A. Licata, Taking vitamin D with the largest meal improves absorption and results in higher serum levels of 25-hydroxyvitamin D, *Journal of Bone and Mineral Research* 25 (2010): 928–930.
40. Committee on Dietary Reference Intakes, 2000.
41. C. S. Yang and coauthors, Inhibition of inflammation and carcinogenesis in the lung and colon by tocopherols, *Annals of the New York Academy of Sciences* 1203 (2010): 29–34; J. Ju and coauthors, Cancer-preventive activities of tocopherols and tocotrienols, *Carcinogenesis* 31 (2010): 533–542; S. R. Wells and coauthors, α-, γ-, and δ-tocopherols reduce inflammatory angiogenesis in human microvascular endothelial cells, *Journal of Nutritional Biochemistry* 21 (2009): 589–597.
42. Committee on Dietary Reference Intakes, 2000.
43. G. J. Merli and J. Fink, Vitamin K and thrombosis, *Vitamins and Hormones* 78 (2008): 265–279.
44. H. M. Macdonald and coauthors, Vitamin K_1 intake is associated with higher bone mineral density and reduced bone resorption in early postmenopausal Scottish women: No evidence of gene-nutrient interaction with apolipoprotein E polymorphisms, *American Journal of Clinical Nutrition* 87 (2008): 1513–1520.
45. S. Cockayne and coauthors, Vitamin K and the prevention of fractures: Systematic review and meta-analysis of randomized controlled trials, *Archives of Internal Medicine* 166 (2006): 1256–1261; J. Iwamoto, T. Takeda, and Y. Sato, Menatetrenone (vitamin K_2) and bone quality in the treatment of postmenopausal osteoporosis, *Nutrition Reviews* 64 (2006): 509–517; K. D. Cashman, Vitamin K status may be an important determinant of childhood bone health, *Nutrition Reviews* 63 (2005): 284–293.
46. S. L. Booth, Roles for vitamin K beyond coagulation, *Annual Review of Nutrition* 29 (2009): 89–110.
47. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*, (Washington, D.C.: National Academies Press, 2001), pp. 174–175.
48. M. G. Traber, B. Frei, and J. S. Beckman, Vitamin E revisited: Do new data validate benefits for chronic disease prevention? *Current Opinion in Lipidology* 19 (2008): 30–38; M. G. Traber, Vitamin E and K interactions—a 50-year-old problem, *Nutrition Reviews* 66 (2008): 624–629.
49. J. M. Oliveira and coauthors, Influence of iron on vitamin A nutritional status, *Nutrition Reviews* 66 (2008): 141–147.

LEARN IT Describe how antioxidants defend against free radicals that contribute to diseases.



© Istockphoto.com/Nicole S. Young

Antioxidant Nutrients in Disease Prevention

Count on supplement manufacturers to exploit the day's hot topics in nutrition. The moment bits of research news surface, new supplements appear—and terms such as *antioxidants* and *lycopene* become household words. Friendly faces in TV commercials try to persuade us that these supplements hold magic in the fight against aging and disease. New supplements hit the market and cash registers ring. Vitamin C, for years the leading single nutrient supplement, gains new popularity, and sales of lutein, beta-carotene, and vitamin E supplements soar as well.

In the meantime, scientists and medical experts around the world continue their work to clarify and confirm the roles of antioxidants in preventing chronic diseases. This highlight summarizes some of the accumulating evidence. It also revisits the advantages of foods over supplements. But first it is important to introduce the troublemaker—an unstable molecule known as a **free radical.** (The accompanying glossary defines free radicals and related terms.)

Free Radicals and Disease

Chapter 7 describes how the body's cells use oxygen in metabolic reactions. In the process, oxygen reacts with body compounds and produces highly unstable molecules known as free radicals.[1] In addition to normal body processes, environmental factors such as ultraviolet radiation, air pollution, and tobacco smoke generate free radicals.

A free radical is a molecule with one or more unpaired electrons.* An electron without a partner is unstable and highly reactive. To regain its stability, the free radical quickly finds a stable but vulnerable compound from which to steal an electron.

With the loss of an electron, the formerly stable molecule becomes a free radical itself and steals an electron from another nearby molecule. Thus an electron-snatching chain reaction is under way with free radicals producing more free radicals. **Antioxidants** neutralize free radicals by donating one of their own electrons, thus ending the chain reaction. When they lose electrons, antioxidants do not become free radicals because they are stable in either form. (Review Figure 10-16 on p. 323 to see how ascorbic acid can give up two hydrogens with their electrons and become dehydroascorbic acid.)

Free radicals attack. Occasionally, these free-radical attacks are helpful. For example, cells of the immune system use free radicals as ammunition in an "oxidative burst" that demolishes disease-causing viruses and bacteria. Most often, however, free-radical attacks cause widespread damage. They commonly damage the polyunsaturated fatty acids in lipoproteins and in cell membranes, disrupting the transport of substances into and out of cells. Free radicals also alter DNA, RNA, and proteins, creating excesses and deficiencies of specific proteins, impairing cell functions, and eliciting an inflammatory response. All of these actions contribute to cell damage, disease progression, and aging (see Figure H11-1).

The body's natural defenses and repair systems try to control the destruction caused by free radicals, but these systems are not 100 percent effective. In fact, they become less effective with age, and the unrepaired damage accumulates. To some extent, dietary antioxidants defend the body against **oxidative stress**, but if antioxidants are unavailable or if free-radical production becomes excessive, health problems may develop.[2] Oxygen-derived free radicals may cause diseases, not only by indiscriminately destroying the valuable components of cells, but also by serving as signals for specific activities within the cells. Scientists have identified oxidative stress as a causative factor and antioxidants as a protective factor in cognitive performance and the aging process as well as in the development of diseases such as cancer, arthritis, cataracts, diabetes, hypertension, and heart disease.[3]

*Many free radicals exist, but oxygen-derived free radicals are most common in the human body. Examples of oxygen-derived free radicals include superoxide radical ($O_2^{\cdot-}$), hydroxyl radical ($OH^{\cdot}$), and nitric oxide ($NO^{\cdot}$). (The dots in the symbols represent the unpaired electrons.) Technically, hydrogen peroxide (H_2O_2) and singlet oxygen are not free radicals because they contain paired electrons, but the unstable conformation of their electrons makes radical-producing reactions likely. Scientists sometimes use the term *reactive oxygen species (ROS)* to describe all of these compounds.

GLOSSARY

antioxidants: in the body, substances that significantly decrease the adverse effects of free radicals on normal physiological functions.

free radical: an unstable molecule with one or more unpaired electrons. (See Appendix B for a review of basic chemistry concepts.)

oxidants (OKS-ih-dants): compounds (such as oxygen itself) that oxidize other compounds. Compounds that prevent oxidation are called *antioxidants*, whereas those that promote it are called *prooxidants*.

- **anti** = against
- **pro** = for

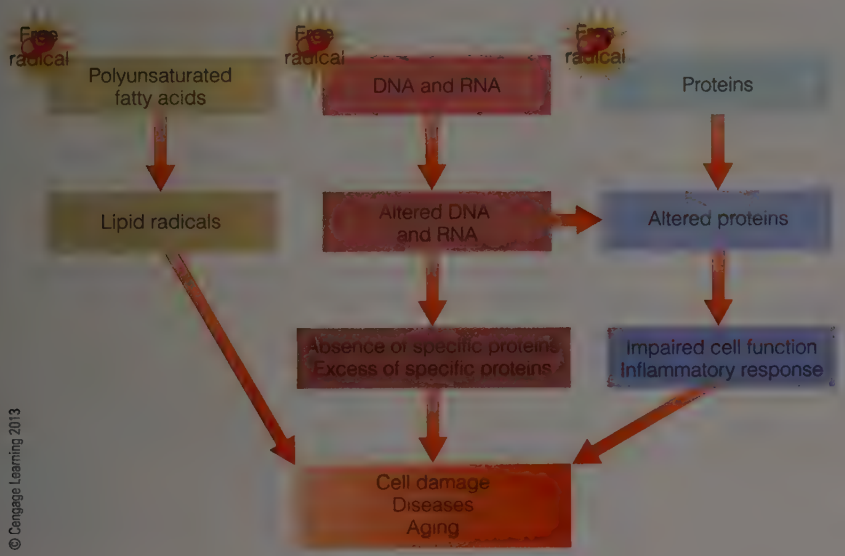
oxidative stress: a condition in which the production of oxidants and free radicals exceeds the body's ability to handle them and prevent damage.

phytochemicals: nonnutrient compounds found in plant-derived foods that have biological activity in the body.

prooxidants: substances that significantly induce oxidative stress.

> FIGURE H11-1 Free-Radical Damage

Free radicals are highly reactive. They might attack the polyunsaturated fatty acids in a cell membrane, which generates lipid radicals that damage cells and accelerate disease progression. Free radicals might also attack and damage DNA, RNA, and proteins, which interferes with the body's ability to maintain normal cell function, causing disease and premature aging.



© Cengage Learning 2013

Defending against Free Radicals

The body maintains a couple lines of defense against free-radical damage. A system of enzymes disarms the most harmful **oxidants.*** The action of these enzymes depends on the minerals selenium, copper, manganese, and zinc. If the diet fails to provide adequate supplies of these minerals, this line of defense weakens. The body also uses the antioxidant vitamins—vitamin E, beta-carotene, and vitamin C. Vitamin E defends the body's lipids (cell membranes and lipoproteins, for example) by efficiently stopping the free-radical chain reaction. Beta-carotene also acts as an antioxidant in lipid membranes. Vitamin C protects other tissues, such as the skin and fluid of the blood, against free-radical attacks. Vitamin C seems especially adept at neutralizing free radicals from polluted air and cigarette smoke; it also restores oxidized vitamin E to its active state.[4]

Dietary antioxidants also include some of the **phytochemicals** (featured in Highlight 13). Together, nutrients and phytochemicals with antioxidant activity minimize damage and prevent disease in the following ways:[5]

- Limiting free-radical formation
- Destroying free radicals or their precursors
- Stimulating antioxidant enzyme activity
- Repairing oxidative damage
- Stimulating repair enzyme activity
- Supporting a healthy immune system

These actions play key roles in defending the body against chronic diseases such as cancer and heart disease.

*These enzymes include *glutathione peroxidase, thioredoxin reductase, superoxide dismutase,* and *catalase.*

Defending against Cancer

Cancers arise when cellular DNA is damaged—sometimes by free-radical attacks. Antioxidants may reduce cancer risks by protecting DNA from this damage. Many researchers have reported low rates of cancer in people whose diets include abundant vegetables and fruits, rich in antioxidants. Preliminary reports suggest an inverse relationship between DNA damage and vegetable intake and a positive relationship with beef and pork intake.[6]

Foods rich in vitamin C seem to protect against certain types of cancers, especially those of the esophagus. Such a correlation may reflect the benefits of a diet rich in fruits and vegetables and low in fat; it does not necessarily support taking vitamin C supplements to treat or prevent cancer. At high doses vitamin C acts as a **prooxidant,** generating free radicals. Limited research suggests this action may be useful in destroying cancer cells.[7] Evidence that vitamin C supplements reduce the risk of cancer is lacking.[8]

Researchers hypothesize that vitamin E might inhibit cancer formation by attacking free radicals that damage DNA. Evidence that vitamin E supplements help guard against cancer, however, is lacking.[9]

Several studies report a cancer-preventing benefit of vegetables and fruits rich in beta-carotene and the other carotenoids as well. Carotenoids may protect against oxidative damage to DNA. Some research suggests that high concentrations of beta-carotene are associated with lower rates of some cancers, but intervention studies do not find a reduction in cancer risk with beta-carotene supplementation.[10] Benefits most likely reflect a healthy diet abundant in fruits and vegetables.[11]

Defending against Heart Disease

Decades of research have contributed to our understanding of how oxidative stress contributes to atherosclerosis and how antioxidants might protect against heart disease, yet questions remain.[12] High blood cholesterol carried in LDL (low-density lipoproteins) is a major risk factor for cardiovascular disease, but how do LDL exert their damage? One scenario is that free radicals within the arterial walls oxidize LDL, changing their structure and function. The oxidized LDL then accelerate the formation of artery-clogging plaques. These free radicals also oxidize the polyunsaturated fatty acids of the cell membranes, sparking additional changes in the arterial walls, which impede the flow of blood. Susceptibility to such oxidative damage within the arterial walls is heightened by a diet high in saturated fat and by cigarette smoke. In contrast, diets that include plenty of fruits and vegetables, especially when combined with little saturated fat, strengthen antioxidant defenses against LDL oxidation.

Antioxidants, especially vitamin E, may protect against hypertension and cardiovascular disease.[13] Epidemiological studies suggest

that people who eat foods rich in vitamin E have relatively few atherosclerotic plaques and low rates of death from heart disease. Among its many protective roles, vitamin E defends against LDL oxidation, inflammation, arterial injuries, and blood clotting. Whether vitamin E supplements may slow the progression of heart disease is less clear.[14]

Some studies suggest that vitamin C protects against LDL oxidation, raises HDL, lowers total cholesterol, and improves blood pressure. Vitamin C may also minimize inflammation and the free-radical action within the arterial wall. Like vitamin E, the role of vitamin C supplements in reducing the risk of heart disease remains uncertain.[15]

Foods, Supplements, or Both?

In the process of scavenging and quenching free radicals, antioxidants themselves become oxidized. To some extent, they can be regenerated, but losses still occur and free radicals attack continuously. To maintain defenses, a person must replenish dietary antioxidants regularly. But should antioxidants be replenished from foods or from supplements?[16]

Foods—especially fruits and vegetables—offer not only antioxidants, but an array of other valuable vitamins and minerals as well. Importantly, deficiencies of these nutrients can damage DNA as readily as free radicals can. Eating fruits and vegetables in abundance protects against both deficiencies and diseases—and may protect against DNA damage.[17] A major review of the evidence gathered from metabolic studies, epidemiologic studies, and dietary intervention trials identified three dietary strategies most effective in preventing heart disease:

- Use unsaturated fats (that have not been hydrogenated) instead of saturated or *trans* fats (see Highlight 5).
- Select foods rich in omega-3 fatty acids (see Chapter 5).
- Consume a diet high in fruits, vegetables, nuts, and whole grains and low in refined grain products.

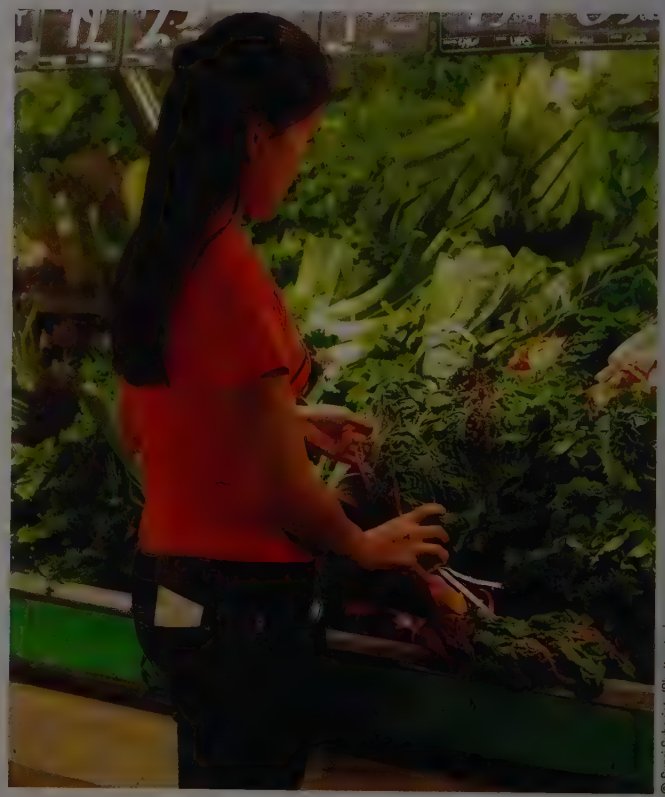
Such a diet combined with exercise, weight control, and not smoking serves as the best prescription for health. Notably, taking supplements is not among these disease-prevention recommendations.

Diets that deliver sufficient quantities of antioxidant vitamins may protect against cancer and heart disease—but only a small fraction of the US population consumes recommended amounts.[18] Some research suggests a protective effect from as little as a daily glass of orange juice or carrot juice (rich sources of vitamin C and beta-carotene, respectively). Other intervention studies, however, have used levels of nutrients that far exceed current recommendations and can be achieved only by taking supplements. In making their recommendations for the antioxidant nutrients, members of the DRI Committee considered whether these studies support substantially higher intakes to help protect against chronic diseases. They did raise the recommendations for vitamins C and E, but they do not support taking supplements over eating a healthy diet.

Though fruits and vegetables containing many antioxidant nutrients and phytochemicals have been associated with a diminished risk of many chronic diseases, supplements have not always proved beneficial.[19] In fact, sometimes the benefits are more apparent when the vitamins come from foods rather than from supplements. In other words, the antioxidant actions of fruits and vegetables are greater than their nutrients alone can explain. Without data to confirm the benefits of supplements, we cannot accept the potential risks. And the risks are real.

Consider the findings from a meta-analysis of the relationships between supplements of vitamin A, vitamin E, beta-carotene, or combinations and total mortality. Researchers concluded that supplements either had *no benefit* or *increased* mortality and should be avoided. In fact, beta-carotene *increases* the risk of lung cancer in smokers by supporting the formation of free radicals.[20]

Even if research clearly proves that a particular nutrient is the ultimate protective ingredient in foods, supplements would not be the answer because their contents are limited. Vitamin E supplements, for example, usually contain alpha-tocopherol, but foods provide an assortment of tocopherols among other nutrients, many of which provide valuable protection against free-radical damage. In addition to a full array of nutrients, foods provide phytochemicals that also fight against many diseases. Supplements shortchange users. Furthermore, supplements should be used only as an adjunct to other measures such as



© Supri Suharjoto/Shutterstock.com

Many cancer-fighting products are available now at your local produce counter.

TABLE H11-1 Antioxidants and Chronic Disease Risk

Antioxidant	Disease	Risk from Foods	Risk from Supplements
Vitamin C	Coronary heart disease	Inconsistent results	Inconsistent results
	Breast cancer	Inconsistent results	—
	Colorectal cancer	Inconsistent results	—
	Gastrointestinal cancer	—	Not known
	Lung cancer	No effect	Not known
Vitamin E	Coronary heart disease	Inconsistent results	No effect or possible increased risk
	Breast cancer	—	No effect
	Colorectal cancer	Inconsistent results	—
	Gastrointestinal cancer	—	No effect
	Lung cancer	No effect	No effect
	Prostate cancer	Decreased risk	Decreased risk in smokers
Beta-carotene	Coronary heart disease	Decreased risk	No effect in nonsmokers, increased risk in smokers
	Lung cancer	Inconsistent results	No effect in nonsmokers, increased risk in smokers
	Colorectal cancer	Decreased risk	—
	Gastrointestinal cancer	—	No effect
	Prostate cancer	No effect	—
Other carotenoids	Lung cancer	Decreased risk for beta-cryptoxanthin	—
	Colorectal cancer	Decreased risk	—
	Prostate cancer	Decreased risk for lycopene	—
Fruits and vegetables	Coronary heart disease	Decreased risk	
	Breast cancer	No effect	
	Colorectal cancer	Inconsistent results	
	Gastric and esophageal cancer	Decreased risk	
	Lung cancer	Decreased risk for fruits, no effect for vegetables	
	Prostate cancer	No effect	
Supplement containing a combination of antioxidants	Coronary heart disease		Possibly increased risk
	Gastrointestinal cancer		Possibly increased risk
	Lung cancer		No effect in nonsmokers, increased risk in smokers

SOURCE: Adapted from H. Verhagen and coauthors, The state of antioxidant affairs, *Nutrition Today* 41 (2006): 244–249.

© Cengage Learning 2013

smoking cessation, weight control, physical activity, and medication as needed.

Clearly, much more research is needed to define optimal and harmful levels of intake. This much we know: antioxidants behave differently under various conditions. At physiological levels typical of a healthy diet, they act as antioxidants, but at pharmacological doses typical of supplements, they may act as prooxidants, stimulating the production of free radicals and altering metabolism in a way that may promote disease. A high intake of vitamin C from supplements, for example, may *increase* the risk of heart disease in women with diabetes. Until the optimum intake of antioxidant nutrients can be determined, the risks of supplement use remain unclear. Table H11-1 presents a summary of the relationships between antioxidants and chronic diseases—sorted by foods or supplements. As you can see, many studies report either no effect or inconsistent results. Any decrease in risk is attributed to foods 9 out of 10 times. Any increase in risk is always from supplements, and often in smokers. Clearly, the best way to add antioxidants to the diet is to eat generous servings of fruits and vegetables daily.

It should be clear by now that we cannot know the identity and action of every chemical in every food. Even if we did, why create a supplement to replicate a food? Why not eat foods and enjoy the pleasure, nourishment, and health benefits they provide? The beneficial constituents in foods are widespread among plants. Among the fruits, pomegranates, berries, and citrus rank high in antioxidants; top antioxidant vegetables include kale, spinach, and brussels sprouts; millet and oats contain the most antioxidants among the grains; pinto beans and soybeans are outstanding legumes; and walnuts outshine the other nuts. But don't try to single out one particular food for its "magical" nutrient, antioxidant, or phytochemical. Instead, eat a wide variety of fruits, vegetables, grains, legumes, and nuts every day—and get *all* the benefits these foods have to offer.

REFERENCES

1. D. Orsucci and coauthors, Electron transfer mediators and other metabolites and cofactors in the treatment of mitochondrial dysfunction, *Nutrition Reviews* 67 (2009): 427–438.
2. Z. Zadák and coauthors, Antioxidants and vitamins in clinical conditions, *Physiological Research* 58 (2009): S13–S17.
3. A. Whaley-Connell, P. A. McCullough, and J. R. Sowers, The role of oxidative stress in the metabolic syndrome, *Reviews in Cardiovascular Medicine* 12 (2011): 21–29.
4. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids* (Washington, D.C.: National Academies Press, 2000), p. 225.
5. H. Yao and coauthors, Dietary flavonoids as cancer prevention agents, *Environmental Carcinogenesis and Ecotoxicology Reviews* 29 (2011): 1–31.
6. P. Riso and coauthors, DNA damage and repair activity after broccoli intake in young healthy smokers, *Mutagenesis* 25 (2010): 595–602; A. Brevik and coauthors, Polymorphisms in base excision repair genes as colorectal cancer risk factors and modifiers of the effects of diets high in red meat, *Cancer Epidemiology, Biomarkers and Prevention* 19 (2010): 3167–3173; L. C. Yong and coauthors, High dietary antioxidant intakes are associated with decreased chromosome translocation frequency in airline pilots, *American Journal of Clinical Nutrition* 90 (2009): 1402–1410.
7. Q. Chen and coauthors, Pharmacologic doses of ascorbate act as a prooxidant and decrease growth of aggressive tumor xenografts in mice, *Proceedings of the National Academy of Sciences* 105 (2008): 11105–11109.
8. J. M. Gaziano and coauthors, Vitamins E and C in the prevention of prostate and total cancer in men: The Physicians' Health Study II Randomized Controlled Trial, *Journal of the American Medical Association* 301 (2009): 52–62.
9. Gaziano and coauthors, 2009; S. M. Lippman and coauthors, Effect of selenium and vitamin E on risk of prostate cancer and other cancers: The Selenium and Vitamin E Cancer Prevention Trial (SELECT), *Journal of the American Medical Association* 301 (2009): 39–51.
10. K. Musa-Veloso and coauthors, Influence of observational study design on the interpretation of cancer risk reduction by carotenoids, *Nutrition Reviews* 67 (2009): 527–545.
11. L. Gallicchio and coauthors, Carotenoids and the risk of developing lung cancer: A systematic review, *American Journal of Clinical Nutrition* 88 (2008): 372–383.
12. B. J. Willcox, J. D. Curb, and B. L. Rodriguez, Antioxidants in cardiovascular health and disease: Key lessons from epidemiologic studies, *American Journal of Cardiology* 101 (2008): 75D-86D.
13. E. L. Schiffrin, Antioxidants in hypertension and cardiovascular disease, *Molecular Interventions* 10 (2010): 354–362.
14. S. Czernichow and coauthors, Effects of long-term antioxidant supplementation and association of serum antioxidant concentrations with risk of metabolic syndrome in adults, *American Journal of Clinical Nutrition* 90 (2009): 329–335; J. Zingg, A. Azzi, and M. Meydani, Genetic polymorphisms as determinants for disease-preventive effects of vitamin E, *Nutrition Reviews* 66 (2008): 406–414.
15. Czernichow and coauthors, 2009.
16. E. Herrera and coauthors, Aspects of antioxidant foods and supplements in health and disease, *Nutrition Reviews* 67 (2009): S140–S144.
17. M. K. Shanmugam, R. Kannaiyan, and G. Sethi, Targeting cell signaling and apoptotic pathways by dietary agents: Role in the prevention and treatment of cancer, *Nutrition and Cancer* 63 (2011): 161–173; Yong and coauthors, 2009.
18. M. G. Traber, B. Frei, and J. S. Beckman, Vitamin E revisited: Do new data validate benefits for chronic disease prevention? *Current Opinion in Lipidology* 19 (2008): 30–38.
19. B. Halliwell, Free radicals and antioxidants: Quo vadis? *Trends in Pharmacological Sciences* 32 (2011): 125–130.
20. T. Tanvetyanon and G. Bepler, Beta-carotene in multivitamins and the possible risk of lung cancer among smokers versus former smokers: A meta-analysis and evaluation of national brands, *Cancer* 113 (2008): 150–157; Y. G. J. van Helden and coauthors, β-Carotene metabolites enhance inflammation-induced oxidative DNA damage in lung epithelial cells, *Free Radical Biology and Medicine* 46 (2009): 299–304.





CENGAGE LEARNING'S GLOBAL NUTRITION
GLOBAL NUTRITION RESOURCE CENTER

Water is essential for many body functions. Go to Nutrition Basics and Tools → Hydration to review recommendations on proper hydration. In what ways would inadequate hydration affect your daily activities?

12 Water and the Major Minerals

LEARNING GPS

12.1 Water and the Body Fluids 368

LEARN IT Explain how the body regulates fluid balance.

- Water Balance and Recommended Intakes 368
- Blood Volume and Blood Pressure 371
- Fluid and Electrolyte Balance 373
- Fluid and Electrolyte Imbalance 375
- Acid-Base Balance 376

12.2 The Minerals—An Overview 377

LEARN IT List some of the ways minerals differ from vitamins and other nutrients.

12.3 The Major Minerals 379

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the major minerals (sodium, chloride, potassium, calcium, phosphorus, magnesium, and sulfate).

- Sodium 379
- Chloride 382
- Potassium 383
- Calcium 384
- Phosphorus 390
- Magnesium 391
- Sulfate 393

Highlight 12 Osteoporosis and Calcium 396

LEARN IT Describe factors that contribute to the development of osteoporosis and strategies to prevent it.

Nutrition in Your Life

What's your beverage of choice? If you said water, then congratulate yourself for recognizing its importance in maintaining your body's fluid balance. If you answered milk, then pat yourself on the back for taking good care of your bones. Without water, you would realize within days how vital it is to your survival. The consequences of a lack of milk (or other calcium-rich foods) are also dramatic, but may not become apparent for decades. Water, calcium, and all the other major minerals support fluid balance and bone health. Before getting too comfortable reading this chapter, pour yourself a glass of water or milk. Your body will thank you. In the Nutrition Portfolio at the end of this chapter, you can determine whether the foods you are eating are meeting your water and major mineral needs.

Water is an essential nutrient, more important to life than any of the others. The body needs more water each day than any other nutrient. Furthermore, you can survive only a few days without water, whereas a deficiency of the other nutrients may take weeks, months, or even years to develop.

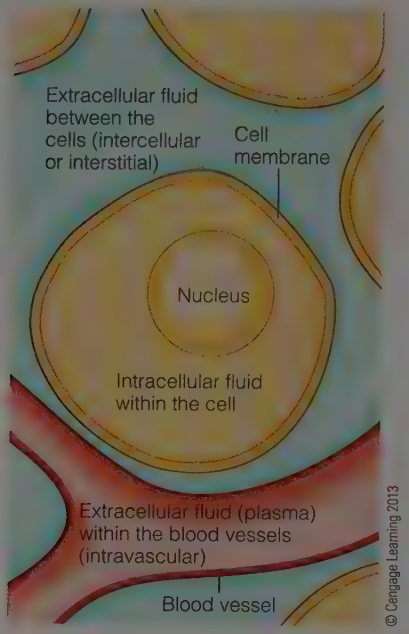
This chapter begins with a look at water and the body's fluids. The body maintains an appropriate balance and distribution of fluids with the help of another class of nutrients—the minerals. In addition to introducing the minerals that help regulate body fluids, this chapter describes many of the other important functions minerals perform in the body. Chapter 19 revisits water as a beverage and addresses consumer concerns about its safety.



© Tetra Images/Alamy

Water is the most indispensable nutrient.

> FIGURE 12-1 One Cell and Its Associated Fluids



♦ Water balance: intake = output

♦ Fluids in the body:
- Intracellular (inside cells)
- Extracellular (outside cells)
- Interstitial (between cells)
- Intravascular (inside blood vessels)

water balance: the balance between water intake and output (losses).

intracellular fluid: fluid within the cells, usually high in potassium and phosphate. Intracellular fluid accounts for approximately two-thirds of the body's water.
- **intra** = within

extracellular fluid: fluid outside the cells. Extracellular fluid includes two main components—the interstitial fluid between cells and the intravascular fluid of plasma. Extracellular fluid accounts for approximately one-third of the body's water.
- **extra** = outside

interstitial (IN-ter-STISH-al) **fluid:** fluid between the cells (intercellular), usually high in sodium and chloride. Interstitial fluid is a large component of extracellular fluid.
- **inter** = in the midst, between

thirst: a conscious desire to drink.

hypothalamus: a brain center that controls activities such as maintenance of water balance, regulation of body temperature, and control of appetite.

dehydration: the condition in which body water output exceeds water input. Symptoms include thirst, dry skin and mucous membranes, rapid heartbeat, low blood pressure, and weakness.

water intoxication: the rare condition in which body water contents are too high in all body fluid compartments.

hyponatremia (HIGH-po-na-TREE-me-ah): a decreased concentration of sodium in the blood.

12.1 Water and the Body Fluids

LEARN IT Explain how the body regulates fluid balance.

Water constitutes about 60 percent of an adult's body weight and a higher percentage of a child's (see Figure 1-1, p. 7). Because water makes up about 75 percent of the weight of lean tissue and less than 25 percent of the weight of fat, a person's body composition influences how much of the body's weight is water. The proportion of water is generally smaller in females, obese people, and the elderly because of their smaller proportion of lean tissue.

In the body, water is the fluid in which all life processes occur. The water in the body fluids:

- Carries nutrients and waste products throughout the body
- Maintains the structure of large molecules such as proteins and glycogen
- Participates in metabolic reactions
- Serves as the solvent for minerals, vitamins, amino acids, glucose, and many other small molecules so that they can participate in metabolic activities
- Acts as a lubricant and cushion around joints and inside the eyes, the spinal cord, and, in pregnancy, the amniotic sac surrounding the fetus in the womb
- Aids in the regulation of normal body temperature, as the evaporation of sweat from the skin removes excess heat from the body
- Maintains blood volume

To support these and other vital functions, the body actively maintains an appropriate **water balance.** ♦

Water Balance and Recommended Intakes

Every cell contains fluid of the exact composition that is best for that cell. Fluid inside cells is called **intracellular fluid,** whereas fluid outside cells is called **extracellular fluid.** ♦ The extracellular fluid that surrounds each cell is called **interstitial fluid.** Figure 12-1 illustrates a cell and its associated fluids. The compositions of intercellular and extracellular fluids differ from each other. They continuously lose and replace their components, yet the composition in each compartment remains remarkably constant under normal conditions. Because imbalances can be devastating, the body quickly responds by adjusting both water intake and excretion as needed. Consequently, the entire system of cells and fluids remains in a delicate, but controlled, state of homeostasis.

Water Intake

Thirst and satiety influence water intake, apparently in response to changes sensed by the mouth, **hypothalamus,** and nerves.[1] When water intake is inadequate, the blood becomes concentrated (having lost water but not the dissolved substances within it), the mouth becomes dry, and the hypothalamus initiates drinking behavior. When water intake is excessive, the stomach expands and stretch receptors send signals to stop drinking. Similar signals are sent from receptors in the heart as blood volume increases.

When too much water is lost from the body and not replaced, **dehydration** develops. A first sign of dehydration is thirst, the signal that the body has lost some fluid. If a person is unable to obtain water or, as in many elderly people, fails to perceive the thirst message, the symptoms of dehydration may progress rapidly from thirst to weakness, exhaustion, and delirium—and end in death if not corrected (see Table 12-1). Dehydration develops with either water deprivation or excessive water losses. (Chapter 14 revisits dehydration and the fluid needs of athletes.)

Water intoxication, on the other hand, is rare but can occur with excessive water intake and kidney disorders that reduce urine production. The symptoms may include confusion, convulsions, and even death in extreme cases. Excessive water ingestion (10 to 20 liters) within a few hours dilutes the sodium concentration of the blood and contributes to a dangerous condition known as **hyponatremia.** For this reason, guidelines suggest limiting fluid intake during times of heavy sweating to between 1 and 1.5 liters per hour. (Chapter 14 revisits hyponatremia as sometimes seen in endurance athletes.)

TABLE 12-1 Signs of Dehydration

Body Weight Lost (%)	Symptoms
1–2	Thirst, fatigue, weakness, vague discomfort, loss of appetite
3–4	Impaired physical performance, dry mouth, reduction in urine, flushed skin, impatience, apathy
5–6	Difficulty concentrating, headache, irritability, sleepiness, impaired temperature regulation, increased respiratory rate
7–10	Dizziness, spastic muscles, loss of balance, delirium, exhaustion, collapse

© Cengage Learning 2013

NOTE: The onset and severity of symptoms at various percentages of body weight lost depend on the activity, fitness level, degree of acclimation, temperature, and humidity. If not corrected, dehydration can lead to death.

Water Sources The obvious dietary sources of water are water itself and other beverages, but nearly all foods also contain water. Most fruits and vegetables contain up to 90 percent water, and many meats and cheeses contain at least 50 percent. See Table 12-2 for selected foods and Appendix H for many more. Also, **metabolic water** is generated as an end product during condensation reactions and the oxidation of energy-yielding nutrients. Recall from Chapter 7 that when the energy-yielding nutrients break down, their carbons and hydrogens combine with oxygen to yield carbon dioxide (CO_2) and water (H_2O). As Table 12-3 (p. 370) shows, the water derived daily from these three sources—beverages, foods, and metabolism—averages about 2500 milliliters (roughly 2.5 quarts or 10.5 cups).

Water Losses At the very least, the body must excrete enough water to carry away the waste products generated by a day's metabolic activities. This **obligatory water excretion** is a minimum of about 500 milliliters (about 2 cups) of water each day. Above this amount, excretion adjusts to balance intake. If a person drinks more water, the kidneys excrete more urine, and the urine becomes more dilute. In addition to urine, water is lost from the lungs as vapor and from the skin as sweat; some is also lost in feces.* The amount of fluid lost from each source varies, depending on the environment (such as heat or humidity) and physical conditions (such as exercise or fever). On average, daily losses total about 2500 milliliters. Table 12-3 (p. 370) shows how daily water losses and intakes balance; maintaining this balance requires healthy kidneys and an adequate intake of fluids.

Water Recommendations Because water needs vary depending on diet, activity, environmental temperature, and humidity, a general water requirement is difficult to establish. Recommendations ♦ are sometimes expressed in proportion to the amount of energy expended under average environmental conditions. The recommended

♦ Water recommendation:
- 1.0 to 1.5 mL/kcal expended (adults)*
- 1.5 mL/kcal expended (infants and athletes)

Conversion factors:
- 1 mL = 0.03 fluid oz
- 125 mL ≈ ½ c

Easy estimation: ½ c per 100 kcal expended

*For those using kilojoules: 4.2 to 6.3 mL/kJ expended.

TABLE 12-2 Percentage of Water in Selected Foods

100%	Water
90–99%	Fat-free milk, strawberries, watermelon, lettuce, cabbage, celery, spinach, broccoli
80–89%	Fruit juice, yogurt, apples, grapes, oranges, carrots
70–79%	Shrimp, bananas, corn, potatoes, avocados, cottage cheese, ricotta cheese
60–69%	Pasta, legumes, salmon, ice cream, chicken breast
50–59%	Ground beef, hot dogs, feta cheese
40–49%	Pizza
30–39%	Cheddar cheese, bagels, bread
20–29%	Pepperoni sausage, cake, biscuits
10–19%	Butter, margarine, raisins
1–9%	Crackers, cereals, pretzels, taco shells, peanut butter, nuts
0%	Oils, sugars

© Cengage Learning 2013

*Water lost from the lungs and skin accounts for almost one-half of the daily losses even when a person is not visibly perspiring; these losses are commonly referred to as *insensible water losses.*

metabolic water: water generated during metabolism.

obligatory (ah-BLIG-ah-TORE-ee) **water excretion:** the minimum amount of water the body has to excrete each day to dispose of its wastes—about 500 mL (about 2 cups, or 1 pint).

TABLE 12-3 Water Balance

Water Sources	Amount (mL)	Water Losses	Amount (mL)
Beverages	550 to 1500	Kidneys (urine)	500 to 1400
Foods	700 to 1000	Skin (sweat)	450 to 900
Metabolism	200 to 300	Lungs (breath)	350
		GI tract (feces)	150
Total	1450 to 2800	Total	1450 to 2800

NOTE: For perspective, 100 milliliters is a little less than ½ cup and 1000 milliliters is a little more than 1 quart (1 mL = 0.03 oz).

© Cengage Learning 2013

water intake for a person who expends 2000 kcalories a day, for example, is 2 to 3 liters of water (about 8 to 12 cups). This recommendation is in line with the Adequate Intake (AI) for *total* water set by the DRI Committee. ♦ Total water includes not only drinking water, but water in other beverages and in foods as well. Adults in the United States report drinking about 3 liters of water and other beverages a day.[2]

♦ AI for *total* water:
- Men: 3.7 L/day
- Women: 2.7 L/day

Conversion factors:
- 1 L ≈ 1 qt ≈ 32 oz ≈ 4 c

Because a wide range of water intakes will prevent dehydration and its harmful consequences, the AI is based on average intakes. People who are physically active or who live in hot environments may need more.

Which beverages are best? Any beverage can readily meet the body's fluid needs, but those with few or no kcalories do so without contributing to weight gain. Given that obesity is a major health problem and that beverages currently represent more than 20 percent of the total energy intake in the United States, water is the best choice for most people. Other choices include tea, coffee, nonfat and low-fat milk and soymilk, artificially sweetened beverages, fruit and vegetable juices, sports drinks, and lastly, sweetened nutrient-poor beverages.

Some research indicates that people who drink caffeinated beverages lose a little more fluid than when drinking water because caffeine acts as a diuretic. The DRI Committee considered such findings in their recommendations for water intake and concluded: "Caffeinated beverages contribute to the daily total water intake similar to that contributed by non-caffeinated beverages."[3] In other words, it doesn't seem to matter whether people rely on caffeine-containing beverages or other beverages to meet their fluid needs.

As Highlight 7 explains, alcohol acts as a diuretic and can impair a person's health. Alcohol should not be used to meet fluid needs.

Health Effects of Water Water supports good health.[4] Physical and mental performances depend on it, as does the optimal functioning of the GI tract, kidneys, heart, and other body systems.

The kind of water a person drinks may also make a difference to health. Water is usually either hard or soft. **Hard water** has high concentrations of calcium and magnesium; the principal mineral of **soft water** is sodium or potassium. (See the accompanying glossary for other common terms used to describe water.) In practical terms, soft water makes more bubbles with less soap; hard water leaves a ring on the tub, a crust of rocklike crystals in the teakettle, and a gray residue in the laundry.

Soft water may seem more desirable around the house, and some homeowners purchase water softeners that replace magnesium and calcium with sodium. In the body, however, soft water with sodium may aggravate hypertension and heart disease. In contrast, the minerals in hard water may benefit these conditions.

Soft water also more easily dissolves certain contaminant minerals, such as cadmium and lead, from old plumbing pipes. As Chapter 13 explains, these contaminant minerals harm the body by displacing the nutrient minerals from their normal sites of action. People who live in buildings with old plumbing should run the cold water tap a minute or two to flush out harmful minerals whenever the water faucet has been off for more than 6 hours.[5]

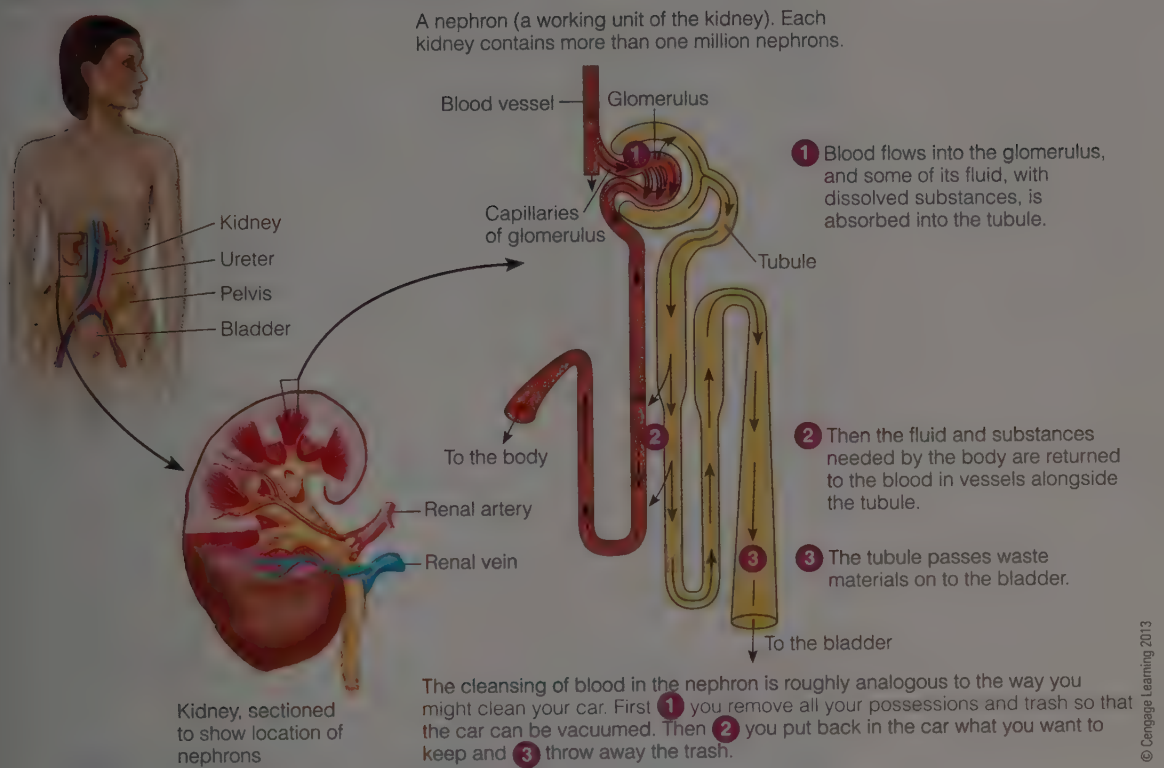
Many people select **bottled water,** believing it to be safer than tap water and therefore worth its substantial cost. Chapter 19 offers a discussion of bottled water safety and regulations.

hard water: water with a high calcium and magnesium content.

soft water: water with a high sodium or potassium content.

bottled water: drinking water sold in bottles.

FIGURE 12-2 ***Animated*** **A Nephron, One of the Kidney's Many Functioning Units**



© Cengage Learning 2013

Blood Volume and Blood Pressure Fluids maintain the blood volume, which in turn influences blood pressure. The kidneys are central to the regulation of blood volume and blood pressure. All day, every day, the kidneys reabsorb needed substances and water and excrete wastes with some water in the urine (see Figure 12-2). The kidneys meticulously adjust the volume and the concentration of the urine to accommodate changes in the body, including variations in the day's food and beverage intakes. Instructions on whether to retain or release substances or water come from ADH, renin, angiotensin, and aldosterone.

ADH Whenever blood volume or blood pressure falls too low, or whenever the extracellular fluid becomes too concentrated, the hypothalamus signals the pituitary gland to release **antidiuretic hormone (ADH)**. ADH is a water-conserving hormone that stimulates the kidneys to reabsorb water. Consequently, the more

antidiuretic hormone (ADH): a hormone produced by the pituitary gland in response to dehydration (or a high sodium concentration in the blood) that stimulates the kidneys to reabsorb more water and therefore to excrete less. In addition to its antidiuretic effect, ADH elevates blood pressure and so is also called *vasopressin* (VAS-oh-PRES-in).

- **vaso** = vessel
- **press** = pressure

GLOSSARY OF TYPES OF WATER

artesian water: water drawn from a well that taps a confined aquifer in which the water is under pressure.

carbonated water: water that contains carbon dioxide gas, either naturally occurring or added, that causes bubbles to form in it; also called *bubbling* or *sparkling water*. The FDA defines seltzer, soda, and tonic waters as soft drinks; they are not regulated as water.

distilled water: water that has been vaporized and recondensed, leaving it free of dissolved minerals.

filtered water: water treated by filtration, usually through *activated carbon filters* that reduce the lead in tap water, or by *reverse osmosis* units that force pressurized water across a membrane removing lead, arsenic, and some microorganisms from tap water.

mineral water: water from a spring or well that naturally contains at least 250 parts per million (ppm) of minerals. Minerals give water a distinctive flavor. Many mineral waters are high in sodium.

natural water: water obtained from a spring or well that is certified to be safe and sanitary. The mineral content may not be changed, but the water may be treated in other ways such as with ozone or by filtration.

public water: water from a municipal or county water system that has been treated and disinfected.

purified water: water that has been treated by distillation or other physical or chemical processes that remove dissolved solids. Because purified water contains no minerals or contaminants, it is useful for medical and research purposes.

spring water: water originating from an underground spring or well. It may be bubbly (carbonated), or "flat" or "still," meaning not carbonated. Brand names such as "Spring Pure" do not necessarily mean that the water comes from a spring.

well water: water drawn from groundwater by tapping into an aquifer.

water you need, the less your kidneys excrete. These events also trigger thirst. Drinking water and retaining fluids raise the blood volume and dilute the concentrated fluids, thus helping to restore homeostasis. (Recall from Highlight 7 that alcohol depresses ADH activity, thus promoting fluid losses and dehydration.)

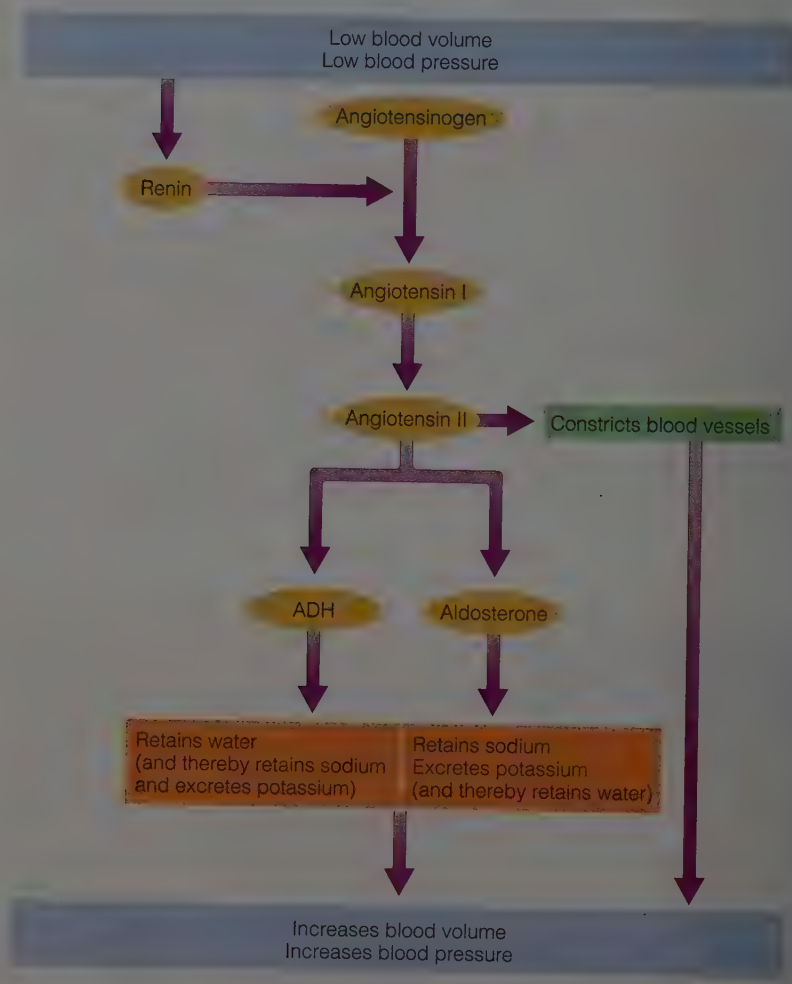
Renin Cells in the kidneys respond to low blood pressure by releasing an enzyme called **renin.** Through a complex series of events, renin causes the kidneys to reabsorb sodium. Sodium reabsorption, in turn, is always accompanied by water retention, which helps to raise blood volume and blood pressure.

Angiotensin In addition to its role in sodium retention, renin hydrolyzes a protein from the liver called angiotensinogen to **angiotensin I.** Angiotensin I is inactive until another enzyme converts it to its active form—**angiotensin II.** Angiotensin II is a powerful **vasoconstrictor** that narrows the diameters of blood vessels, thereby raising the blood pressure.

Aldosterone In addition to acting as a vasoconstrictor, angiotensin II stimulates the release of the hormone **aldosterone** from the **adrenal glands.** Aldosterone signals the kidneys to excrete potassium and to retain more sodium, and therefore water, because when sodium moves, water follows. Again, the effect is that when more water is needed, less is excreted.

All of these actions are presented in Figure 12-3 and help to explain why high-sodium diets aggravate conditions such as hypertension or edema.

> **FIGURE 12-3** ***Animated*** **How the Body Regulates Blood Volume and Blood Pressure**
The renin-angiotensin-aldosterone system helps regulate blood volume and therefore blood pressure.



© Cengage Learning 2013

renin (REN-in): an enzyme from the kidneys that hydrolyzes the protein angiotensinogen to angiotensin I, which results in the kidneys reabsorbing sodium.

angiotensin I (AN-gee-oh-TEN-sin): an inactive precursor that is converted by an enzyme to yield active angiotensin II.

angiotensin II: a hormone involved in blood pressure regulation.

vasoconstrictor (VAS-oh-kon-STRIK-tor): a substance that constricts or narrows the blood vessels.

aldosterone (al-DOS-ter-own): a hormone secreted by the adrenal glands that regulates blood pressure by increasing the reabsorption of sodium by the kidneys. Aldosterone also regulates chloride and potassium concentrations.

adrenal glands: glands adjacent to, and just above, each kidney.

Too much sodium causes water retention and an accompanying rise in blood pressure or swelling in the interstitial spaces. Chapter 18 discusses hypertension in detail.

Fluid and Electrolyte Balance Maintaining a balance of about two-thirds of the body fluids inside the cells and one-third outside is vital to the life of the cells. If too much water were to enter the cells, they might rupture; if too much water were to leave, they would collapse. To control the movement of water, the cells direct the movement of the major minerals. ♦

♦ The major minerals:
- Sodium
- Chloride
- Potassium
- Calcium
- Phosphorus
- Magnesium
- Sulfur

♦ To remember the difference between cations and anions, think of the "t" in cations as a "plus" (+) sign and the "n" in anions as a "negative."

Dissociation of Salt in Water When a mineral **salt** such as sodium chloride (NaCl) dissolves in water, it separates **(dissociates)** into **ions**—positively and negatively charged particles (Na^+ and Cl^-). The positive ions are **cations**; the negative ones are **anions.** ♦ Unlike pure water, which conducts electricity poorly, ions dissolved in water carry electrical current. For this reason, salts that dissociate into ions are called **electrolytes**, and fluids that contain them are **electrolyte solutions.**

In all electrolyte solutions, anion and cation concentrations are balanced (the number of negative and positive charges are equal). If a fluid contains 1000 negative charges, it must contain 1000 positive charges too. If an anion enters the fluid, a cation must accompany it or another anion must leave so that electrical neutrality will be maintained. Thus, whenever sodium (Na^+) ions leave a cell, potassium (K^+) ions enter, for example. In fact, it's a good bet that whenever Na^+ and K^+ ions are moving, they are going in opposite directions.

Table 12-4 shows that, indeed, the positive and negative charges inside and outside cells are perfectly balanced even though the numbers of each kind of ion differ over a wide range. Inside the cells, the positive charges total 202 and the negative charges balance these perfectly. Outside the cells, the amounts and proportions of the ions differ from those inside, but again the positive and negative charges balance. Scientists count these charges in **milliequivalents per liter (mEq/L).**

Electrolytes Attract Water Electrolytes attract water. Each water molecule has a net charge of zero, but the oxygen side of the molecule has a slight negative

TABLE 12-4 Important Body Electrolytes

Electrolytes	Intracellular (inside cells) Concentration (mEq/L)	Extracellular (outside cells) Concentration (mEq/L)
Cations (positively charged ions)		
Sodium (Na^+)	10	142
Potassium (K^+)	150	5
Calcium (Ca^{++})	2	5
Magnesium (Mg^{++})	40	3
	202	155
Anions (negatively charged ions)		
Chloride (Cl^-)	2	103
Bicarbonate (hCO_3^-)	10	27
Phosphate ($hpO_4^=$)	103	2
Sulfate ($SO_4^=$)	20	1
Organic acids (lactate, pyruvate)	10	6
Proteins	57	16
	202	155

NOTE: The numbers of positive and negative charges in a given fluid are the same. For example, in extracellular fluid, the cations and anions both equal 155 milliequivalents per liter (mEq/L). Of the cations, sodium ions make up 142 mEq/L; and potassium, calcium, and magnesium ions make up the remainder. Of the anions, chloride ions number 103 mEq/L; bicarbonate ions number 27; and the rest are provided by phosphate ions, sulfate ions, organic acids, and protein.

© Cengage Learning 2013

salt: a compound composed of a positive ion other than H^+ and a negative ion other than OH^-. An example is sodium chloride ($Na^+ Cl^-$).
- **Na** = sodium
- **Cl** = chloride

dissociates (dis-SO-see-ates) physically separates.

ions (EYE-uns): atoms or molecules that have gained or lost electrons and therefore have electrical charges. Examples include the positively charged sodium ion (Na^+) and the negatively charged chloride ion (Cl^-). For a closer look at ions, see Appendix B.

cations (CAT-eye-uns): positively charged ions.

anions (AN-eye-uns): negatively charged ions.

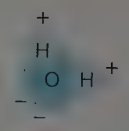
electrolytes: salts that dissolve in water and dissociate into charged particles called ions.

electrolyte solutions: solutions that can conduct electricity.

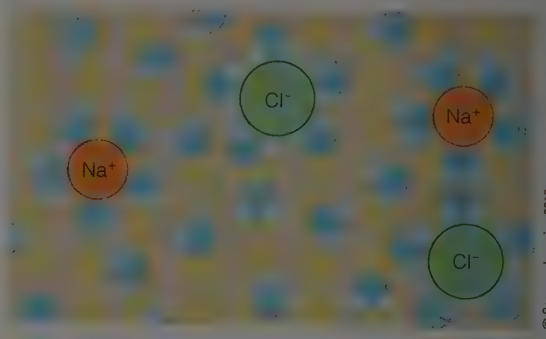
milliequivalents per liter (mEq/L): the concentration of electrolytes in a volume of solution. Milliequivalents reveal characteristics about the solution that are not evident when the concentration is expressed in terms of weight.

FIGURE 12-4 Water Dissolves Salts and Follows Electrolytes

The structural arrangement of the two hydrogen atoms and one oxygen atom enables water to dissolve salts. Water's role as a solvent is one of its most valuable characteristics.



The negatively charged electrons that bond the hydrogens to the oxygen spend most of their time near the oxygen atom. As a result, the oxygen is slightly negative, and the hydrogens are slightly positive (see Appendix B).

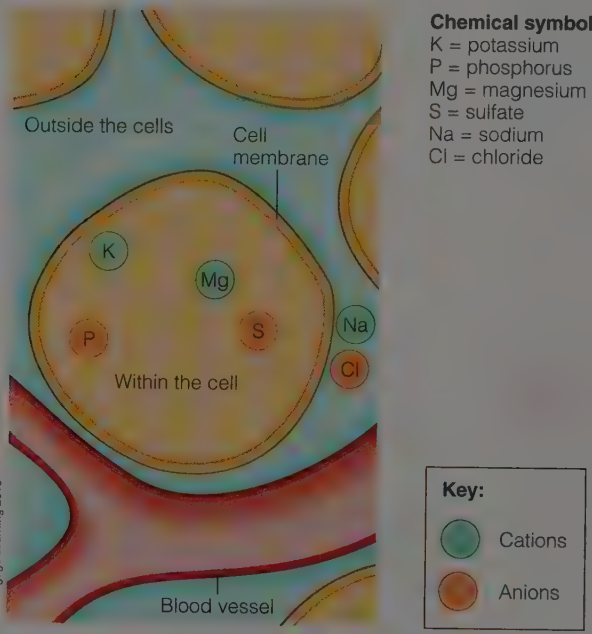


In an electrolyte solution, water molecules are attracted to both anions and cations. Notice that the negative oxygen atoms of the water molecules are drawn to the sodium cation (Na^+), whereas the positive hydrogen atoms of the water molecules are drawn to the chloride ions (Cl^-).

© Cengage Learning 2013

FIGURE 12-5 A Cell and Its Electrolytes

All of these electrolytes are found both inside and outside the cells, but each can be found mostly on one side or the other of the cell membrane.



Chemical symbols:
K = potassium
P = phosphorus
Mg = magnesium
S = sulfate
Na = sodium
Cl = chloride

Key:
Cations
Anions

© Cengage Learning 2013

charge, and the hydrogens have a slight positive charge. Figure 12-4 shows the result in an electrolyte solution: both positive and negative ions attract clusters of water molecules around them. This attraction dissolves salts in water and enables the body to move fluids into appropriate compartments.

Water Follows Electrolytes As Figure 12-5 shows, some electrolytes reside primarily outside the cells (notably, sodium and chloride), whereas others reside predominantly inside the cells (notably, potassium, magnesium, phosphate, and sulfate). Cell membranes are *selectively permeable*, meaning that they allow the passage of some molecules, but not others. Whenever electrolytes move across the membrane, water follows.

The movement of water across a membrane toward the more concentrated **solutes** is called **osmosis.** The amount of pressure needed to prevent the movement of water across a membrane is called the **osmotic pressure.** Figure 12-6 presents osmosis, and the photos of salted eggplant and rehydrated raisins provide familiar examples.

Proteins Regulate Flow of Fluids and Ions Chapter 6 describes how proteins attract water and help to regulate fluid movement. In addition, transport proteins in the cell membranes regulate the passage of positive ions and other substances from one side of the membrane to the other. Negative ions follow positive ions, and water flows toward the more concentrated solution.

An example of a protein that regulates the flow of fluids and ions in and out of cells is the sodium-potassium pump. The pump actively exchanges sodium for potassium across the cell membrane, using ATP as an energy source. Figure 6-10 on p. 177 illustrates this action.

Regulation of Fluid and Electrolyte Balance The amounts of various minerals in the body must remain nearly constant. Regulation occurs chiefly at two sites: the GI tract and the kidneys.

Minerals in foods enter the body by way of the GI tract. In addition, the digestive juices of the GI tract contain minerals. These minerals and those from foods are absorbed in the large intestine or excreted as needed. Each day, 8 liters of fluids and associated minerals are recycled this way, providing ample opportunity for the regulation of electrolyte balance.

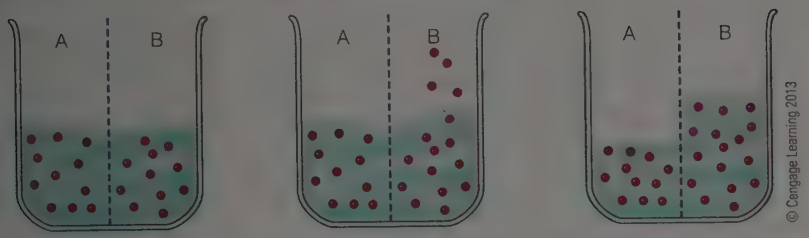
solutes (SOLL-yutes): the substances that are dissolved in a solution. The number of molecules in a given volume of fluid is the *solute concentration.*

osmosis: the movement of water across a membrane *toward* the side where the solutes are more concentrated.

osmotic pressure: the amount of pressure needed to prevent the movement of water across a membrane.

> **FIGURE 12-6 Osmosis**

Water flows in the direction of the more highly concentrated solution.



1. With equal numbers of solute particles on both sides of the semipermeable membrane, the concentrations are equal, and the tendency of water to move in either direction is about the same.
2. Now additional solute is added to side B. Solute cannot flow across the divider (in the case of a cell, its membrane).
3. Water can flow both ways across the divider, but has a greater tendency to move from side A to side B, where there is a greater concentration of solute. The volume of water becomes greater on side B, and the concentrations on side A and B become equal.

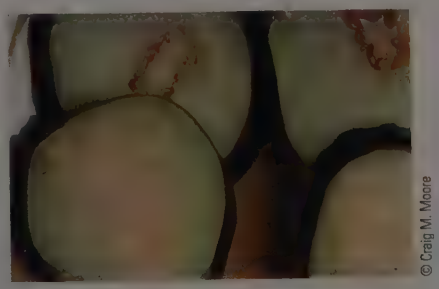
The kidneys' control of the body's *water* content by way of the hormone ADH has already been described (see pp. 371–372). The kidneys regulate the *electrolyte* contents by responding to the hormone aldosterone (also explained on p. 372). If the body's sodium is low, aldosterone stimulates sodium reabsorption from the kidneys. As sodium is reabsorbed, potassium (another positive ion) is excreted in accordance with the rule that total positive charges must remain in balance with total negative charges.

Fluid and Electrolyte Imbalance Normally, the body defends itself successfully against fluid and electrolyte imbalances. Certain situations and some medications, however, may overwhelm the body's ability to compensate. Severe, prolonged vomiting and diarrhea as well as heavy sweating, burns, and traumatic wounds may incur such great fluid and electrolyte losses as to precipitate a medical emergency.

Different Solutes Lost by Different Routes Different solutes are lost depending on why fluid is lost. If fluid is lost by vomiting or diarrhea, sodium is lost indiscriminately. If the adrenal glands oversecrete aldosterone, as may occur when they develop a tumor, the kidneys may excrete too much potassium. A person with uncontrolled diabetes may lose glucose, a solute not normally excreted, and large amounts of fluid with it. Each situation results in dehydration, but drinking water alone will not restore electrolyte balance. Medical intervention is required.



When immersed in water, raisins become plump because water moves toward the higher concentration of sugar inside the raisins.



When sprinkled with salt, vegetables "sweat" because water moves toward the higher concentration of salt outside the eggplant.



© Helder Almeida/Shutterstock.com

Physically active people must remember to replace their body fluids.

♦ A simple ORT recipe (cool before giving):
- ½ L boiling water
- A small handful of sugar (4 tsp)
- 3 pinches of salt (½ tsp)

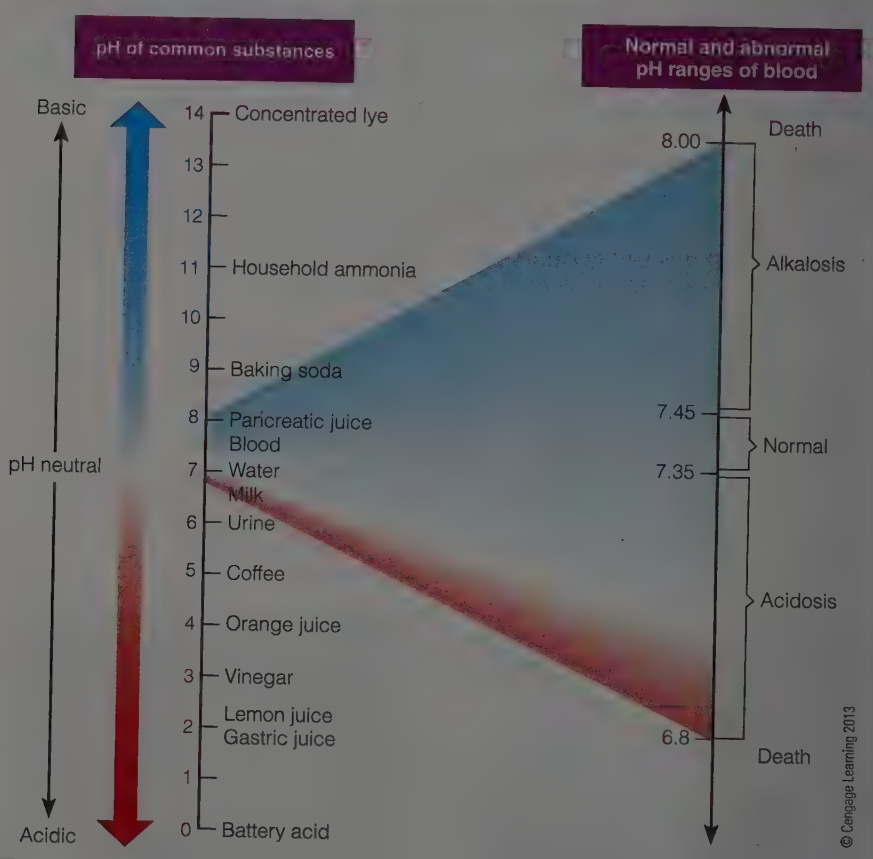
Replacing Lost Fluids and Electrolytes In many cases, people can replace the fluids and minerals lost in sweat or in a temporary bout of diarrhea by drinking plain cool water and eating regular foods. Some cases, however, demand rapid replacement of fluids and electrolytes—for example, when diarrhea threatens the life of a malnourished child. Caregivers around the world have learned to use **oral rehydration therapy (ORT)**—a simple solution of sugar, salt, and water, taken by mouth—to treat dehydration caused by diarrhea. These lifesaving formulas do not require hospitalization and can be prepared from ingredients available locally. ♦ Caregivers need only learn to measure ingredients carefully and use sanitary water. Once rehydrated, a person can begin eating foods. (Chapter 14 presents a discussion of sport drinks.)

Acid-Base Balance

The body uses its ions not only to help maintain fluid and electrolyte balance, but also to regulate the acidity (pH) of its fluids. The pH scale introduced in Chapter 3 is repeated here, in Figure 12-7, with the normal and abnormal pH ranges of the blood added. As you can see, the body must maintain the pH within a narrow range to avoid life-threatening consequences. Slight deviations in either direction can denature proteins, rendering them useless. Enzymes couldn't catalyze reactions and hemoglobin couldn't carry oxygen—to name just two examples.

The acidity of the body's fluids is determined by the concentration of hydrogen ions (H^+).* A high concentration of hydrogen ions is very acidic. Normal energy metabolism generates hydrogen ions, as well as many other acids, that must be

> **FIGURE 12-7 The pH Scale**



NOTE: Each step is 10 times as concentrated in base (1/10 as much as acid, or H^+) as the one below it.

oral rehydration therapy (ORT): the administration of a simple solution of sugar, salt, and water, taken by mouth, to treat dehydration caused by diarrhea.

*The lower the pH, the higher the H^+ ion concentration and the stronger the acid. A pH above 7 is alkaline, or base—a solution in which OH^- ions predominate.

neutralized. Three systems defend the body against fluctuations in pH—buffers in the blood, respiration in the lungs, and excretion in the kidneys.

Regulation by the Buffers Bicarbonate (a base) and carbonic acid (an acid) in the body fluids, as well as some proteins, protect the body against changes in acidity by acting as **buffers**—substances that can neutralize acids or bases. Carbon dioxide, which is formed all the time during energy metabolism, dissolves in water to form carbonic acid in the blood. Carbonic acid, in turn, dissociates to form hydrogen ions and bicarbonate ions. The appropriate balance between carbonic acid and bicarbonate is essential to maintaining optimal blood pH. Figure 12-8 presents the chemical reactions of this buffer system, which is primarily under the control of the lungs and kidneys.

Respiration in the Lungs The lungs control the concentration of carbonic acid by raising or slowing the respiration rate, depending on whether the pH needs to be increased or decreased. If too much carbonic acid builds up, the respiration rate speeds up; this hyperventilation increases the amount of carbon dioxide exhaled, thereby lowering the carbonic acid concentration and restoring homeostasis. Conversely, if bicarbonate builds up, the respiration rate slows; carbon dioxide is retained and forms more carbonic acid. Again, homeostasis is restored.

Excretion in the Kidneys The kidneys control the concentration of bicarbonate by either reabsorbing or excreting it, depending on whether the pH needs to be increased or decreased, respectively. Their work is complex, but the net effect is easy to sum up. The *body's* total acid burden remains nearly constant; the acidity of the *urine* fluctuates to accommodate that balance.

> FIGURE 12-8 Bicarbonate–Carbonic Acid Buffer System

The reversible reactions of the bicarbonate–carbonic acid buffer system help to regulate the body's pH. Recall from Chapter 7 that carbon dioxide and water are formed during energy metabolism.

Carbon dioxide (CO_2) is a volatile gas that quickly dissolves in water (H_2O), forming carbonic acid (H_2CO_3):

$$CO_2 + H_2O \longleftrightarrow H_2CO_3$$

carbon dioxide + water ⟷ carbonic acid

Carbonic acid readily dissociates to a hydrogen ion (H^+) and a bicarbonate ion (HCO_3^-):

$$H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

carbonic acid ⟷ hydrogen ion + bicarbonate ion

© Cengage Learning 2013

REVIEW IT Explain how the body regulates fluid balance.

Water makes up about 60 percent of the adult body's weight. It assists with the transport of nutrients and waste products throughout the body, participates in chemical reactions, acts as a solvent, serves as a shock absorber, and regulates body temperature. To maintain water balance, intake from liquids, foods, and metabolism must equal losses from the kidneys, skin, lungs, and GI tract. Whenever the body experiences low blood volume, low blood pressure, or highly concentrated body fluids, the actions of ADH, renin, angiotensin, and aldosterone restore homeostasis. Electrolytes (charged minerals) in the fluids help distribute the fluids inside and outside the cells, thus ensuring the appropriate water balance and acid-base balance to support all life processes. Excessive losses of fluids and electrolytes upset these balances, and the kidneys play a key role in restoring homeostasis.

12.2 The Minerals—An Overview

LEARN IT List some of the ways minerals differ from vitamins and other nutrients.

Figure 12-9 (p. 378) shows the amounts of the **major minerals** found in the body and, for comparison, some of the **trace minerals**. The distinction between the major and trace minerals does not mean that one group is more important than the other—all minerals are vital. The major minerals are so named because they are present, and needed, in larger amounts in the body. They are shown at the top of the figure and are discussed in this chapter. The trace minerals, shown at the bottom, are discussed in Chapter 13. A few generalizations pertain to all of the minerals and distinguish them from the vitamins. Especially notable is their chemical nature.

Inorganic Elements Unlike the organic vitamins, which are easily destroyed, minerals are inorganic elements that always retain their chemical identity. Once minerals enter the body proper, they remain there until excreted; they cannot be changed into anything else. Iron, for example, may temporarily combine with other charged

bicarbonate: an alkaline compound with the formula HCO_3 that is produced in all cell fluids from the dissociation of carbonic acid to help maintain the body's acid-base balance. Bicarbonate is also secreted from the pancreas as part of the pancreatic juice.

carbonic acid: a compound with the formula H_2CO_3 that results from the combination of carbon dioxide (CO_2) and water (H_2O); of particular importance in maintaining the body's acid-base balance.

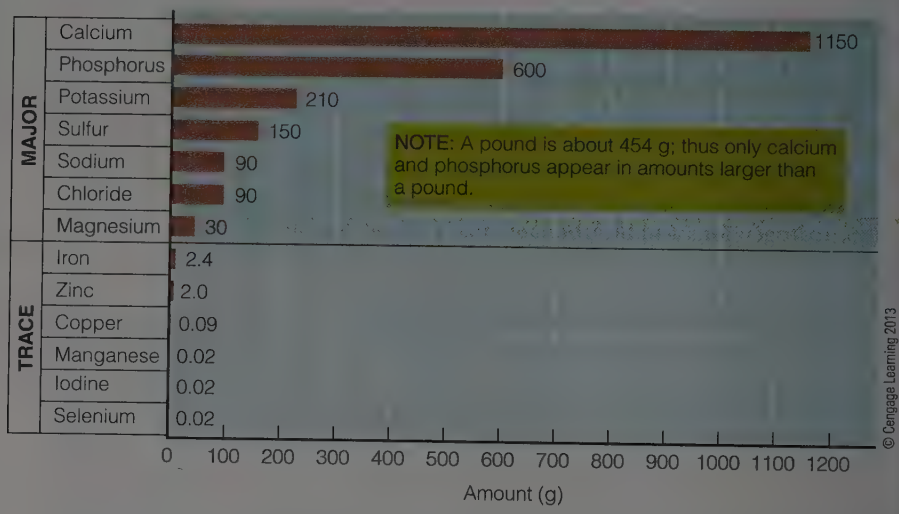
buffers: compounds that keep a solution's pH constant when acids or bases are added.

major minerals: essential mineral nutrients the human body requires in relatively large amounts (greater than 100 milligrams per day); sometimes called *macrominerals*.

trace minerals: essential mineral nutrients the human body requires in relatively small amounts (less than 100 milligrams per day); sometimes called *microminerals*.

FIGURE 12-9 Minerals in a 60-kilogram (132-pound) Human Body

Not only are the major minerals needed by the body in larger amounts, but they are also present in the body in larger amounts than the trace minerals.



© Cengage Learning 2013

elements in salts, but it is always iron. Neither can minerals be destroyed by heat, air, acid, or mixing. Consequently, little care is needed to preserve minerals during food preparation. In fact, the ash that remains when a food is burned contains all the minerals that were in the food originally. Minerals can be lost from food only when they leach into cooking water that is then poured down the drain.

The Body's Handling of Minerals The minerals also differ from the vitamins in the amounts the body can absorb and in the extent to which they must be specially handled. Some minerals, such as potassium, are easily absorbed into the blood, transported freely, and readily excreted by the kidneys, much like the water-soluble vitamins. Other minerals, such as calcium, are more like fat-soluble vitamins in that they must have carriers to be absorbed and transported. And, like some of the fat-soluble vitamins, minerals taken in excess can be toxic.

Variable Bioavailability The **bioavailability** of minerals varies. Some foods contain **binders** that combine chemically with minerals, preventing their absorption and carrying them out of the body with other wastes. Examples of binders include phytates, which are found primarily in legumes and grains, and oxalates, which are present in rhubarb and spinach, among other foods. These foods contain more minerals than the body actually receives for use.

Nutrient Interactions Chapter 10 describes how the presence or absence of one vitamin can affect another's absorption, metabolism, and excretion. The same is true of the minerals. The interactions between sodium and calcium, for example, cause both to be excreted when sodium intakes are high. Phosphorus binds with magnesium in the GI tract, so magnesium absorption is limited when phosphorus intakes are high. These are just two examples of the interactions involving minerals featured in this chapter. Discussions in both this chapter and the next point out additional problems that arise from such interactions. Notice how often they reflect an excess of one mineral creating an inadequacy of another and how supplements—not foods—are most often to blame.

REVIEW IT List some of the ways minerals differ from vitamins and other nutrients.

Compared with the trace minerals, major minerals are found, and needed, in larger quantities in the body. Unlike vitamins and the energy-yielding nutrients, minerals are inorganic elements that retain their chemical identities. Minerals usually receive special handling and regulation in the body, and they may bind with other substances or interact with other minerals, thus limiting their absorption.

bioavailability: the rate at and the extent to which a nutrient is absorbed and used.

binders: chemical compounds in foods that combine with nutrients (especially minerals) to form complexes the body cannot absorb. Examples include *phytates* (FYE-tates) and *oxalates* (OCK-sa-lates).

12.3 The Major Minerals

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the major minerals (sodium, chloride, potassium, calcium, phosphorus, magnesium, and sulfate).

Although all the major minerals help to maintain the body's fluid balance as described earlier, sodium, chloride, and potassium are most noted for that role. ♦ For this reason, these three minerals are discussed first here. Later sections describe the minerals most noted for their roles in bone growth and health—calcium, phosphorus, and magnesium. The chapter closes with a brief discussion on sulfate, a mineral required for the synthesis of several sulfur-containing compounds.

♦ Key fluid balance nutrients:
- Sodium, potassium, chloride

Sodium

People have held salt (sodium chloride) in high regard throughout recorded history. We describe someone we admire as "the salt of the earth" and people we consider worthless as "not worth their salt." Even the word *salary* comes from the Latin word for salt.

Cultures vary in their use of salt, but most people find its taste innately appealing. Salt brings its own tangy taste and enhances other flavors, most likely by suppressing the bitter flavors. You can taste this effect for yourself: tonic water with its bitter quinine tastes sweeter with a little salt added.

Sodium Roles in the Body

Sodium is the principal cation of the extracellular fluid and the primary regulator of its volume. Sodium also helps maintain acid-base balance and is essential to nerve impulse transmission and muscle contraction.*

Sodium is readily absorbed by the intestinal tract and travels freely in the blood until it reaches the kidneys, which filter all the sodium out of the blood. Then, with great precision, the kidneys return to the blood the exact amount of sodium the body needs. Normally, the amount excreted is approximately equal to the amount ingested on a given day. When blood sodium rises, as when a person eats salted foods, thirst signals the person to drink until the appropriate sodium-to-water concentration is restored. Then the kidneys excrete both the excess water and the excess sodium together.

Sodium Recommendations

Diets rarely lack sodium, and even when intakes are low, the body adapts by reducing sodium losses in urine and sweat, thus making deficiencies unlikely. Sodium recommendations ♦ are set low enough to protect against high blood pressure, but high enough to allow an adequate intake of other nutrients with a typical diet. Because high sodium intakes correlate with high blood pressure, the Upper Level (UL) for adults is set at 2300 milligrams per day, slightly lower than the Daily Value used on food labels (2400 milligrams). The average sodium intake for adults in the United States is 3400 milligrams, which exceeds the UL—and most adults will develop hypertension at some point in their lives.[6]

♦ AI for sodium:
- 1500 mg/day (19–50 yr)
- 1300 mg/day (51–70 yr)
- 1200 mg/day (>70 yr)

Sodium and Hypertension

For years, a high *sodium* intake was considered the primary factor responsible for high blood pressure. Then research pointed to *salt* (sodium chloride) ♦ as the dietary culprit. Salt has a greater effect on blood pressure than either sodium or chloride alone or in combination with other ions. The increase in blood pressure in response to a high salt intake may be immediate and is reversible with salt restriction. The elevation of blood pressure in response to a high-salt diet over years is progressive, and the damage caused to blood vessels is irreversible.[7]

♦ Salt (sodium chloride) is about 40% sodium.
- 1 g salt contributes about 400 mg sodium
- 6 g salt = 1 tsp
- 1 tsp salt contributes about 2300 mg sodium

Blood pressure increases in response to excesses in salt intake—most notably for those with hypertension, African Americans, and people older than 40 years of age.[8] **Salt sensitivity** is apparent in about 25 percent of those with normal blood pressure and in about 50 percent of those with high blood pressure.** For them, a high salt intake correlates strongly with heart disease, and salt restriction (to no more than 1500 milligrams of sodium per day) helps to lower blood pressure.

sodium: the principal cation in the extracellular fluids of the body; critical to the maintenance of fluid balance, nerve impulse transmissions, and muscle contractions.

salt sensitivity: a characteristic of individuals who respond to a high salt intake with an increase in blood pressure or to a low salt intake with a decrease in blood pressure.

*One of the ways the kidneys regulate acid-base balance is by excreting hydrogen ions (H^+) in exchange for sodium ions (Na^+).

**Compared with others, salt-sensitive individuals have elevated concentrations of renin in their blood.

>How To

Cut Salt (and Sodium) Intake

Most people eat more salt (and therefore sodium) than they need. Some people can lower their blood pressure by avoiding highly salted foods and removing the salt shaker from the table. Foods eaten without salt may seem less tasty at first, but with repetition, people can learn to enjoy the natural flavors of many unsalted foods. Strategies to cut salt intake include:

- Select fresh, unprocessed foods.
- Cook with little or no added salt.
- Prepare foods with sodium-free spices such as basil, bay leaves, curry, garlic, ginger, mint, oregano, pepper, rosemary, and thyme; lemon juice; vinegar; or wine.
- Add little or no salt at the table; taste foods before adding salt.
- Read labels with an eye open for sodium. (See the glossary on p. 57 for terms used to describe the sodium contents of foods on labels.)
- Select low-salt or salt-free products when available.

Use these foods sparingly:

- Foods prepared in brine, such as pickles, olives, and sauerkraut
- Salty or smoked meats, such as bologna, corned or chipped beef, bacon, frankfurters, ham, lunchmeats, salt pork, sausage, and smoked tongue
- Salty or smoked fish, such as anchovies, caviar, salted and dried cod, herring, sardines, and smoked salmon
- Snack items such as potato chips, pretzels, salted popcorn, salted nuts, and crackers
- Condiments such as bouillon cubes; seasoned salts; MSG; soy, teriyaki, Worcestershire, and barbeque sauces; prepared horseradish, ketchup, and mustard
- Cheeses, especially processed types
- Canned and instant soups

TRY IT Compare the sodium contents of 1 ounce of the following foods: a plain bagel, potato chips, and animal crackers.

♦ AHA goals:
- Blood pressure: <120/80 mmHg
- Sodium intake: <1500 mg/day

♦ Hypertension
Beneficial factors:
- Dietary fiber
- Physical activity
- Potassium

Harmful factors:
- Overweight/obesity
- Sodium in excess
- Alcohol in excess

A salt-restricted diet lowers blood pressure and improves blood vessel dilation in people without hypertension as well.[9] Because reducing salt intake causes no harm and diminishes the risk of hypertension and heart disease, the *Dietary Guidelines for Americans* advise limiting daily *salt* intake to about 1 teaspoon (the equivalent of about 2.3 grams or 2300 milligrams of *sodium*).[10] The American Heart Association goal ♦ is to lower blood pressure by reducing sodium intake to less than 1500 milligrams a day.[11] The accompanying "How To" feature offers strategies for cutting salt (and therefore sodium) intake.



> DIETARY GUIDELINES FOR AMERICANS 2010
Choose foods low in sodium and prepare foods with little salt. Reduce daily sodium intake to less than 2300 milligrams and further reduce intake to 1500 milligrams among persons who are 51 and older and those of any age who are African American or have hypertension, diabetes, or chronic kidney disease.

One eating pattern, known as the DASH (Dietary Approaches to Stop Hypertension) Eating Plan, is effective in lowering blood pressure. Like other USDA Food Patterns, the DASH Eating Plan reflects the *Dietary Guidelines* and allows people to stay within their energy allowance, meet nutrient needs, and reduce chronic disease risk. The DASH approach emphasizes potassium-rich fruits, vegetables, and low-fat milk products; includes whole grains, nuts, poultry, and fish; and calls for reduced intakes of sodium, red and processed meats, sweets, and sugar-containing beverages. In combination with a reduced sodium intake, DASH is even more effective at lowering blood pressure than either strategy alone. Chapter 18 offers a complete discussion of hypertension and the dietary recommendations ♦ for its prevention and treatment.



© Carmen Steiner /Shutterstock.com

Fresh herbs add flavor to a recipe without adding salt.

Sodium and Bone Loss (Osteoporosis) A high salt intake is also associated with increased calcium excretion, but its influence on bone loss is less clear. In addition, potassium may prevent the calcium excretion caused by a high-salt diet. For these reasons, dietary advice to prevent bone loss parallels that suggested for hypertension—a DASH eating pattern that is low in sodium and abundant in potassium-rich fruits and vegetables and calcium-rich low-fat milk.

Sodium in Foods In general, processed foods have the most sodium, whereas unprocessed foods such as fresh fruits and vegetables have the least. In fact, as much as 75 percent of the sodium in people's diets comes from salt added to foods by manufacturers; about 15 percent comes from salt added during cooking and at the table; and only 10 percent comes from the natural content in foods. To help consumers limit their intake, public health organizations and policymakers worldwide are calling for manufacturers to reduce sodium in the food supply.[12] Reducing the sodium content in processed foods could prevent an estimated 100,000 deaths and save up to $24 billion in health care costs in the United States annually.[13]

Because processed foods may contain sodium without chloride, as in additives such as sodium bicarbonate or sodium saccharin, they do not always taste salty. Most people are surprised to learn that 1 ounce of some cereals contains more sodium than 1 ounce of salted peanuts—and that ½ cup of instant chocolate pudding contains still more. The peanuts taste saltier because the salt is all on the surface, where the tongue's taste receptors immediately pick it up.

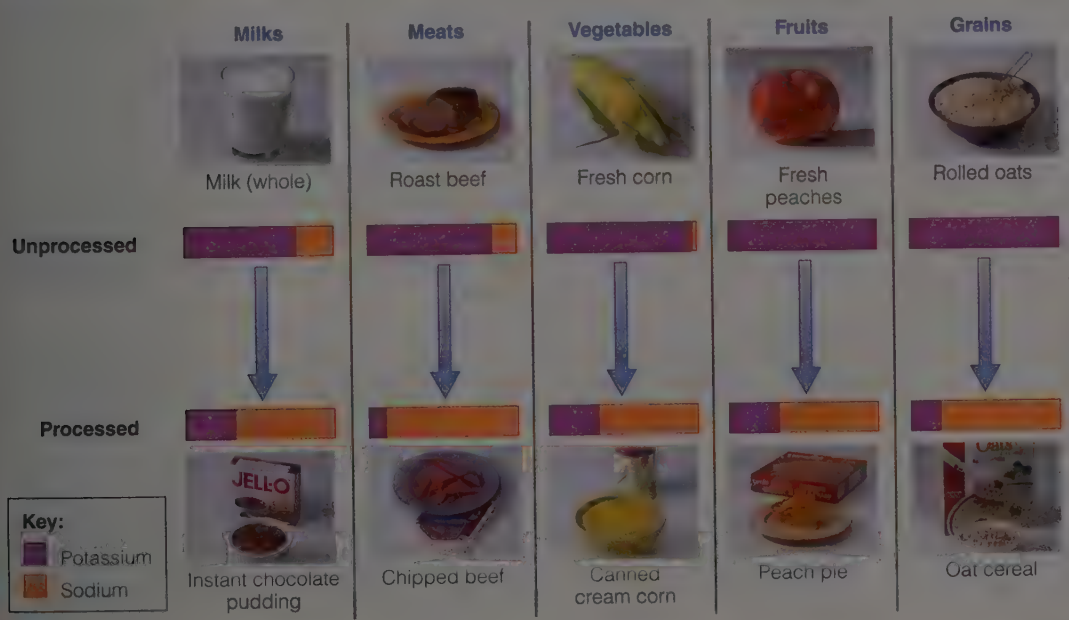
Figure 12-10 shows that processed foods not only contain more sodium than their less-processed counterparts but also have less potassium. Low potassium may be as significant as high sodium when it comes to blood pressure regulation, so processed foods have two strikes against them.

Sodium Deficiency Sodium deficiency does not develop from an inadequate diet. The body needs so little and diets provide enough. Blood sodium may drop with vomiting, diarrhea, or heavy sweating, and in these cases, both sodium and water must be replenished. Under normal conditions of sweating due to physical activity, salt losses can easily be replaced later in the day with ordinary foods. Salt tablets are not recommended because too much salt, especially if taken with too little water, can induce dehydration. During intense activities, such as ultra-endurance events, athletes can lose so much sodium and drink so much water that they develop hyponatremia—the dangerous condition ♦ of having too little sodium in the blood. Hyponatremia is caused by excessive sodium losses, not from inadequate sodium intake.[14] (Chapter 14 offers details about hyponatremia and guidelines for ultra-endurance athletes.)

♦ Symptoms of hyponatremia:
- Headache, confusion, stupor
- Seizures, coma

> FIGURE 12-10 What Processing Does to the Sodium and Potassium Contents of Foods

People who eat foods high in salt often happen to be eating fewer potassium-containing foods at the same time. Notice how potassium is lost and sodium is gained as foods become more processed, causing the potassium-to-sodium ratio to fall dramatically. Even when potassium isn't lost, the addition of sodium still lowers the potassium-to-sodium ratio. Selecting fresh, unprocessed foods lowers blood pressure in two ways, then—by lowering sodium intakes and by raising potassium intakes.



Photos: Matthew Farruggio (all); art: © Cengage Learning 2013

Sodium Toxicity and Excessive Intakes The immediate symptoms of acute sodium toxicity are edema and high blood pressure. Prolonged excessive sodium intake may also contribute to hypertension in some people, as explained earlier.

REVIEW IT

Sodium is the main cation outside cells and one of the primary electrolytes responsible for maintaining fluid balance. Dietary deficiency is unlikely, and excesses raise blood pressure in many people. For this reason, health professionals advise a diet moderate in salt and sodium. The accompanying table provides a summary of sodium.

Sodium

Adequate Intake (AI)	Deficiency Symptoms
Adults: 1500 mg/day (19–50 yr) 1300 mg/day (51–70 yr) 1200 mg/day (>70 yr)	Not from inadequate intakes Hyponatremia from excessive losses
Upper Level	**Toxicity Symptoms**
Adults: 2300 mg/day	Edema, acute hypertension
Chief Functions in the Body	**Significant Sources**
Maintains normal fluid and electrolyte balance; assists in nerve impulse transmission and muscle contraction	Table salt, soy sauce; moderate amounts in meats, milks, breads, and vegetables; large amounts in processed foods

Chloride

The element *chlorine* (Cl_2) is a poisonous gas. When chlorine reacts with sodium or hydrogen, however, it forms the negative chloride ion (Cl^-). *Chloride,* an essential nutrient, is required in the diet.

Chloride Roles in the Body **Chloride** is the major anion of the extracellular fluids (outside the cells), where it occurs mostly in association with sodium. Chloride moves passively across membranes through channels and so also associates with potassium inside cells. Like sodium and potassium, chloride maintains fluid and electrolyte balance.

In the stomach, the chloride ion is part of hydrochloric acid, which maintains the strong acidity of gastric juice. One of the most serious consequences of vomiting is the loss of this acid from the stomach, which upsets the acid-base balance.* Such imbalances are commonly seen in bulimia nervosa, as described in Highlight 8.

Chloride Recommendations and Intakes Chloride is abundant in foods (especially processed foods) as part of sodium chloride and other salts. Chloride recommendations are slightly higher than, but still equivalent to, those of sodium. In other words, ¾ teaspoon of salt ♦ will deliver some sodium, more chloride, and still meet the AI for both.

♦ Salt (sodium chloride) is about 60% chloride.
- 1 g salt contributes about 600 mg chloride
- 6 g salt = 1 tsp
- 1 tsp salt contributes about 3700 mg chloride

Chloride Deficiency and Toxicity Diets rarely lack chloride. Like sodium losses, chloride losses may occur in conditions such as heavy sweating, chronic diarrhea, and vomiting. The only known cause of elevated blood chloride concentrations is dehydration due to water deficiency. In both cases, consuming ordinary foods and beverages can restore chloride balance.

REVIEW IT

Chloride is the major anion outside cells, and it associates closely with sodium. In addition to its role in fluid balance, chloride is part of the stomach's hydrochloric acid. The accompanying table provides a summary of chloride.

chloride (KLO-ride): the major anion in the extracellular fluids of the body. Chloride is the ionic form of chlorine, Cl^-. See Appendix B for a description of the chlorine-to-chloride conversion.

*Hydrochloric acid secretion into the stomach involves the addition of bicarbonate ions (base) to the plasma. These bicarbonate ions (HCO_3^-) are neutralized by hydrogen ions (H^+) from the gastric secretions that are reabsorbed into the plasma. When hydrochloric acid is lost during vomiting, these hydrogen ions are no longer available for reabsorption, and so, in effect, the concentrations of bicarbonate ions in the plasma are increased. In this way, excessive vomiting of acidic gastric juices leads to *metabolic alkalosis*—an above-normal alkalinity in the blood and body fluids.

REVIEW IT Chloride (*continued*)

Adequate Intake (AI)
Adults: 2300 mg/day (19–50 yr) 2000 mg/day (51–70 yr) 1800 mg/day (>70 yr)

Upper Level
Adults: 3600 mg/day

Chief Functions in the Body
Maintains normal fluid and electrolyte balance; part of hydrochloric acid found in the stomach, necessary for proper digestion

Deficiency Symptoms
Do not occur under normal circumstances

Toxicity Symptoms
Vomiting

Significant Sources
Table salt, soy sauce; moderate amounts in meats, milks, eggs; large amounts in processed foods

Potassium

Like sodium, **potassium** is a positively charged ion. In contrast to sodium, potassium is the body's principal intracellular cation, *inside* the body cells.

Potassium Roles in the Body

Potassium plays a major role in maintaining fluid and electrolyte balance and cell integrity. During nerve impulse transmissions and muscle contractions, potassium and sodium briefly trade places across the cell membrane. The cell then quickly pumps them back into place. Controlling potassium distribution is a high priority for the body because it affects many aspects of homeostasis, including a steady heartbeat.

Potassium Recommendations and Intakes

Potassium is abundant in all living cells. Because cells remain intact unless foods are processed, the richest sources of potassium are *fresh* foods—as Figure 12-11 (p. 384) shows. In contrast, most processed foods such as canned vegetables, ready-to-eat cereals, and luncheon meats contain less potassium—and more sodium (recall Figure 12-10, p. 381). To meet the AI for potassium, most people need to increase their intake of fruits and vegetables to five to nine servings daily.



> DIETARY GUIDELINES FOR AMERICANS 2010

Choose foods that provide more potassium, a nutrient of concern in American diets. Potassium is found in all food groups, notably vegetables, fruits, and milk and milk products.

Potassium and Hypertension

Diets low in potassium, especially when combined with high sodium intakes, raise blood pressure and increase the risk of death from heart disease.[15] In contrast, high potassium intakes, especially when combined with low sodium intakes, appear to both prevent and correct hypertension. Recall that the DASH eating pattern described earlier is used to lower blood pressure and emphasizes potassium-rich foods such as fruits and vegetables. Potassium-rich fruits and vegetables also appear to reduce the risk of stroke—more so than can be explained by the reduction in blood pressure alone.

Potassium Deficiency

Potassium deficiency is characterized by an increase in blood pressure, salt sensitivity, kidney stones, and bone turnover. As deficiency progresses, symptoms include irregular heartbeats, muscle weakness, and glucose intolerance.

Potassium Toxicity

Potassium toxicity does not result from overeating foods high in potassium; therefore a UL has not been set. It can result from overconsumption of potassium salts or supplements (including some "energy fitness shakes") and from certain diseases or treatments. Given more potassium than the body needs, the kidneys accelerate excretion. If potassium is injected directly into a vein, however, it can stop the heart.



© Polara Studios, Inc

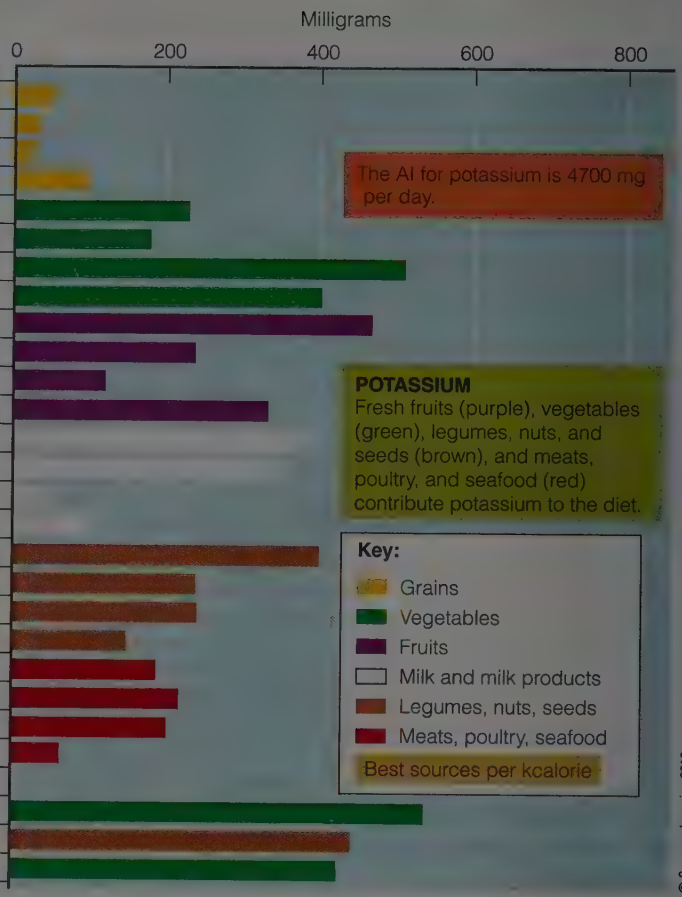
Fresh foods, especially fruits and vegetables, provide potassium in abundance.

potassium: the principal cation within the body's cells; critical to the maintenance of fluid balance, nerve impulse transmissions, and muscle contractions.

> **FIGURE 12-11 Potassium in Selected Foods**

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Squash, acorn	½ c baked (69 kcal)
Soybeans	½ c cooked (149 kcal)
Artichoke	1 (60 kcal)



© Cengage Learning 2013

REVIEW IT

Potassium, like sodium and chloride, is an electrolyte that plays an important role in maintaining fluid balance. Potassium is the primary cation inside cells; fresh foods, notably fruits and vegetables, are its best sources. The accompanying table provides a summary of potassium.

Potassium

Adequate Intake (AI)

Adults: 4700 mg/day

Chief Functions in the Body

Maintains normal fluid and electrolyte balance; facilitates many reactions; supports cell integrity; assists in nerve impulse transmission and muscle contractions

Deficiency Symptoms[a]

Irregular heatbeat, muscular weakness, glucose intolerance

Toxicity Symptoms

Muscular weakness; vomiting; if given into a vein, can stop the heart

Significant Sources

All whole foods: meats, milks, fruits, vegetables, grains, legumes

[a]Deficiency accompanies dehydration.

Calcium

Calcium is the most abundant mineral in the body. It receives much emphasis in this chapter and in the highlight that follows because an adequate intake helps grow a healthy skeleton in early life and minimize bone loss in later life.

calcium: the most abundant mineral in the body; found primarily in the body's bones and teeth.

Calcium Roles in the Body

Ninety-nine percent of the body's calcium is in the bones (and teeth), where it plays two roles. First, it is an integral part of bone

structure, providing a rigid frame that holds the body upright and serves as attachment points for muscles, making motion possible. Second, it serves as a calcium bank, offering a readily available source of calcium to the body fluids should a drop in blood calcium occur. The remaining 1 percent of the body's calcium is in the body fluids.

As bones begin to form, calcium salts form crystals, called **hydroxyapatite**, on a matrix of the protein collagen. During **mineralization**, as the crystals become denser, they give strength and rigidity to the maturing bones. As a result, the long leg bones of children can support their weight by the time they have learned to walk.

Many people have the idea that once a bone is built, it is inert like a rock. Actually, the bones are gaining and losing minerals continuously in an ongoing process of remodeling. Growing children gain more bone than they lose, and healthy adults maintain a reasonable balance. When withdrawals substantially exceed deposits, problems such as osteoporosis develop (as described in Highlight 12).

The formation of teeth follows a pattern similar to that of bones. The turnover of minerals in teeth is not as rapid as in bone, however; fluoride hardens and stabilizes the crystals of teeth, opposing the withdrawal of minerals from them.

Although only 1 percent of the body's calcium circulates in the extracellular and intracellular fluids, its presence there is vital to life. Cells throughout the body can detect calcium in the extracellular fluids and respond accordingly. Many of calcium's actions help to maintain normal blood pressure, perhaps by stabilizing the smooth muscle cells of the blood vessels or by releasing relaxing factors from the blood vessel cell walls. Extracellular calcium also participates in blood clotting.

The calcium in intracellular fluids binds to proteins within the cells and activates them. For example, when the protein **calmodulin** binds with calcium, it activates the enzymes involved in breaking down glycogen, which releases energy for muscle contractions. Many such proteins participate in the regulation of muscle contractions, the transmission of nerve impulses, the secretion of hormones, and the activation of some enzyme reactions.

Calcium in Disease Prevention Calcium may protect against some chronic diseases, including hypertension.[16] Considering the success of DASH in lowering blood pressure, restricting sodium to treat hypertension may be narrow advice. The DASH eating pattern is rich in calcium, as well as in magnesium and potassium. As mentioned earlier, the combination of DASH with a reduced sodium intake is more effective in lowering blood pressure than either strategy alone.

Some research also suggests protective relationships between dietary calcium and blood cholesterol, diabetes, and colon cancer.[17] Highlight 12 explores calcium's role in preventing osteoporosis.

Calcium from dairy foods, but *not* from supplements, may play a role in maintaining a healthy body weight.[18] Some epidemiological studies suggest an inverse relationship between calcium intake and body weight: the higher the calcium intake, the lower the prevalence of overweight. Teenagers who drink little or no milk gain more weight than their peers who do drink milk.[19]

An adequate dietary calcium intake may help prevent excessive fat accumulation by stimulating hormonal action that targets the breakdown of stored fat. Alternatively, milk may weaken the motivation to eat that typically accompanies weight loss.[20] Not all research suggests that consumption of calcium from dairy foods alters fat metabolism, energy expenditure, or body weight.[21] But even when body weight does not improve, dairy foods seem to help in another way—by suppressing the inflammation commonly associated with overweight.[22]

Calcium Balance Calcium homeostasis involves a system of hormones and vitamin D.[23] Whenever blood calcium falls too low or rises too high, three organ systems respond: the intestines, bones, and kidneys. Figure 12-12 (p. 386) illustrates how vitamin D and two hormones—**parathyroid hormone** and **calcitonin**—return blood calcium to normal.

hydroxyapatite (high-drox-ee-APP-ah-tite): crystals made of calcium and phosphorus.

mineralization: the process in which calcium, phosphorus, and other minerals crystallize on the collagen matrix of a growing bone, hardening the bone.

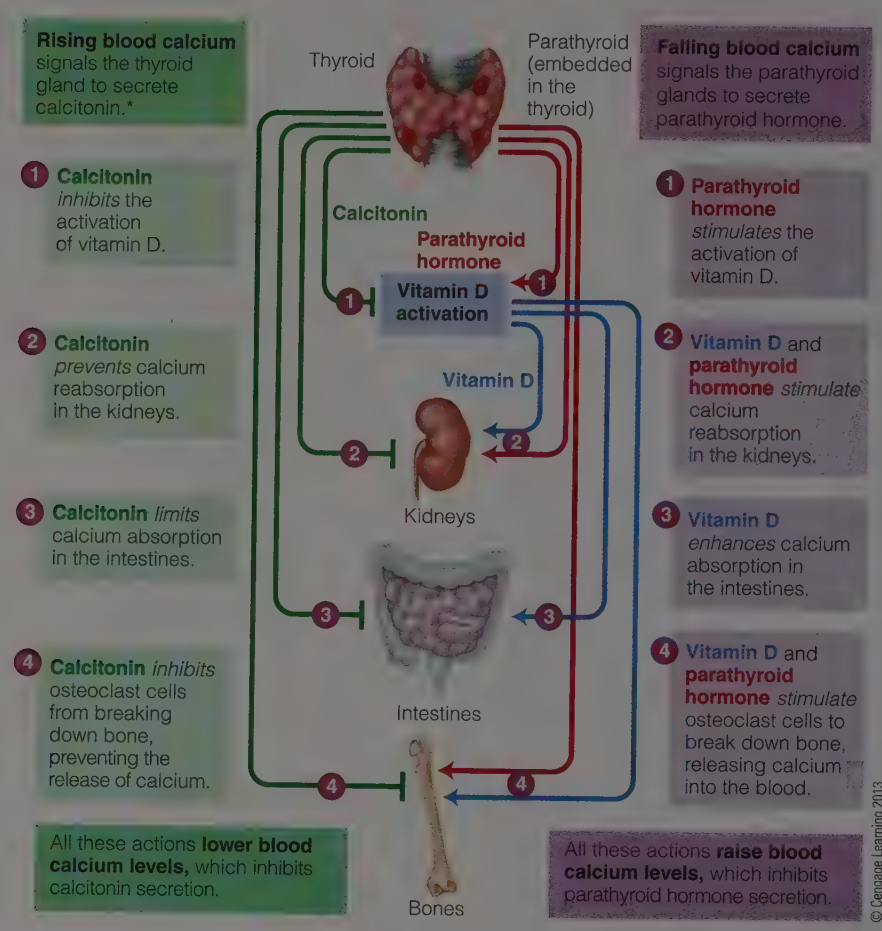
calmodulin (cal-MOD-you-lin): a calcium-binding protein that regulates such cell activities as muscle contractions.

parathyroid hormone: a hormone from the parathyroid glands that regulates blood calcium by raising it when levels fall too low; also known as *parathormone* (PAIR-ah-THOR-moan).

calcitonin (KAL-seh-TOE-nin): a hormone secreted by the thyroid gland that regulates blood calcium by lowering it when levels rise too high.

FIGURE 12-12 ***Animated*** **Calcium Balance**

Blood calcium is regulated by vitamin D and two hormones—calcitonin and parathyroid hormone. Bones serve as a reservoir when blood calcium is high and as a source of calcium when blood calcium is low. Osteoclasts break down bone and release calcium into the blood; osteoblasts build new bone using calcium from the blood.



*Calcitonin plays a major role in defending infants and young children against the dangers of rising blood calcium that can occur when regular feedings of milk deliver large quantities of calcium to a small body. In contrast, calcitonin plays a relatively minor role in adults because their absorption of calcium is less efficient and their bodies are larger, making elevated blood calcium unlikely.

The calcium in bones provides a nearly inexhaustible bank of calcium for the blood. The blood borrows and returns calcium as needed so that even with an inadequate diet, *blood* calcium remains normal—even as *bone* calcium diminishes (see Figure 12-13). Blood calcium changes only in response to abnormal regulatory control, not to diet. A person can have an inadequate calcium intake for years and have no noticeable symptoms. Only later in life does it become apparent that bone integrity has been compromised.

Blood calcium above normal results in **calcium rigor:** the muscles contract and cannot relax. Similarly, blood calcium below normal causes **calcium tetany**—also characterized by uncontrolled muscle contraction. These conditions do *not* reflect a *dietary* excess or lack of calcium; they are caused by a lack of vitamin D or by abnormal secretion of the regulatory hormones. A chronic *dietary* deficiency of calcium, or a chronic deficiency due to poor absorption over the years, depletes the bones. Again: the *bones*, not the blood, are robbed by a calcium deficiency.

Calcium Absorption Because many factors affect calcium absorption, the most effective way to ensure adequacy is to increase calcium intake.[24] On average, adults absorb about 30 percent of the calcium they ingest. The stomach's acidity helps to keep calcium soluble, and vitamin D helps to make the **calcium-binding protein** needed for absorption. This relationship explains why calcium-rich milk is a good choice for vitamin D fortification.

Whenever calcium is needed, the body increases its calcium absorption. The result is obvious in the case of a newborn infant, whose calcium absorption is 55 to 60 percent. Similarly, a pregnant woman doubles her absorption of calcium. Growing children and teens absorb up to 50 percent of the calcium they consume. Then, when bone growth slows or stops, absorption falls to the adult level of about 30 percent. In addition, absorption becomes more efficient during times of inadequate intakes.

Many of the conditions that enhance calcium absorption limit its absorption when they are absent. For example, sufficient vitamin D supports absorption, and a deficiency impairs it. In addition, fiber in general, and the binders phytate and oxalate in particular, interfere with calcium absorption, but their effects are relatively minor in typical US diets. Vegetables with oxalates and whole grains with phytates are nutritious foods, of course, but they are not useful calcium sources. The margin note ♦ presents factors that influence calcium balance.

Calcium Recommendations Calcium is unlike most other nutrients in that hormones maintain its *blood* concentration regardless of dietary intake. As Figure 12-13 shows, when calcium intake is high, the *bones* benefit; when intake is low, the *bones* suffer. Calcium recommendations are therefore based on the amount needed to

♦ *Enhance* calcium absorption:
- Stomach acid
- Vitamin D
- Lactose (in infants only)

Limit calcium absorption:
- Lack of stomach acid
- Vitamin D deficiency
- High phosphorus intake
- Phytates (in seeds, nuts, grains)
- Oxalates (in beet greens, rhubarb, spinach, sweet potatoes)

calcium rigor: hardness or stiffness of the muscles caused by high blood calcium concentrations.

calcium tetany (TET-ah-nee): intermittent spasm of the extremities due to nervous and muscular excitability caused by low blood calcium concentrations.

calcium-binding protein: a protein in the intestinal cells, made with the help of vitamin D, that facilitates calcium absorption.

retain the most calcium in bones. By retaining the most calcium possible, the bones can develop to their fullest potential in size and density—their **peak bone mass**—within genetic limits.

Calcium recommendations have been set high enough to accommodate a 30 percent absorption rate. Because obtaining enough calcium during growth helps to ensure that the skeleton will be strong and dense, the recommendation for adolescents to the age of 18 years is 1300 milligrams daily. Between the ages of 19 and 50, recommendations are lowered to 1000 milligrams a day; for women older than 50 and all adults older than 70, recommendations are raised again to 1200 milligrams a day to minimize the bone loss that tends to occur later in life. Some authorities advocate as much as 1500 milligrams a day for women older than 50. Most people in the United States have calcium intakes below current recommendations.[25] Those meeting recommendations for calcium are likely to be using calcium supplements.[26] High intakes of calcium from supplements may have adverse effects such as kidney stone formation. For this reason, a UL has been established. ♦

High intakes of both dietary protein and sodium increase calcium losses, but whether these losses impair bone development remains unclear. In the case of protein, any effects of high intakes are offset by the beneficial effects of accompanying nutrients—for example, by potassium in legumes and calcium in milk.[27] In fact, protein may even improve calcium absorption and bone strength.[28] The DRI Committee considered these nutrient interactions in establishing the RDA for calcium and did not adjust dietary recommendations based on this information.[29]

Calcium Food Sources Figure 12-14 (p. 388) shows that calcium is found most abundantly in a single class of foods—milk and milk products. ♦ The person who doesn't like to drink milk may prefer to eat cheese or yogurt. Alternatively, milk and milk products can be concealed in foods. Powdered fat-free milk can be added to casseroles, soups, and other mixed dishes during preparation; 5 heaping tablespoons offer the equivalent of 1 cup of milk. This simple step is an excellent way for older women to obtain not only extra calcium, but more protein, vitamins, and minerals as well.

It is especially difficult for children who don't drink milk to meet their calcium needs. The consequences of drinking too little milk during childhood and adolescence persist into adulthood. Women who seldom drank milk as children or teenagers have lower bone density and greater risk of fractures than those who drank milk regularly. It is possible for people who do not drink milk to obtain adequate calcium, but only if they carefully select other calcium-rich foods.



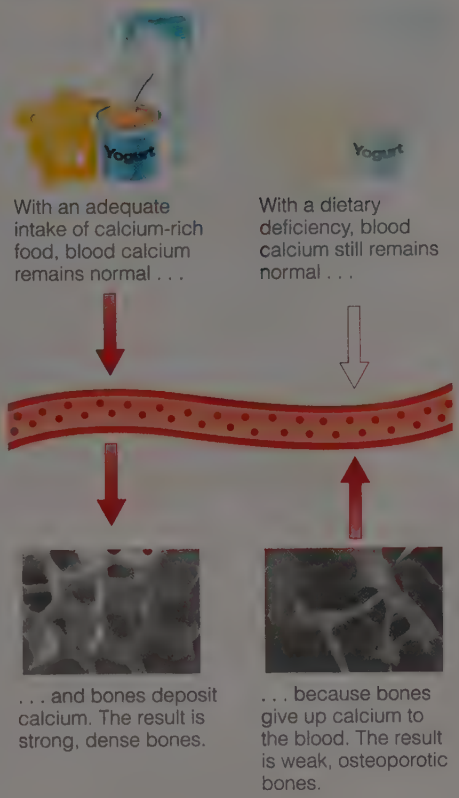
> DIETARY GUIDELINES FOR AMERICANS 2010

Choose foods that provide more calcium, a nutrient of concern in American diets. The best sources of calcium are milk and milk products.

Many people, for a variety of reasons, cannot or do not drink milk. Some cultures do not use milk in their cuisines; some vegetarians exclude milk as well as meat; and some people are allergic to milk protein or are lactose intolerant. Others simply do not enjoy the taste of milk. These people need to find other foods to help meet their calcium needs. Some brands of tofu, corn tortillas, some nuts (such as almonds), and some seeds (such as sesame seeds) can supply calcium for the person who doesn't use milk products. A slice of most breads contains only about 5 to 10 percent of the calcium found in milk, but it can be a major source for people who eat many slices because the calcium is well absorbed. Oysters are also a rich source of calcium, as are small fish eaten with their bones, such as canned sardines.

Among the vegetables, mustard and turnip greens, bok choy, kale, parsley, watercress, and broccoli are good sources of available calcium. So are some seaweeds such as the nori popular in Japanese cooking. Some dark green, leafy vegetables—notably spinach and Swiss chard—appear to be calcium-rich but actually provide little, if any, calcium because they contain binders that limit absorption. It would

> FIGURE 12-13 Maintaining Blood Calcium from the Diet and from the Bones



© Permission by David Dempster from J Bone Miner Res, 1986 (both)

♦ UL for calcium:
- 2500 mg/day (adults 19–50 yr)
- 2000 mg/day (adults >50 yr)

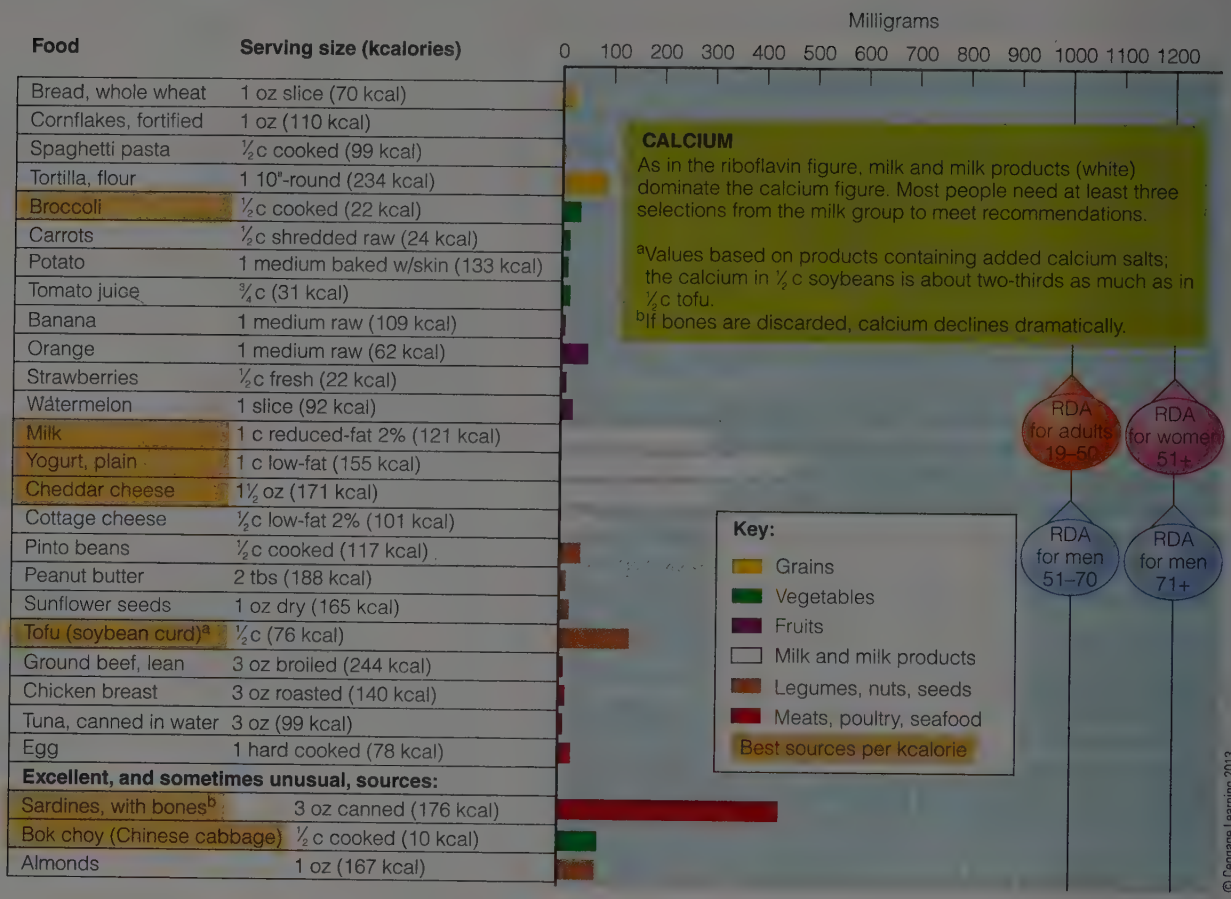
♦ Suggested daily milk amounts:
- Young children (2 to 8 yr): 2 c
- Older children, teenagers, and all adults: 3 c

peak bone mass: the highest attainable bone density for an individual, developed during the first three decades of life.

> FIGURE 12-14 Calcium in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)[a]	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Sardines, with bones[b]	3 oz canned (176 kcal)
Bok choy (Chinese cabbage)	½ c cooked (10 kcal)
Almonds	1 oz (167 kcal)



© Cengage Learning 2013



© Matthew Farruggio

Milk and milk products are well known for their calcium, but calcium-set tofu, bok choy, kale, calcium-fortified orange juice, and broccoli are also rich in calcium.

take 8 cups of spinach—containing six times as much calcium as 1 cup of milk—to deliver the equivalent in *absorbable* calcium.

With the exception of foods such as spinach that contain calcium binders, the calcium content of foods is usually more important than bioavailability. Consequently, recognizing that people eat a variety of foods containing calcium, the DRI Committee did not adjust for calcium bioavailability when setting recommendations. Figure 12-15 ranks selected foods according to their calcium bioavailability.

Some mineral waters provide as much as 500 milligrams of calcium per liter, offering a convenient way to meet both calcium and water needs. Similarly, calcium-fortified orange juice and other fruit and vegetable juices allow a person to obtain both calcium and vitamins easily. Other examples of calcium-fortified foods include high-calcium milk (milk with extra calcium added) and calcium-fortified cereals. Fortified juices and foods help consumers increase calcium intakes, but depending on the calcium sources, the bioavailability may be significantly less than quantities listed on food labels. The accompanying "How To" feature describes a quick way to estimate calcium intake. Highlight 12 discusses calcium supplements.

A generalization that has been gaining strength throughout this book is supported by the information given here about calcium. A balanced diet that supplies a variety of foods is the best plan to ensure adequacy for all essential nutrients. All food groups should be included, and none should be overemphasized. In our culture, calcium intake is usually inadequate wherever milk is lacking in the diet. By contrast, iron is usually lacking whenever milk is overemphasized, as Chapter 13 explains.

Calcium Deficiency A low calcium intake during the growing years limits the bones' ability to reach their optimal mass and density. Most people achieve a

>How To

Estimate Your Calcium Intake

Most dietitians have developed useful shortcuts to help them estimate nutrient intakes and "see" inadequacies in the diet. They can tell at a glance whether a day's meals fall short of calcium recommendations, for example.

To estimate calcium intakes, keep two bits of information in mind:

- A cup of milk provides about 300 milligrams of calcium.
- Adults need between 1000 and 1200 milligrams of calcium per day, which represents 3 to 4 cups of milk—or the equivalent:

1000 mg ÷ 300 mg/c = 3⅓ c
1200 mg ÷ 300 mg/c = 4 c

If a person drinks 3 to 4 cups of milk a day, it's easy to see that calcium needs are being met. If not, it takes some detective work to identify the other sources and estimate total calcium intake.

To estimate a person's daily calcium intake, use this shortcut, which compares the calcium in calcium-rich foods to the calcium content of milk. The calcium in a cup of milk is assigned 1 point, and the goal is to attain 3 to 4 points per day. Foods are given points as follows:

- 1 c milk, yogurt, or fortified soy milk or 1½ oz cheese = 1 point
- 4 oz canned fish with bones (sardines) = 1 point
- 1 c ice cream, cottage cheese, or calcium-rich vegetable (see the text) = ½ point

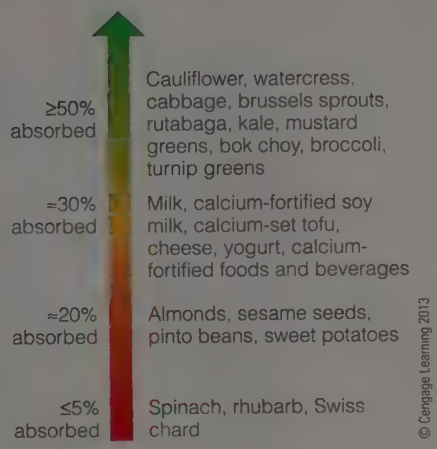
Then, because other foods also contribute small amounts of calcium, together they are given a point.

- Well-balanced diet containing a variety of foods = 1 point

Now consider a day's meals with calcium in mind. Cereal with 1 cup of milk for breakfast (1 point for milk), a ham and cheese sub sandwich for lunch (1 point for cheese), and a cup of broccoli and lasagna for dinner (½ point for calcium-rich vegetable and 1 point for cheese in lasagna)—plus 1 point for all other foods eaten that day—adds up to 4½ points. This shortcut estimate indicates that calcium recommendations have been met, and a diet analysis of these few foods reveals a calcium intake of more than 1000 milligrams. By knowing the best sources of each nutrient, you can learn to scan the day's meals and quickly see if you are meeting your daily goals.

TRY IT Compare the calcium contents of ½ cup of the following foods: almonds, broccoli, and yogurt.

> FIGURE 12-15 Bioavailability of Calcium from Selected Foods



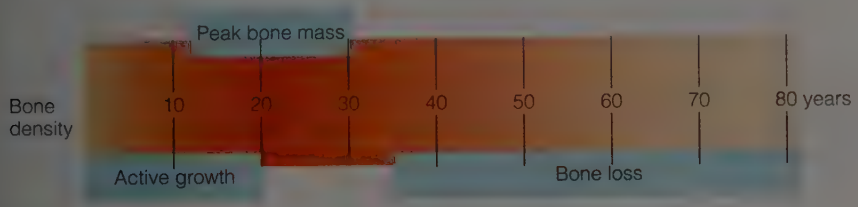
© Cengage Learning 2013

peak bone mass by their late 20s, and dense bones best protect against age-related bone loss and fractures (see Figure 12-16). All adults lose bone as they grow older, beginning between the ages of 30 and 40. When bone losses reach the point of causing fractures under common, everyday stresses, the condition is known as **osteoporosis.** Osteoporosis and low bone mass (osteopenia) affect an estimated 44 million people in the United States, mostly older women.[30]

Unlike many diseases that make themselves known through symptoms such as pain, shortness of breath, skin lesions, tiredness, and the like, osteoporosis is

> FIGURE 12-16 Phases of Bone Development throughout Life

The active growth phase occurs from birth to approximately age 20. The phase of peak bone mass development occurs between the ages of 12 and 30. The final phase, when bone resorption exceeds formation, begins between the ages of 30 and 40 and continues through the remainder of life.



© Cengage Learning 2013

osteoporosis (OS-tee-oh-pore-OH-sis) a disease in which the bones become porous and fragile due to a loss of minerals; also called *adult bone loss.*

- **osteo** = bone
- **porosis** = porous

silent. The body sends no signals saying bones are losing their calcium and, as a result, their integrity. Blood samples offer no clues because blood calcium remains normal regardless of bone content, and measures of bone density may not be routinely taken until later in life. Highlight 12 suggests strategies to protect against bone loss, of which eating calcium-rich foods is only one.

REVIEW IT

Most of the body's calcium is in the bones, where it provides a rigid structure and a reservoir of calcium for the blood. Blood calcium participates in muscle contraction, blood clotting, and nerve impulses, and it is closely regulated by a system of hormones and vitamin D. Calcium is found predominantly in milk and milk products. Even when calcium intake is inadequate, blood calcium remains normal, but at the expense of bone loss, which can lead to osteoporosis. The accompanying table provides a summary of calcium.

Calcium

2011 RDA

Adults: 1000 mg/day (adults, 19–50 yr)
1000 mg/day (men, 51–70 yr)
1200 mg/day (men, ≥71 yr)
1200 mg/day (women, ≥51 yr)

Upper Level

Adults: 2500 mg/day (adults, 19–50 yr)
2000 mg/day (adults, ≥51 yr)

Chief Functions in the Body

Mineralization of bones and teeth; also involved in muscle contraction and relaxation, nerve functioning, blood clotting, blood pressure

Deficiency Symptoms

Stunted growth in children; bone loss (osteoporosis) in adults

Toxicity Symptoms

Constipation; increased risk of urinary stone formation and kidney dysfunction; interference with absorption of other minerals

Significant Sources

Milk and milk products, small fish (with bones), calcium-set tofu (bean curd), greens (bok choy, broccoli, chard, kale), legumes

Phosphorus

Phosphorus is the second most abundant mineral in the body. About 85 percent of it is found combined with calcium in the hydroxyapatite crystals of bones and teeth.

Phosphorus Roles in the Body

Phosphorus is found not only in bones and teeth, but in all body cells as part of a major buffer system. Phosphorus is also part of DNA and RNA and is therefore necessary for all growth.

Phosphorus assists in energy metabolism. The high-energy compound ATP uses three phosphate groups to do its work. Many enzymes and the B vitamins become active only when a phosphate group is attached.

Phosphorus provides structure to the phospholipid vehicles that help to transport lipids in the blood. Phospholipids are also the major structural components of cell membranes, where they control the transport of nutrients into and out of the cells. Some proteins, such as the casein in milk, contain phosphorus as part of their structures (phosphoproteins).

Phosphorus Recommendations and Intakes

Because phosphorus is commonly found in almost all foods, dietary deficiencies are unlikely. As Figure 12-17 shows, foods rich in proteins are the best sources of phosphorus. Milk and cheese contribute about 25 percent of the phosphorus in the US diet.

Over the years, researchers have emphasized the importance of an ideal calcium-to-phosphorus ratio to support calcium metabolism, but there is little or no evidence to support this concept. The quantities of calcium and phosphorus in the diet are far more important than their ratio to each other. A high phosphorus intake has been blamed for bone loss when, in fact, a low calcium intake—not a phosphorus toxicity or an improper ratio—is responsible. Research shows that the displacement of milk in the diet by cola drinks, not the phosphoric acid content of the beverages, limits bone density. No adverse effects of high dietary phosphorus intakes have been reported; still, a UL ♦ has been established.

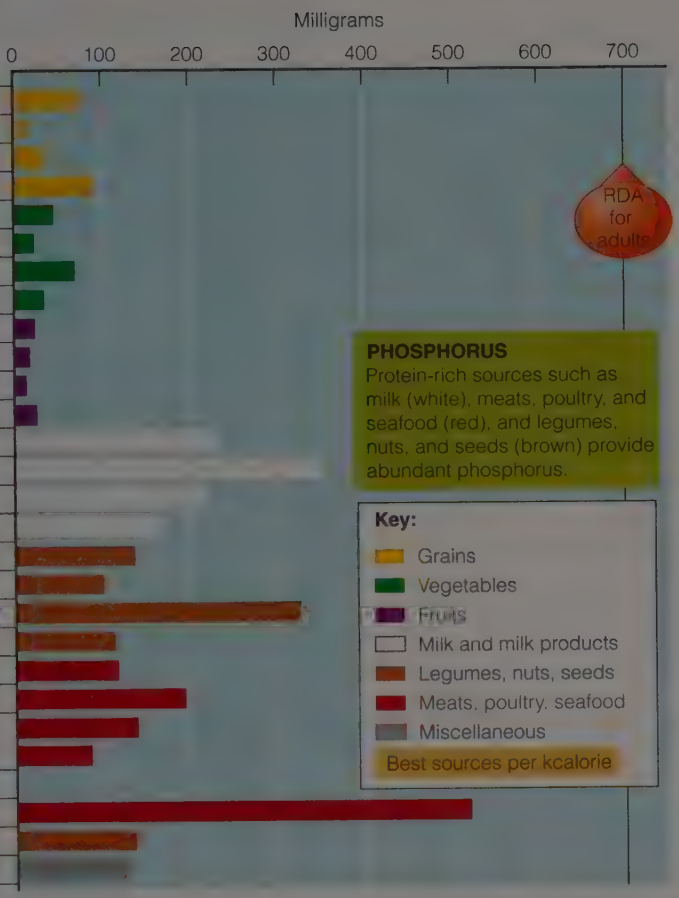
♦ Phosphorus UL:
- 4000 mg/day (adults 19–70 yr)

phosphorus: a major mineral found mostly in the body's bones and teeth.

> **FIGURE 12-17 Phosphorus in Selected Foods**

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Liver	3 oz (184 kcal)
Almonds	1 oz (165 kcal)
Candy bar	2.2 oz (278 kcal)



© Cengage Learning 2013

REVIEW IT

Phosphorus accompanies calcium both in the crystals of bone and in many foods such as milk. Phosphorus is also important in energy metabolism as part of ATP, in lipid transport as part of phospholipids, and in genetic materials as part of DNA and RNA. The accompanying table provides a summary of phosphorus.

Phosphorus

RDA

Adults: 700 mg/day

Upper Level

Adults (19–70 yr): 4000 mg/day

Chief Functions in the Body

Mineralization of bones and teeth; part of every cell; important in genetic material, part of phospholipids, used in energy transfer and in buffer systems that maintain acid-base balance

Deficiency Symptoms

Muscular weakness, bone pain[a]

Toxicity Symptoms

Calcification of nonskeletal tissues, particularly the kidneys

Significant Sources

Foods derived from animals (meat, fish, poultry, eggs, milk)

[a]Dietary deficiency rarely occurs, but some drugs can bind with phosphorus making it unavailable and resulting in bone loss that is characterized by weakness and pain.

Magnesium Only about 1 ounce of **magnesium** is present in the body of a 132-pound person (review Figure 12-9, p. 378). More than half of the body's magnesium is in the bones. Much of the rest is in the muscles and soft tissues, with

magnesium: a cation within the body's cells, active in many enzyme systems.

only 1 percent in the extracellular fluid. As with calcium, bone magnesium may serve as a reservoir to ensure normal blood concentrations.

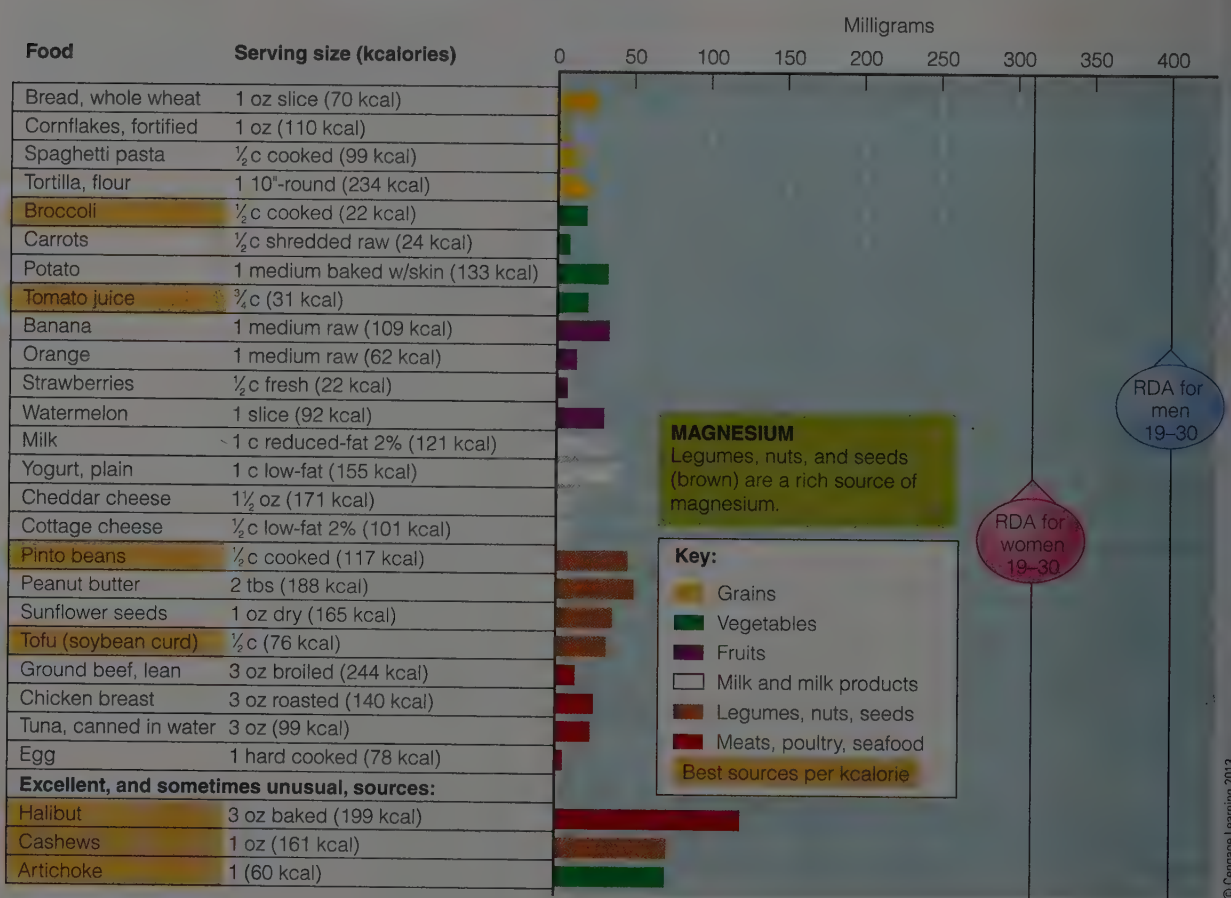
Magnesium Roles in the Body In addition to maintaining bone health, magnesium acts in all the cells of the soft tissues, where it forms part of the protein-making machinery and is necessary for energy metabolism. It participates in hundreds of enzyme systems. A major role of magnesium is as a catalyst in the reaction that adds the last phosphate to the high-energy compound ATP, making it essential to the body's use of glucose; the synthesis of protein, fat, and nucleic acids; and the cells' membrane transport systems. Together with calcium, magnesium is involved in muscle contraction and blood clotting: calcium promotes the processes, whereas magnesium inhibits them. This dynamic interaction between the two minerals helps regulate blood pressure and lung function. Like many other nutrients, magnesium supports the normal functioning of the immune system.

Magnesium Intakes The brown bars in Figure 12-18 indicate that legumes, nuts, and seeds make significant magnesium contributions. Magnesium is part of the chlorophyll molecule, so dark green, leafy vegetables are also good sources. In areas with hard water, the water contributes both calcium and magnesium to daily intakes. Mineral waters noted earlier for their calcium content may also be magnesium-rich and can be important sources of this mineral for those who drink them. Bioavailability of magnesium from mineral water is about 50 percent, but it improves when the water is consumed with a meal.

Magnesium Deficiency Average magnesium intakes typically fall below recommendations, which may upset bone metabolism and increase the risk for osteoporosis.[31] In addition, magnesium deficiency may exacerbate inflammation and contribute to

> FIGURE 12-18 Magnesium in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.



Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Halibut	3 oz baked (199 kcal)
Cashews	1 oz (161 kcal)
Artichoke	1 (60 kcal)

© Cengage Learning 2013

chronic diseases such as heart disease, hypertension, diabetes, and cancer.[32] A severe magnesium deficiency causes a tetany similar to the calcium tetany described earlier. Magnesium deficiencies also impair central nervous system activity and may be responsible for the hallucinations experienced during alcohol withdrawal.

Magnesium and Hypertension Magnesium is critical to heart function and seems to protect against hypertension and heart disease. Interestingly, people living in areas of the country with hard water, which contains high concentrations of calcium and magnesium, tend to have low rates of heart disease. With magnesium deficiency, the walls of the arteries and capillaries tend to constrict—a possible explanation for the hypertensive effect.

Magnesium Toxicity Magnesium toxicity is rare, but it can be fatal. The UL for magnesium applies only to nonfood sources such as supplements or magnesium salts.

REVIEW IT

Like calcium and phosphorus, magnesium supports bone mineralization. Magnesium is also involved in numerous enzyme systems and in heart function. It is found abundantly in legumes and dark green, leafy vegetables and, in some areas, in water. The accompanying table offers a summary of magnesium.

Magnesium

RDA	Deficiency Symptoms
Men (19–30 yr): 400 mg/day	Weakness; confusion; if extreme, convulsions, bizarre muscle movements (especially of eye and face muscles), hallucinations, and difficulty in swallowing; in children, growth failure[a]
Women (19–30 yr): 310 mg/day	
Upper Level	**Toxicity Symptoms**
Adults: 350 mg nonfood magnesium/day	From nonfood sources only; diarrhea, alkalosis, dehydration
Chief Functions in the Body	**Significant Sources**
Bone mineralization, building of protein, enzyme action, normal muscle contraction, nerve impulse transmission, maintenance of teeth, and functioning of immune system	Nuts, legumes, whole grains, dark green vegetables, seafood, chocolate, cocoa

[a]A still more severe deficiency causes tetany, an extreme, prolonged contraction of the muscles similar to that caused by low blood calcium.

Sulfate Sulfate is the oxidized form of the mineral **sulfur**, as it exists in food and water. The body's need for sulfate is easily met by a variety of foods and beverages. In addition, the body receives sulfate from the amino acids methionine and cysteine, which are found in dietary proteins. These sulfur-containing amino acids help determine the contour of protein molecules. The sulfur-containing side chains in cysteine molecules can link to each other via disulfide bridges, which stabilize the protein structure. (See the drawing of insulin with its disulfide bridges on p. 170.) Skin, hair, and nails contain some of the body's more rigid proteins, which have a high sulfur content.

Because the body's sulfate needs are easily met with normal protein intakes, there is no recommended intake for sulfate. Deficiencies do not occur when diets contain protein. Only when people lack protein to the point of severe deficiency will they lack the sulfur-containing amino acids.

REVIEW IT Identify the main roles, deficiency symptoms, and food sources for each of the major minerals (sodium, chloride, potassium, calcium, phosphorus, magnesium, and sulfate).

Like the other nutrients, minerals' actions are coordinated to get the body's work done. The major minerals, especially sodium, chloride, and potassium, influence the body's fluid balance; whenever an anion moves, a cation moves—always maintaining homeostasis. Sodium, chloride, potassium, calcium, and magnesium are key members of the team of nutrients that direct nerve impulse transmission and muscle contraction. They are also the primary nutrients involved in regulating blood pressure. Phosphorus and magnesium participate in many reactions involving glucose, fatty acids, amino acids, and the vitamins. Calcium, phosphorus, and magnesium combine to form the structure of the bones and teeth. Each major mineral also plays other specific roles in the body. The table on p. 394 provides a summary of the major minerals.

sulfate: a salt produced from the oxidation of sulfur.

sulfur: a mineral present in the body as part of some proteins.

REVIEW IT The Major Minerals

Chief Functions	Deficiency Symptoms	Toxicity Symptoms	Significant Sources
Sodium Maintains normal fluid and electrolyte balance; assists in nerve impulse transmission and muscle contraction	Muscle cramps, mental apathy, loss of appetite	Edema, acute hypertension	Table salt, soy sauce; moderate amounts in meats, milks, breads, and vegetables; large amounts in processed foods
Chloride Maintains normal fluid and electrolyte balance; part of hydrochloric acid found in the stomach, necessary for proper digestion	Do not occur under normal circumstances	Vomiting	Table salt, soy sauce; moderate amounts in meats, milks, eggs; large amounts in processed foods
Potassium Maintains normal fluid and electrolyte balance; facilitates many reactions; supports cell integrity; assists in nerve impulse transmission and muscle contractions	Irregular heartbeat, muscular weakness, glucose intolerance	Muscular weakness; vomiting; if injected into a vein, can stop the heart	All whole foods; meats, milks, fruits, vegetables, grains, legumes
Calcium Mineralization of bones and teeth; also involved in muscle contraction and relaxation, nerve functioning, blood clotting, and blood pressure	Stunted growth in children; bone loss (osteoporosis) in adults	Constipation; increased risk of urinary stone formation and kidney dysfunction; interference with absorption of other minerals	Milk and milk products, small fish (with bones), tofu, greens (bok choy, broccoli, chard), legumes
Phosphorus Mineralization of bones and teeth; part of every cell; important in genetic material, part of phospholipids, used in energy transfer and in buffer systems that maintain acid-base balance	Muscular weakness, bone pain[a]	Calcification of nonskeletal tissues, particularly the kidneys	All animal tissues (meat, fish, poultry, eggs, milk)
Magnesium Bone mineralization, building of protein, enzyme action, normal muscle contraction, nerve impulse transmission, maintenance of teeth, and functioning of immune system	Weakness; confusion; if extreme, convulsions, bizarre muscle movements (especially of eye and face muscles), hallucinations, and difficulty in swallowing; in children, growth failure[b]	From nonfood sources only; diarrhea, alkalosis, dehydration	Nuts, legumes, whole grains, dark green vegetables, seafood, chocolate, cocoa
Sulfate As part of proteins, stabilizes their shape by forming disulfide bridges; part of the vitamins biotin and thiamin and the hormone insulin	None known; protein deficiency would occur first	Toxicity would occur only if sulfur-containing amino acids were eaten in excess; this (in animals) suppresses growth	All protein-containing foods (meats, fish, poultry, eggs, milk, legumes, nuts)

[a]Dietary deficiency rarely occurs, but some drugs can bind with phosphorus making it unavailable and resulting in bone loss that is characterized by weakness and pain.
[b]A still more severe deficiency causes tetany, an extreme, prolonged contraction of the muscles similar to that caused by low blood calcium.

With all of the tasks these minerals perform, they are of great importance to life. Consuming enough of each of them every day is easy, given a variety of foods from each of the food groups. Whole-grain breads supply magnesium; fruits, vegetables, and legumes provide magnesium and potassium too; milk products offer calcium and phosphorus; meats, poultry, and seafood offer phosphorus and sulfate as well; all foods provide sodium and chloride, with excesses being more problematic than inadequacies. The message is quite simple and has been repeated throughout this text: for an adequate intake of all the nutrients, including the major minerals, choose a variety of foods from each of the five food groups. And drink plenty of water.

Nutrition Portfolio

Many people may miss the mark when it comes to drinking enough water to keep their bodies well hydrated or obtaining enough calcium to promote strong bones; in contrast, sodium intakes often exceed those recommended for health. Go to Diet Analysis Plus and choose one of the days on which you tracked your diet for an entire day. Select the Intake vs. Goals report and then consider the following questions. Remember that scoring 100 percent on this report means you met your goal.

- Did you exceed, fail to meet, or meet your goal for water intake? Was that a typical day for you? Describe your strategy for ensuring that you drink plenty of water—about eight glasses—every day.
- Take a look at your sodium intake in this report. Most people in the United States exceed the UL. Did you? Explain the importance of selecting and preparing foods with less salt.
- How was your intake of calcium for that day? If you are not getting enough calcium, consult Chapter 12 for ideas to help you get more, then list at least three foods or beverages you would be willing to eat or drink that would improve your intake.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

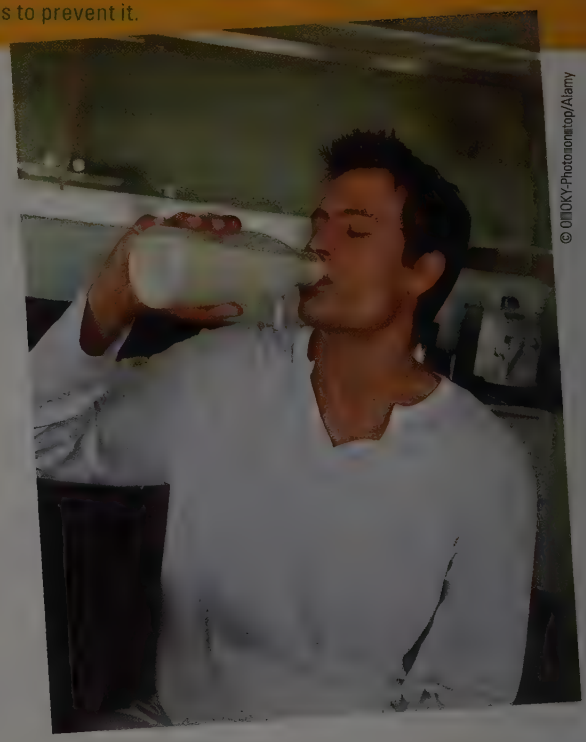
STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. A. K. Johnson, The sensory psychobiology of thirst and salt appetite, *Medicine and Science in Sports and Exercise* 39 (2007): 1388–1400.
2. A. K. Kant, B. I. Graubard, and E. A. Atchison, Intakes of plain water, moisture in foods and beverages, and total water in the adult US population—Nutritional, meal pattern, and body weight correlates: National Health and Nutrition Examination Surveys 1999–2006, *American Journal of Clinical Nutrition* 90 (2009): 655–663.
3. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate* (Washington, D.C.: National Academies Press, 2004), p. 67.
4. B. M. Popkin, K. E. D'Anci, and I. H. Rosenberg, Water, hydration, and health, *Nutrition Reviews* 68 (2010): 439–458.
5. Actions You Can Take to Reduce Lead in Drinking Water, www.epa.gov/ogwdw/lead/lead1.html, updated April 2008.
6. Centers for Disease Control and Prevention, Application of lower sodium intake recommendations to adults: United States, 1999–2006, *Morbidity and Mortality Weekly Report* 58 (2009): 281–283.
7. B. N. Van Vliet and J. P. Montani, The time course of salt-induced hypertension, and why it matters, *International Journal of Obesity* 32 (2008): S35–S47.
8. Centers for Disease Control and Prevention, 2009.
9. K. M. Dickinson, J. B. Keogh, and P. M. Clifton, Effects of a low-salt diet on flow-mediated dilation in humans, *American Journal of Clinical Nutrition* 89 (2009): 485–490.
10. US Department of Agriculture and US Department of Health and Human Services, *Dietary Guidelines for Americans, 2010*, www.dietaryguidelines.gov.
11. L. J. Appel and coauthors, The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke: A call to action from the American Heart Association, *Circulation* 123 (2011): 1138–1143.
12. C. N. Mhurchu and coauthors, Sodium content of processed foods in the United Kingdom: Analysis of 44,000 foods purchased by 21,000 households, *American Journal of Clinical Nutrition* 93 (2011): 594–600; C.A.M. Anderson and coauthors, Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 years: The INTERMAP Study, *Journal of the American Dietetic Association* 110 (2010): 736–745; J. L. Webster, E. K. Dunford, and B. C. Neal, *American Journal of Clinical Nutrition* 91 (2010): 413–420; F. J. He and G. A. MacGregor, A comprehensive review on salt and health and current experience of worldwide salt reduction programmes, *Journal of Human Hypertension* 23 (2009): 363–384; R. A. Forshee, Innovative regulatory approaches to reduce sodium consumption: Could a cap-and-trade system work? *Nutrition Reviews* 66 (2008): 280–285.
13. K. Bibbins-Domingo and coauthors, Projected effect of dietary salt reductions on future cardiovascular disease, *New England Journal of Medicine* 362 (2010): 590–599; Institute of Medicine (US) Committee on Strategies to Reduce Sodium Intake, *Strategies to Reduce Sodium Intake in the United States* (Washington, D.C.: National Academies Press, 2010).
14. Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate* (Washington, D.C.: National Academies Press, 2005), p. 281.
15. M. Umesawa and coauthors, Relations between dietary sodium and potassium intakes and mortality from cardiovascular disease: The Japan Collaborative Cohort Study for Evaluation of Cancer Risks, *American Journal of Clinical Nutrition* 88 (2008): 195–202.
16. J. Kaluza and coauthors, Dietary calcium and magnesium intake and mortality: A prospective study of men, *American Journal of Epidemiology* 171 (2010): 801–807; I. R. Reid and coauthors, Effects of calcium supplementation on lipids, blood pressure, and body composition in healthy older men: A randomized controlled trial, *American Journal of Clinical Nutrition* 91 (2010): 131–139; V. Centeno and coauthors, Molecular mechanisms triggered by low-calcium diets, *Nutrition Research Reviews* 22 (2009): 163–174; L. Wang and coauthors, Dietary intake of dairy products, calcium, and vitamin D and the risk of hypertension in middle-aged and older women, *Hypertension* 51 (2008): 1073–1079.
17. M. Huncharek, J. Muscat, and B. Kupelnick, Colorectal cancer risk and dietary intake of calcium, vitamin D, and dairy products: A meta-analysis of 26,335 cases from 60 observational studies, *Nutrition and Cancer* 61 (2009): 47–69; Y. Park and coauthors, Dairy food, calcium, and risk of cancer in the NIH-AARP Diet and Health Study, *Archives of Internal Medicine* 169 (2009): 391–401; J. Ishihara and coauthors, Dietary calcium, vitamin D, and the risk of colorectal cancer, *American Journal of Clinical Nutrition* 88 (2008): 1576 –1583.
18. D. R. Shahar and coauthors, Dairy calcium intake, serum vitamin D, and successful weight loss, *American Journal of Clinical Nutrition* 92 (2010): 1017–1022; R. P. Heaney and K. Rafferty, Preponderance of the evidence: An example from the issue of calcium intake and body composition, *Nutrition Reviews* 67 (2009): 32–39; G. C. Major and coauthors, Recent developments in calcium-related obesity research, *Obesity Reviews* 9 (2008): 428–445.
19. M. S. Vanselow and coauthors, Adolescent beverage habits and changes in weight over time: Findings from Project EAT, *American Journal of Clinical Nutrition* 90 (2009): 1489–1495.
20. J. A. Gilbert and coauthors, Milk supplementation facilitates appetite control in obese women during weight loss: A randomized, single-blind, placebo-controlled trial, *British Journal of Nutrition* 105 (2011): 133–143.
21. M. Bortolotti and coauthors, Dairy calcium supplementation in overweight or obese persons: Its effect on markers of fat metabolism, *American Journal of Clinical Nutrition* 88 (2008): 877–885; A. J. Lanou and N. D. Barnard, Dairy and weight-loss hypothesis: An evaluation of the clinical trials, *Nutrition Reviews* 66 (2008): 272–279; D. Teegarden and C. W. Gunther, Can the controversial relationship between dietary calcium and body weight be mechanistically explained by alterations in appetite and food intake? *Nutrition Reviews* 66 (2008): 601–605.
22. M. B. Zemel and coauthors, Effects of dairy compared with soy on oxidative and inflammatory stress in overweight and obese subjects, *American Journal of Clinical Nutrition* 91 (2010): 16–22.
23. R. C. Khanal and I. Nemere, Regulation of intestinal calcium transport, *Annual Review of Nutrition* 28 (2008): 179–196.
24. F. Bronner, Recent developments in intestinal calcium absorption, *Nutrition Reviews* 67 (2009): 109–113.
25. C. M. Weaver, Closing the gap between calcium intake and requirements, *Journal of the American Dietetic Association* 109 (2009): 812–813.
26. R. L. Bailey and coauthors, Estimation of total usual calcium and vitamin D intakes in the United States, *Journal of Nutrition* 140 (2010): 817–822.
27. J. R Hunt, L. K. Johnson, and Z.K.F. Roughead, Dietary protein and calcium interact to influence calcium retention: A controlled feeding study, *American Journal of Clinical Nutrition* 89 (2009): 1357–1365; K. Rafferty and R. P. Heaney, Nutrient effects on the calcium economy: Emphasizing the potassium controversy, *Journal of Nutrition* 138 (2008): 166S–171S.
28. M. P. Thorpe and E. M. Evans, Dietary protein and bone health: Harmonizing conflicting theories, *Nutrition Reviews* 69 (2011): 215–230; Hunt, Johnson, and Roughead, 2009.
29. S. A. Abrams, Setting Dietary Reference Intakes with the use of bioavailability data: Calcium, *American Journal of Clinical Nutrition* 91 (2010): 1474S–1477S.
30. National Osteoporosis Foundation, **www.nof.org**, accessed July 2011.
31. R. K. Rude, F. R. Singer, and H. E. Gruber, Skeletal and hormonal effects of magnesium deficiency, *Journal of the American College of Nutrition* 28 (2009): 131–141.
32. F. H. Nielsen, Magnesium, inflammation, and obesity in chronic disease, *Nutrition Reviews* 68 (2010): 333–340.

LEARN IT Describe factors that contribute to the development of osteoporosis and strategies to prevent it.

Osteoporosis and Calcium


© ONOKY-Photononstop/Alamy

Osteoporosis becomes apparent during the later years, but it develops much earlier—and without warning. Few people are aware that their bones are being robbed of their strength. The problem often first becomes evident when someone's hip suddenly gives way. People say, "She fell and broke her hip," but in fact the hip may have been so fragile that it broke *before* she fell. Even bumping into a table may be enough to shatter a porous bone into fragments so numerous and scattered that they cannot be reassembled. Removing them and replacing them with an artificial joint requires major surgery. More than 400,000 people in the United States are hospitalized each year because of fractures related to osteoporosis. About a third die of complications within a year; many more will never walk or live independently again.[1] Their quality of life slips downward.

This highlight examines low bone density and osteoporosis, one of the most prevalent diseases of aging, affecting an estimated 44 million people in the United States—most of them women older than 50.[2] It reviews the many factors that contribute to the 2 million fractures in the bones of the hips, vertebrae, wrists, arms, and ankles each year. And it presents strategies to reduce the risks, paying special attention to the role of dietary calcium.

Bone Development and Disintegration

Bone has two compartments: the outer, hard shell of **cortical bone** and the inner, lacy matrix of **trabecular bone.** (The glossary defines these and other bone-related terms.) Both can lose minerals, but in different ways and at different rates. The first photograph in Figure H12-1 shows a human leg bone sliced lengthwise, exposing the lacy, calcium-containing crystals of trabecular bone. These crystals give up calcium to the blood when the diet runs short, and they take up calcium again when the supply is plentiful (review Figure 12-13 on p. 387). For people who have eaten calcium-rich foods throughout the bone-forming years of their youth, these deposits make bones dense and provide a rich reservoir of calcium.

Surrounding and protecting the trabecular bone is a dense, ivorylike exterior shell—the cortical bone. Cortical bone composes the shafts of the long bones, and a thin cortical shell caps the ends of the bones too. Both compartments confer strength on bone: cortical bone provides the sturdy outer wall, and trabecular bone provides support along the lines of stress.

The two types of bone handle calcium in different ways. Supplied with blood vessels and metabolically active, trabecular bone is sensitive to hormones that govern day-to-day deposits and withdrawals of calcium. It readily gives up minerals whenever blood calcium needs replenishing. Losses of trabecular bone start becoming significant for men and women in their 30s, although losses can occur whenever calcium withdrawals exceed deposits. Cortical bone also gives up calcium, but slowly and at a steady pace. Cortical bone losses typically begin at about age 40 and continue slowly but surely thereafter.

As bone loss continues, bone density declines, and osteoporosis becomes apparent (see Figure H12-1). Bones become so fragile that even the body's own weight can overburden the spine—vertebrae may suddenly disintegrate and crush down, painfully pinching major nerves.[3] Or the vertebrae may compress into wedge shapes, forming what is often called a "dowager's hump," the posture many older people assume as they "grow shorter." Figure H12-2 (p. 398) shows the effect of compressed spinal bone on a woman's height and posture. Because both the cortical shell and the trabecular interior weaken, breaks most often occur in the hip, as mentioned in the introductory paragraph.

Physicians can determine bone loss and diagnose osteoporosis by measuring **bone density** using dual-energy X-ray absorptiometry (DEXA scan).[4] They also consider risk factors for osteoporosis, including age, personal and family history of fractures, and physical inactivity.

GLOSSARY

antacids: medications used to relieve indigestion by neutralizing acid in the stomach. Calcium-containing preparations (such as Tums) contain available calcium. Antacids with aluminum or magnesium hydroxides (such as Rolaids) can accelerate calcium losses.

bone meal or **powdered bone:** crushed or ground bone preparations intended to supply calcium to the diet. Calcium from bone is not well absorbed and is often contaminated with toxic minerals such as arsenic, mercury, lead, and cadmium.

bone density: a measure of bone strength. When minerals fill the bone matrix (making it dense), they give it strength.

cortical bone: the very dense bone tissue that forms the outer shell surrounding trabecular bone and comprises the shaft of a long bone.

dolomite: a compound of minerals (calcium magnesium carbonate) found in limestone and marble. Dolomite is powdered and is sold as a calcium-magnesium supplement. However, it may be contaminated with toxic minerals, is not well absorbed, and interacts adversely with absorption of other essential minerals.

osteoporosis: a disease characterized by porous and fragile bones.

oyster shell: a product made from the powdered shells of oysters that is sold as a calcium supplement, but it is not well absorbed by the digestive system.

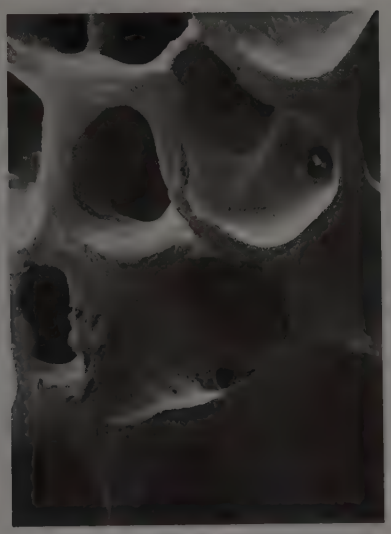
trabecular (tra-BECK-you-lar) **bone:** the lacy inner structure of calcium crystals that supports the bone's structure and provides a calcium storage bank.

> FIGURE H12-1 **Healthy and Osteoporotic Trabecular Bones**

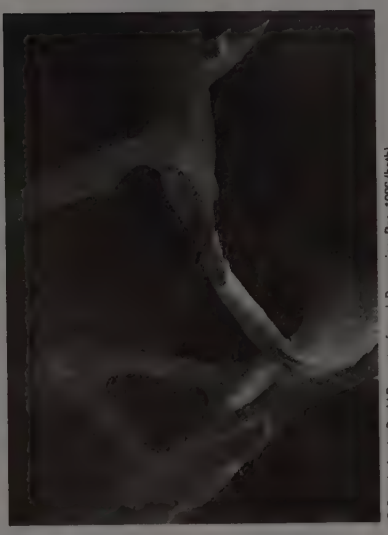


© Courtesy of Gjon Mili

Trabecular bone is the lacy network of calcium-containing crystals that fills the interior. Cortical bone is the dense, ivorylike bone that forms the exterior shell.



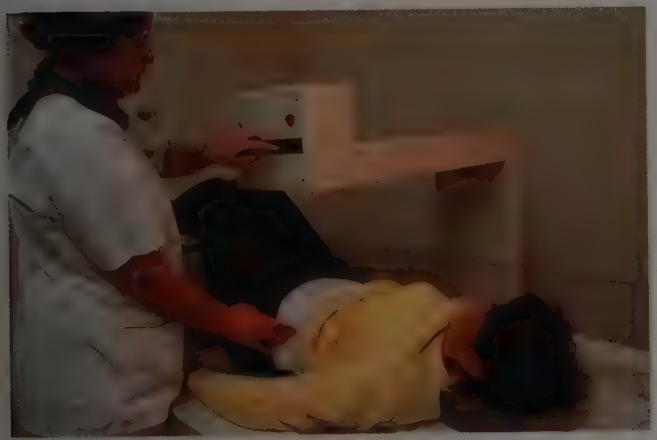
Electron micrograph of healthy trabecular bone.



© Permission by David Dempster from J. Bone miner Res, 1986 (both)

Electron micrograph of trabecular bone affected by osteoporosis.

Table H12-1 summarizes the major risk factors for osteoporosis. The more risk factors that apply to a person, the greater the chances of bone loss. Notice that several risk factors that are influential in the development of osteoporosis—such as age, gender, and genetics—cannot be changed. Other risk factors—such as diet, physical activity, body weight, smoking, and alcohol use—are personal behaviors that can be changed. By eating a calcium-rich, well-balanced diet, being physically active, abstaining from smoking, and drinking alcohol in moderation (if at all), people can defend themselves against osteoporosis. These decisions are particularly important for those with other risk factors that cannot be changed.



© ASTIER/agefotostock

Using a DEXA (dual-energy X-ray absorpiometry) test to measure bone mineral density identifies osteoporosis, determines risks for fractures, and tracks responses to treatment.

Whether a person develops osteoporosis seems to depend on the interactions of several factors, including nutrition. The strongest predictor of bone density is age.

Age and Bone Calcium

Two major stages of life are critical in the development of osteoporosis. The first is the bone-acquiring stage of childhood and adolescence. The second is the bone-losing decades of late adulthood, especially in women after menopause. The bones gain strength and density all through the growing years and into young adulthood. As people age, the cells that build bone gradually become less active, but those that dismantle bone continue working. The result is that bone loss exceeds bone formation. Some bone loss is inevitable, but losses can be curtailed by maximizing bone mass.

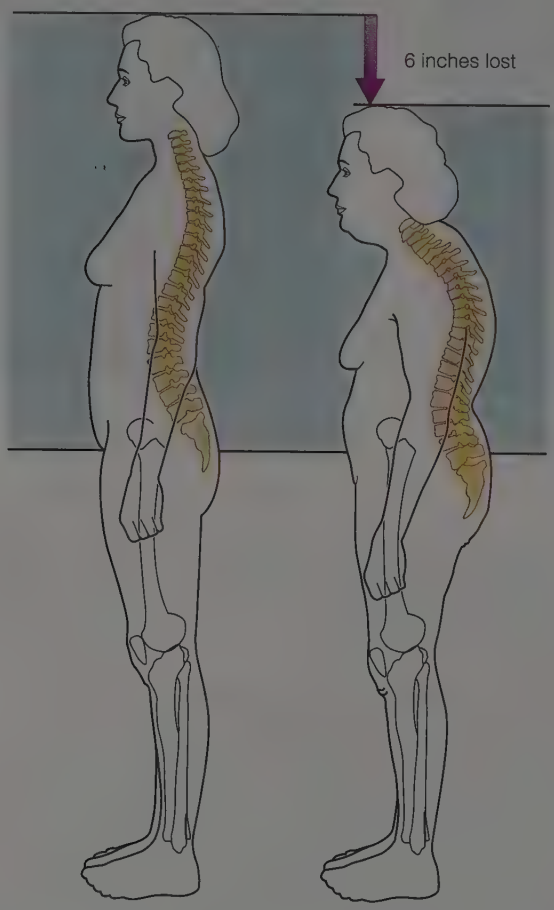
TABLE H12-1 Risk Factors for Osteoporosis

Nonmodifiable	Modifiable
• Female gender	• Sedentary lifestyle
• Older age	• Diet inadequate in calcium and vitamin D
• Small frame	• Diet excessive in protein, sodium, caffeine
• Caucasian, Asian, or Hispanic/Latino	• Cigarette smoking
• Family history of osteoporosis or fractures	• Alcohol abuse
• Personal history of fractures	• Low body weight
• Estrogen deficiency in women (amenorrhea or menopause, especially early or surgically induced); testosterone deficiency in men	• Certain medications, such as glucocorticoids and anticonvulsants

© Cengage Learning 2013

> FIGURE H12-2 Loss of Height in a Woman Caused by Osteoporosis

The woman on the left is about 50 years old. On the right, she is 80 years old. Her legs have not grown shorter. Instead, her back has lost length due to collapse of her spinal bones (vertebrae). Collapsed vertebrae cannot protect the spinal nerves from pressure that causes excruciating pain.



Maximizing Bone Mass

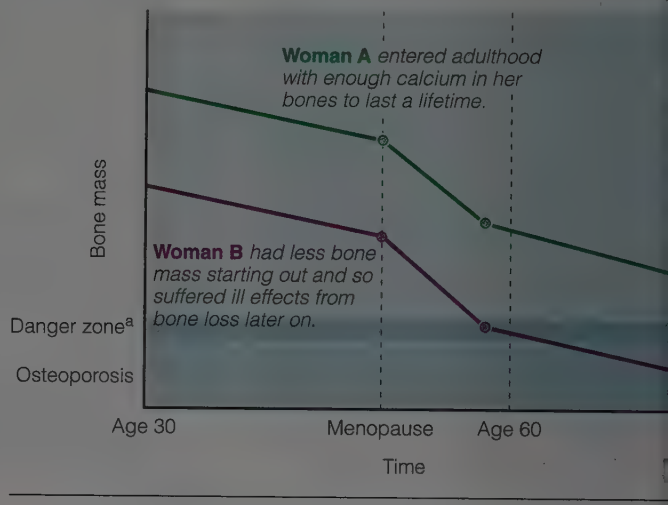
To maximize bone mass, the diet must deliver an adequate supply of calcium during the first three decades of life. Children and teens who consume milk products and get enough calcium have denser bones than those with inadequate intakes.[5] With little or no calcium from the diet, the body must depend on bone to supply calcium to the blood—bone mass diminishes, and bones lose their density and strength. When people reach the bone-losing years of middle age, those who formed dense bones during their youth have the advantage. They simply have more bone starting out and can lose more before suffering ill effects. Figure H12-3 demonstrates this effect.

Minimizing Bone Loss

Not only does dietary calcium build strong bones in youth, but it remains important in protecting against losses in the later years. Unfortunately,

> FIGURE H12-3 Bone Losses over Time Compared

Peak bone mass is achieved by age 30. Women gradually lose bone mass until menopause, when losses accelerate dramatically and then gradually taper off.



[a]People with a moderate degree of bone mass loss are said to have *osteopenia* and are at increased risk of fractures.

calcium intakes of older adults are typically low, and calcium absorption declines after menopause. The kidneys do not activate vitamin D as well as they did earlier (recall that vitamin D enhances calcium absorption). Also, sunlight is needed to form vitamin D, and many older people spend little or no time outdoors in the sunshine. For these reasons, and because intakes of vitamin D are typically low anyway, blood vitamin D declines.

Some of the hormones that regulate bone and calcium metabolism—parathyroid hormone, calcitonin, and estrogen—also change with age and accelerate bone loss. Together, these age-related factors contribute to bone loss: inefficient bone remodeling, reduced calcium intakes, impaired calcium absorption, poor vitamin D status, and hormonal changes that favor bone mineral withdrawal.

Gender and Hormones

After age, gender is the next strongest predictor of osteoporosis. The sex hormones play a major role in regulating the rate of bone turnover.[6] Men have greater bone density than women at maturity, and women have greater losses than men in later life. Consequently, men develop bone problems about 10 years later than women, and women account for two out of three cases of osteoporosis.

Menopause imperils women's bones. Bone dwindles rapidly when the hormone estrogen diminishes and menstruation ceases. The lack of estrogen contributes to the release of cytokines that produce inflammation and accelerate bone loss.[7] Women may lose up to 20 percent of their bone mass during the 6 to 8 years following menopause. Eventually, losses taper off so that women again lose bone at the same rate as men their age. Losses of bone minerals continue throughout the remainder of a woman's lifetime, but not at the free-fall pace of the menopause years (review Figure H12-3).

Rapid bone losses also occur when *young* women's ovaries fail to produce enough estrogen, causing menstruation to cease. In some cases, diseased ovaries are to blame and must be removed; in others, the ovaries fail to produce sufficient estrogen because the women suffer from anorexia nervosa and have unreasonably restricted their body weight (see Highlight 8). The amenorrhea and low body weights explain much of the bone loss seen in these young women, even years after diagnosis and treatment.

Estrogen therapy may help some women prevent further bone loss and reduce the incidence of fractures. Because estrogen therapy may increase the risks for breast cancer, women must carefully weigh any potential benefits against the possible dangers. A combination of drugs or of hormone replacement and a drug may be most beneficial.

Several drug therapies have been developed to inhibit bone loss and enhance bone formation.[8] The FDA has approved the following drugs to prevent or treat osteoporosis: biophosphates, calcitonin, estrogens, estrogen antagonists, and parathyroid hormone.[9]

Some women who choose not to use estrogen therapy turn to soy as an alternative treatment. Interestingly, the phytochemicals commonly found in soybeans mimic the actions of estrogen in the body. When natural estrogen is lacking, as it is after menopause, these phytochemicals may step in to stimulate estrogen-sensitive tissues. By way of this action, soy and its phytochemicals may help to prevent the rapid bone losses of the menopause years.[10] Unfortunately, soy phytochemicals may also stimulate breast cancer cell growth in some women.[11] Because the risks and benefits vary depending on life stage and prior history of breast cancer, women should discuss soy options with their physicians.

As in women, sex hormones—including estrogen—appear to play a key role in men's bone loss as well.[12] Other common causes of osteoporosis in men include corticosteroid use and alcohol abuse.[13]

Genetics

Risks of osteoporosis appear to run along racial lines and reflect genetic differences in bone development. African Americans, for example, seem to use and retain calcium more efficiently than Caucasians. Consequently, even though their calcium intakes are typically lower, black people have denser bones than white people do. Greater bone density expresses itself in less bone loss, fewer fractures, and a lower rate of osteoporosis among blacks.

The exact role of genetics is unclear, and specific genes have yet to be identified.[14] Most likely, genes influence both the peak bone mass achieved during growth and the bone loss incurred during the later years. The extent to which a given genetic potential is realized, however, depends on many outside factors. Diet and physical activity, for example, can maximize peak bone density during growth, whereas alcohol and tobacco abuse can accelerate bone losses later in life. Importantly, these factors are within a person's control.

Physical Activity and Body Weight

Physical activity may be the single most important factor supporting bone growth during adolescence.[15] Muscle strength and bone strength go together.[16] When muscles work, they pull on the bones, stimulating them to grow denser.[17] The hormones that promote new muscle growth also favor the building of bone. As a result, active bones are denser and stronger than sedentary bones.


© Tetra Images/Alamy

Strength training helps to build strong bones.

Both the muscle contraction and the gravitational pull of the body's weight create a load that benefits bone metabolism.[18] To keep bones healthy, a person should engage in weight training or weight-bearing endurance activities (such as tennis and jogging or sprint cycling) regularly.[19] Regular physical activity combined with an adequate calcium intake helps to maximize bone density in adolescence. Adults can also maximize and maintain bone density with a regular program of weight training. Even past menopause, when most women are losing bone, weight training improves bone density.

Heavier body weights and weight gains place a similar stress on the bones and promote their density. The many relationships between bone and fat are beginning to explain how overweight may protect bones.[20] For example, the adipokine leptin may play a key role in the relationship between body weight and bone mass.[21] Obese mice that are deficient in leptin show increases in bone formation. In contrast, weight losses reduce bone density and increase the risk of fractures—in part because energy restriction diminishes calcium absorption and compromises calcium balance. As mentioned in Highlight 8, the combination of underweight, severely restricted energy intake, extreme daily exercise, and amenorrhea reliably predicts bone loss.

Smoking and Alcohol

Add bone damage to the list of ill consequences associated with smoking. The bones of smokers are less dense than those of nonsmokers—even after controlling for differences in age, body weight, and physical activity habits. Fortunately, the damaging effects can be reversed with smoking cessation. Blood indicators of beneficial bone activity are apparent 6 weeks after a person stops smoking. In time, bone density is similar for former smokers and nonsmokers.

People who abuse alcohol often suffer from osteoporosis and experience more bone breaks than others. Several factors appear to be involved. Alcohol enhances fluid excretion, leading to excessive calcium losses in the urine; upsets the hormonal balance required for healthy bones; slows bone formation, leading to lower bone density; stimulates bone breakdown; and increases the risk of falling. Whereas high alcohol intakes are associated with lower bone density, limited research suggests that *moderate* alcohol consumption may benefit bone mineral density.[22]

Dietary Calcium

For older adults, an adequate calcium intake alone cannot protect against bone fractures. Bone strength later in life depends primarily on how well the bones were built during childhood and adolescence. Adequate calcium nutrition during the growing years is essential to achieving optimal peak bone mass. Simply put, growing children who do not get enough calcium do not develop strong bones. For this reason, the DRI Committee recommends 1300 milligrams of calcium per day for everyone 9 through 18 years of age. Unfortunately, few girls meet the recommendations for calcium during these bone-forming years. (Boys generally obtain intakes close to those recommended because they eat more food.) Consequently, most girls start their adult years with less-than-optimal bone density. As adults, women rarely meet their recommended intakes of 1000 to 1200 milligrams from food. Some authorities suggest 1500 milligrams of calcium for postmenopausal women who are not receiving estrogen.

Other Nutrients

Much research has focused on calcium, but other nutrients support bone health too.[23] Adequate protein protects bones and reduces the likelihood of hip fractures.[24] As mentioned earlier, vitamin D is needed to maintain calcium metabolism and optimal bone health.[25] Research suggests that a combination of calcium and vitamin D supplements is the best option for the prevention or treatment of osteoporosis.[26] Daily supplementation with a low dose of vitamin D may reduce bone loss and the risk of fractures, but a single high dose seems to increase the risk of falls and fractures.[27] Vitamin K decreases bone turnover and protects against hip fractures. Vitamin C may slow bone losses.[28] The minerals magnesium and potassium also help to maintain bone mineral density. Vitamin A is needed in the bone-remodeling process, but too much vitamin A may be associated with osteoporosis. Carotenoids may inhibit bone loss.[29] Omega-3 fatty acids may help preserve bone integrity.[30] Additional research points to the bone benefits not of a specific nutrient, but of a diet rich in fruits, vegetables, and whole grains.[31] In contrast, diets containing too much salt are associated with bone losses. Similarly, diets containing too many colas or commercially baked snack and fried foods are associated with low bone mineral density. Clearly, a well-balanced diet that depends on all the food groups to supply a full array of nutrients is central to bone health.

A Perspective on Calcium Supplements

Bone health depends, in part, on calcium. People who do not consume milk products or other calcium-rich foods in amounts that provide even half the recommendation should consider consulting a registered dietitian who can assess the diet and suggest food choices to correct any inadequacies. Calcium from foods may support bone health better than calcium from supplements. For those who are unable to consume enough calcium-rich foods, however, taking calcium supplements—especially in combination with vitamin D—may help to enhance bone density and protect against bone loss and fractures.[32] Because calcium supplements may increase the risk of heart attacks and strokes, women should consult their physicians when making this decision.[33]

An estimated 60 percent of women aged 60 and over take calcium supplements.[34] Selecting a calcium supplement requires a little investigative work to sort through the many options. Before examining calcium supplements, recognize that multivitamin-mineral pills contain little or no calcium. The label may list a few milligrams of calcium, but remember that the recommended intake is a gram or more for adults.

Calcium supplements are typically sold as compounds of calcium carbonate (common in **antacids** and fortified chocolate candies), citrate, gluconate, lactate, malate, or phosphate. These supplements often include magnesium, vitamin D, or both. In addition, some calcium supplements are made from **bone meal, oyster shell,** or **dolomite** (limestone). Many calcium supplements, especially those derived from these natural products, contain lead—which impairs health in numerous ways, as Chapter 13 points out. Fortunately, calcium interferes with the absorption and action of lead in the body.

The first question to ask is how much calcium the supplement provides. Most calcium supplements provide between 250 and 1000 milligrams of calcium. To be safe, total calcium intake from both foods and supplements should not exceed the UL. Read the label to find out how much a dose supplies. Unless the label states otherwise, supplements of calcium carbonate are 40 percent calcium; those of calcium citrate are 21 percent; lactate, 13 percent; and gluconate, 9 percent. Select a low-dose supplement and take it several times a day rather than taking a large-dose supplement all at once. Taking supplements in doses of 500 milligrams or less improves absorption. Small doses also help ease the GI distress (constipation, intestinal bloating, and excessive gas) that sometimes accompanies calcium supplement use.

The next question to ask is how well the body absorbs and uses the calcium from various supplements. Most healthy people absorb calcium equally well from milk and any of these supplements: calcium carbonate, citrate, or phosphate. More important than supplement solubility is tablet disintegration. When manufacturers compress large quantities of calcium into small pills, the stomach acid has difficulty penetrating the pill. To test a supplement's ability to dissolve, drop it into a 6-ounce cup of vinegar, and stir occasionally. A high-quality formulation will dissolve within a half-hour.

Finally, people who choose supplements must take them regularly. Furthermore, consideration should be given to the best time to take the supplements. To circumvent adverse nutrient interactions, take calcium supplements between, not with, meals. (Importantly, do not take calcium supplements with iron supplements or iron-rich meals; calcium inhibits iron absorption.) To enhance calcium absorption, take supplements with meals. If such contradictory advice drives you crazy, reconsider the benefits of food sources of calcium. Most experts agree that foods are the best source of most nutrients.

Some Closing Thoughts

Unfortunately, many of the strongest risk factors for osteoporosis are beyond people's control: age, gender, and genetics. But several strategies are effective for prevention. First, ensure an optimal peak bone mass during childhood and adolescence by eating a balanced diet rich

in calcium and vitamin D and by engaging in regular physical activity. Then, maintain that bone mass in early adulthood by continuing those healthy diet and activity habits, abstaining from cigarette smoking and using alcohol moderately, if at all. Finally, minimize bone loss in later life by maintaining an adequate nutrition and exercise regimen, and, especially for older women, consult a physician about bone density tests, calcium supplements, or other drug therapies that may be effective both in preventing bone loss and in restoring lost bone.[35] The reward is the best possible chance of preserving bone health throughout life.

REFERENCES

1. A. Leboime and coauthors, Osteoporosis and mortality, *Joint Bone Spine* 77 (2010): S107–S112; C. A. Brauer and coauthors, Incidence and mortality of hip fractures in the United States, *Journal of the American Medical Association* 302 (2009): 1573–1579.
2. National Osteoporosis Foundation, www.nof.org, accessed July 2011; R. Nuti and coauthors, Bone fragility in men: Where are we? *Journal of Endocrinological Investigation* 33 (2010): 33–38.
3. A. M. Cheung and A. S. Detsky, Osteoporosis and fractures: Missing the bridge? *Journal of the American Medical Association* 299 (2008): 1468–1470.
4. R. Lorente-Ramos and coauthors, Dual-energy x-ray absorptiometry in the diagnosis of osteoporosis: A practical guide, *American Journal of Roentgenology* 196 (2011): 897–904.
5. L. L. Moore and coauthors, Effects of average childhood dairy intake on adolescent bone health, *Journal of Pediatrics* 153 (2008): 667–673.
6. B. Frenkel and coauthors, Regulation of adult bone turnover by sex steroids, *Journal of Cellular Physiology* 224 (2010): 305–310.
7. Y. Imai and coauthors, Minireview: Osteoprotective action of estrogens is mediated by osteoclastic estrogen receptor-alpha, *Molecular Endocrinology* 24 (2010): 877–885.
8. T. D. Rachner, S. Khosla, and L. C. Hofbauer, Osteoporosis: Now and the future, *Lancet* 377 (2011): 1276–1287.
9. National Osteoporosis Foundation, *Clinician's Guide to Prevention and Treatment of Osteoporosis* (Washington, D.C.: National Osteoporosis Foundation, 2010), pp. 21–24.
10. A. Atmaca and coauthors, Soy isoflavones in the management of postmenopausal osteoporosis, *Menopause* 15 (2008): 748–757; R. C. Poulsen and M. C. Kruger, Soy phytoestrogens: Impact on postmenopausal bone loss and mechanisms of action, *Nutrition Reviews* 66 (2008): 359–374.
11. W. G. Helferich, J. E. Andrade, and M. S. Hoagland, Phytoestrogens and breast cancer: A complex story, *Inflammopharmacology* 16 (2008): 219–226; Y. Zhang and coauthors, Soy isoflavones and their bone protective effect, *Inflammopharmacology* 16 (2008): 213–215.
12. E. Gielen and coauthors, Osteoporosis in men, *Best Practice and Research: Clinical Endocrinology and Metabolism* 25 (2011): 321–335; N. Ducharme, Male osteoporosis, *Clinics in Geriatric Medicine* 26 (2010): 301-309; S. Khosla, Update in male osteoporosis, *Journal of Clinical Endocrinology and Metabolism* 95 (2010): 3–10.
13. P. R. Ebeling, Osteoporosis in men, *New England Journal of Medicine* 358 (2008): 1474–1482.
14. B. D. Mitchell and L. M. Yerges-Armstrong, The genetics of bone loss: Challenges and prospects, *Journal of Clinical Endocrinology and Metabolism* 96 (2011): 1258–1268.
15. K. F. Janz and coauthors, Early physical activity provides sustained bone health benefits later in childhood, *Medicine and Science in Sports and Exercise* 42 (2010): 1072–1078; A. Guadalupe-Grau and coauthors, Exercise and bone mass in adults, *Sports Medicine* 39 (2009): 439–468.
16. B. R. Beck, Muscle forces or gravity—What predominates mechanical loading on bone?: Introduction, *Medicine and Science in Sports and Exercise* 41 (2009): 2033–2036.
17. S. Judex and K. J. Carlson, Is bone's response to mechanical signals dominated by gravitational loading? *Medicine and Science in Sports and Exercise* 41 (2009): 2037–2043.
18. W. M. Kohrt, D. W. Barry, and R. S. Schwartz, Muscle forces or gravity: What predominates mechanical loading on bone? *Medicine and Science in Sports and Exercise* 41 (2009): 2050–2055.
19. A. J. Smock and coauthors, Bone volumetric density, geometry, and strength in female and male collegiate runners, *Medicine and Science in Sports and Exercise* 41 (2009): 2026–2032; D. C. Wilks, S. F. Gilliver, and J. Rittweger, Forearm and tibial bone measures of distance- and sprint-trained master cyclists, *Medicine and Science in Sports and Exercise* 41 (2009): 566–573; American College of Sports Medicine Position Stand, Physical activity and bone health, *Medicine and Science in Sports and Exercise* 36 (2004): 1985–1996.
20. C. J. Rosen and A. Klibanski, Bone, fat, and body composition: Evolving concepts in the pathogenesis of osteoporosis, *The American Journal of Medicine* 122 (2009): 409–414.
21. G. Wolf, Energy regulation by the skeleton, *Nutrition Reviews* 66 (2008): 229–233.
22. K. L. Tucker and coauthors, Effects of beer, wine, and liquor intakes on bone mineral density in older men and women, *American Journal of Clinical Nutrition* 89 (2009): 1188–1196.
23. J. P. Bonjour and coauthors, Minerals and vitamins in bone health: The potential value of dietary enhancement, *British Journal of Nutrition* 101 (2009): 1581–1596.
24. A. L. Darling and coauthors, Dietary protein and bone health: A systematic review and meta-analysis, *American Journal of Clinical Nutrition* 90 (2009): 1674–1692; A. D. Conigrave, E. M. Brown, and R. Rizzoli, Dietary protein and bone health: Roles of amino acid–sensing receptors in the control of calcium metabolism and bone homeostasis, *Annual Review of Nutrition* 28 (2008): 131–155.
25. K. D. Cashman and coauthors, Low vitamin D status adversely affects bone health parameters in adolescents, *American Journal of Clinical Nutrition* 87 (2008): 1039–1044.
26. J. M. Quesada Gómez and coauthors, Calcium citrate and vitamin D in the treatment of osteoporosis, *Clinical Drug Investigation* 31 (2011): 285–298.
27. K. M. Sanders and coauthors, Annual high-dose oral vitamin D and falls and fractures in older women, *Journal of the American Medical Association* 303 (2010): 1815–1822.
28. S. Sahni and coauthors, High vitamin C intake is associated with lower 4-year bone loss in elderly men, *Journal of Nutrition* 138 (2008): 1931–1938.
29. S. Sahni and coauthors, Inverse association of carotenoid intakes with 4-y change in bone mineral density in elderly men and women: The Framingham Osteoporosis Study, *American Journal of Clinical Nutrition* 89 (2009): 416–424.
30. E. P. Weiss and coauthors, Dehydroepiandrosterone replacement therapy in older adults: 1- and 2-y effects on bone, *American Journal of Clinical Nutrition* 89 (2009): 1459–1467.
31. L. Langsetmo and coauthors, Dietary patterns and incident low-trauma fractures in postmenopausal women and men aged ≥50 y: A population-based cohort study, *American Journal of Clinical Nutrition* 93 (2011): 192–199.
32. Quesada Gómez and coauthors, 2011; H. A. Bischoff-Ferrari and coauthors, Effect of calcium supplementation on fracture risk: A double-blind randomized controlled trial, *American Journal of Clinical Nutrition* 87 (2008): 1945–1951; R. M. Daly and coauthors, The skeletal benefits of calcium- and vitamin D_3-fortified milk are sustained in older men after withdrawal of supplementation: An 18-mo follow-up study, *American Journal of Clinical Nutrition* 87 (2008): 771–777.
33. M. J. Bolland and coauthors, Calcium supplements with or without vitamin D and risk of cardiovascular events: Reanalysis of the Women's Health Initiative limited access dataset and meta-analysis, *British Medical Journal* 342 (2011): d2040; Z. Sabbagh and H. Vatanparast, Is calcium supplementation a risk factor for cardiovascular disease in older women? *Nutrition Reviews* 67 (2009): 105–108.
34. J. Gahche and coauthors, Dietary supplement use among US adults has increased since NHANES III (1998-1994), *NCHS Data Brief* 61 (2011): 1–8.
35. R. C. Hamdy and coauthors, Algorithm for the management of osteoporosis, *Southern Medical Journal* 103 (2010): 1009–1015.



© artjamay/Shutterstock.com

CENGAGE LEARNING'S GLOBAL NUTRITION
GLOBAL NUTRITION RESOURCE CENTER

The body requires small amounts of the trace minerals, but that little bit is essential. Go to Nutrition Basics and Tools → Vitamins, Minerals, and Water to review why these minerals are vital in maintaining good health. What individuals are most at risk for deficiency?

13 The Trace Minerals

LEARNING GPS

13.1 The Trace Minerals—An Overview 403
LEARN IT Summarize key factors unique to the trace minerals.

13.2 The Trace Minerals 405
LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the trace minerals (iron, zinc, iodine, selenium, copper, manganese, fluoride, chromium, and molybdenum).

- Iron 405
- Zinc 414
- Iodine 418
- Selenium 419
- Copper 420
- Manganese 421
- Fluoride 422
- Chromium 423
- Molybdenum 423

13.3 Contaminant Minerals 424
LEARN IT Describe how contaminant minerals disrupt body processes and impair nutrition status.

Highlight 13 Phytochemicals and Functional Foods 428
LEARN IT Define *phytochemicals* and explain how they might defend against chronic diseases.

Nutrition in Your Life

Trace—barely a perceptible amount. But the trace minerals tackle big jobs. Your blood can't carry oxygen without iron, and insulin can't deliver glucose without chromium. Teeth become decayed without fluoride, and thyroid glands develop goiter without iodine. Together, the trace minerals keep you healthy and strong. Where can you get these amazing minerals? A variety of foods, especially those from the protein foods group, sprinkled with a little iodized salt and complemented by a glass of fluoridated water will do the trick. It's remarkable what your body can do with only a few milligrams—or even micrograms—of the trace minerals. In the Nutrition Portfolio at the end of this chapter, you can determine whether the foods you are eating are meeting your trace mineral needs.

Figure 12-9 in Chapter 12 (p. 378) showed the tiny quantities of **trace minerals** in the human body. The trace minerals are so named because they are present, and needed, in relatively small amounts in the body. All together, they would hardly fill a teaspoon. Yet they are no less important than the major minerals or any of the other nutrients. Each of the trace minerals performs a vital role. A deficiency of any of them may be fatal, and excesses are equally deadly. Remarkably, a well-balanced diet supplies enough of these minerals to maintain health.

13.1 The Trace Minerals—An Overview

LEARN IT Summarize key factors unique to the trace minerals.

The body requires the trace minerals in minuscule quantities. They participate in diverse tasks all over the body, each having special duties that only it can perform.

Food Sources The trace mineral contents of foods depend on soil and water composition and on how foods are processed. Furthermore, many factors in the diet and within the body affect the minerals' **bioavailability**. Still, outstanding food

trace minerals: essential mineral nutrients the human body requires in relatively small amounts (less than 100 milligrams per day); sometimes called *microminerals*.

bioavailability: the rate at and the extent to which a nutrient is absorbed and used.

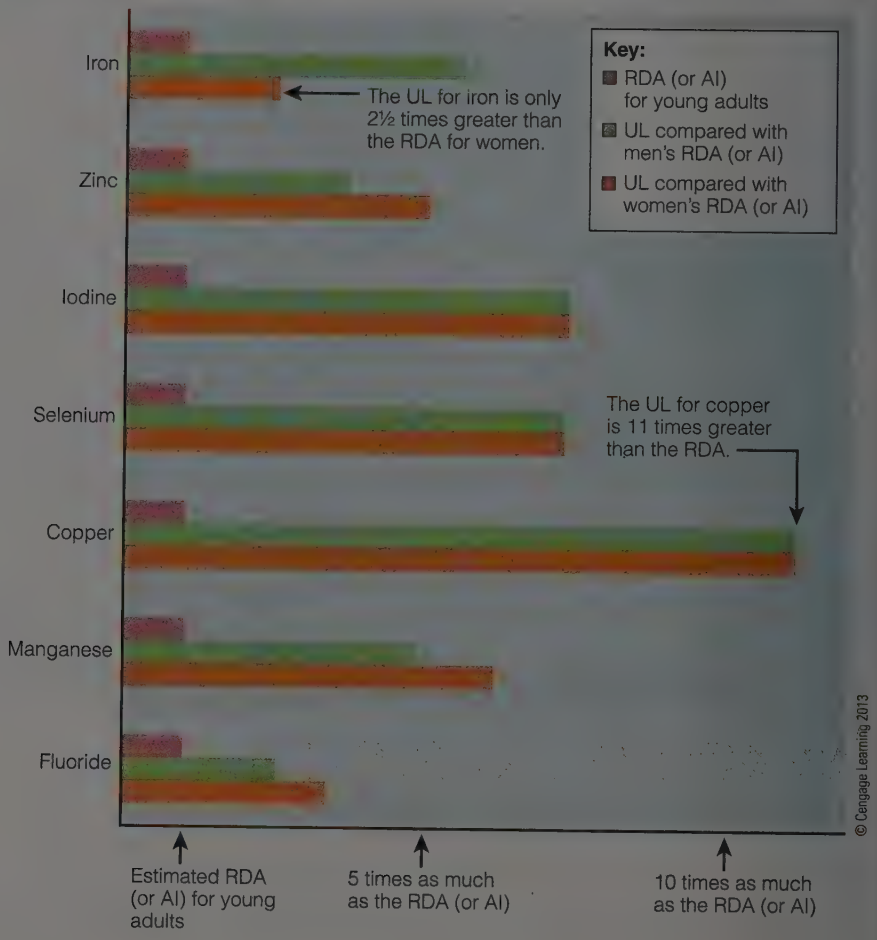
sources for each of the trace minerals, just like those for the other nutrients, include a wide variety of foods.

Deficiencies Assessing trace mineral status is challenging.[1] Severe deficiencies of the better-known minerals are relatively easy to recognize. Deficiencies of the others may be harder to diagnose, and for all minerals, mild deficiencies are easy to overlook. Because the minerals are active in many body systems—digestive, cardiovascular, circulatory, muscular, skeletal, and nervous—deficiencies can have wide-reaching effects and can affect people of all ages. The most common result of a deficiency in children is failure to grow and thrive.

Toxicities Most of the trace minerals are toxic at intakes only two and a half to seven times above the estimated requirements (see Figure 13-1). Thus it is important not to habitually exceed the Upper Level (UL) of recommended intakes (see inside front cover). Many dietary supplements contain trace minerals, making it easy for users to exceed their needs. Highlight 10 discusses supplement use and some of the regulations included in the Dietary Supplement Health and Education Act. As that discussion notes, consumers have demanded the freedom to choose their own doses of nutrients. By law, the Food and Drug Administration (FDA) has no authority to limit the amounts of trace minerals in supplements.* Individuals who take supplements must therefore be aware of the possible dangers and select supplements that contain no more than 100 percent of the Daily Value. It is easier and safer to meet nutrient needs by selecting a variety of foods than by combining an assortment of supplements.

*Canada regulates the amounts of trace minerals in supplements.

> **FIGURE 13-1 RDA (or AI) and UL Compared for Selected Trace Minerals**



Interactions Interactions among the trace minerals are common and often well coordinated to meet the body's needs. For example, several of the trace minerals support insulin's work, influencing its synthesis, storage, release, and action.

At other times, interactions lead to nutrient imbalances. An excess of one may cause a deficiency of another. (A slight manganese overload, for example, may aggravate an iron deficiency.) A deficiency of one may interfere with the work of another. (A selenium deficiency halts the activation of the iodine-containing thyroid hormones.) A deficiency of a trace mineral may even open the way for a contaminant mineral to cause a toxic reaction. (Iron deficiency, for example, makes the body more vulnerable to lead poisoning.) These examples of nutrient interactions highlight one of the many reasons why people should use supplements conservatively, if at all: supplementation can easily create imbalances.

A good food source of one nutrient may be a poor food source of another, and factors that enhance the action of some trace minerals may interfere with others. Meats, for example, are a good source of iron but a poor source of calcium; vitamin C enhances the absorption of iron but hinders that of copper.

Nonessential Trace Minerals This chapter features the essential trace minerals—iron, zinc, iodine, selenium, copper, manganese, fluoride, chromium, and molybdenum. Research to determine whether other trace minerals are essential is difficult because their quantities in the body are so small and also because human deficiencies are unknown. Guessing their functions in the body can be particularly problematic. Much of the available knowledge comes from research using animals.

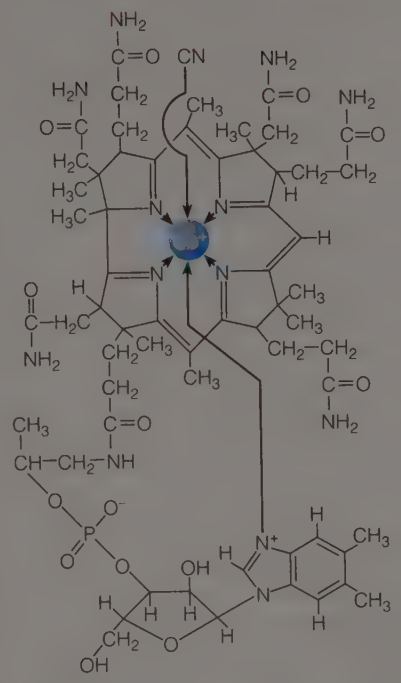
Nickel may serve as a cofactor for certain enzymes. Silicon is involved in the formation of bones and collagen. Vanadium, too, is necessary for growth and bone development and for normal reproduction. Cobalt is a key mineral in the large vitamin B_{12} molecule (see Figure 13-2), but it is not an essential nutrient and no recommendation has been established. Boron may play a key role in bone health, brain activities, and immune response.[2]

In the future, we may discover that these and other trace minerals play key nutritional roles. Even arsenic—famous as a poison used by murderers and known to be a carcinogen—may turn out to be essential for human beings in tiny quantities. It has already proved useful in the treatment of some types of leukemia.[3] Research on all the trace minerals is active, suggesting that we have much more to learn about them.

REVIEW IT Summarize key factors unique to the trace minerals.

Although the body uses only tiny amounts of the trace minerals, they are vital to health. Because so little is required, the trace minerals can be toxic at levels not far above estimated requirements—a consideration for supplement users. Like the other nutrients, the trace minerals are best obtained by eating a variety of foods.

> **FIGURE 13-2 Cobalt in Vitamin B_{12}**



The intricate vitamin B_{12} molecule contains one atom of the mineral cobalt. The alternative name for vitamin B_{12}, cobalamin, reflects the presence of cobalt in its structure.

13.2 The Trace Minerals

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the trace minerals (iron, zinc, iodine, selenium, copper, manganese, fluoride, chromium, and molybdenum).

Iron Iron is an essential nutrient, vital to many of the cells' activities, but it poses a problem for millions of people. Some people simply don't eat enough iron-containing foods to support their health optimally, whereas others absorb so much iron that it threatens their health. Iron exemplifies the principle that both too little and too much of a nutrient in the body can be harmful. In its wisdom, the body has several ways to maintain iron balance, protecting against both deficiency and toxicity.

Iron Roles in the Body Iron has the knack of switching back and forth between two ionic states. ♦ In the reduced state, iron has lost two electrons and therefore has a net positive charge of two; it is known as *ferrous iron*. In the oxidized state, iron has lost a third electron, has a net positive charge of three, and is known as *ferric iron*. Ferrous iron can be oxidized to ferric iron, and ferric iron can be reduced to ferrous iron. By doing so, iron can serve as a cofactor to enzymes

♦ Iron's two ionic states:
- Ferrous iron (reduced): Fe^{++}
- Ferric iron (oxidized): Fe^{+++}

iron: an essential trace mineral that is needed for the transport of oxygen and the metabolism of energy nutrients.

cofactor: a small, inorganic or organic substance that facilitates the action of an enzyme.

involved in the numerous oxidation-reduction reactions that commonly occur in all cells. Enzymes involved in making amino acids, collagen, hormones, and neurotransmitters all require iron. (For details about ions, oxidation, and reduction, see Appendix B.)

Iron forms a part of the electron carriers that participate in the electron transport chain (discussed in Chapter 7).* These carriers transfer hydrogens and electrons to oxygen, forming water, and in the process, make ATP for the cells' energy use.

Most of the body's iron is found in two proteins: **hemoglobin** in the red blood cells and **myoglobin** in the muscle cells. In both, iron helps accept, carry, and then release oxygen.

Iron Absorption The body conserves iron. Because it is difficult to excrete iron once it is in the body, balance is maintained primarily through absorption. More iron is absorbed when stores are empty and less is absorbed when stores are full. Special proteins help the body absorb iron from food (see Figure 13-3).[4] The iron-storage protein **ferritin** captures iron from food and stores it in the cells of the small intestine. When the body needs iron, ferritin releases some iron to an iron transport protein called **transferrin.** If the body does not need iron, it is carried out when the intestinal cells are shed and excreted in the feces; intestinal cells are replaced about every 3 to 5 days. By holding iron temporarily, these cells control iron absorption by either delivering iron when the day's intake falls short or disposing of it when intakes exceed needs.

Iron absorption depends in part on its dietary source. Iron occurs in two forms in foods: as **heme iron,** which is found only in foods derived from the flesh of animals, such as meats, poultry, and fish and as **nonheme iron,** which is found in both plant-derived and animal-derived foods (see Figure 13-4). On average, heme iron represents about 10 percent of the iron a person consumes in a day. Even though heme iron accounts for only a small proportion of the intake, it is so well absorbed that it contributes significant iron. About 25 percent of heme iron and 17 percent of nonheme iron is absorbed, depending on dietary factors and the body's iron stores.[5] In iron deficiency, absorption increases.[6] In iron overload, absorption declines.

hemoglobin: the oxygen-carrying protein of the red blood cells that transports oxygen from the lungs to tissues throughout the body; hemoglobin accounts for 80 percent of the body's iron.

myoglobin: the oxygen-holding protein of the muscle cells.

- **myo** = muscle

ferritin (FAIR-ih-tin): the iron storage protein.

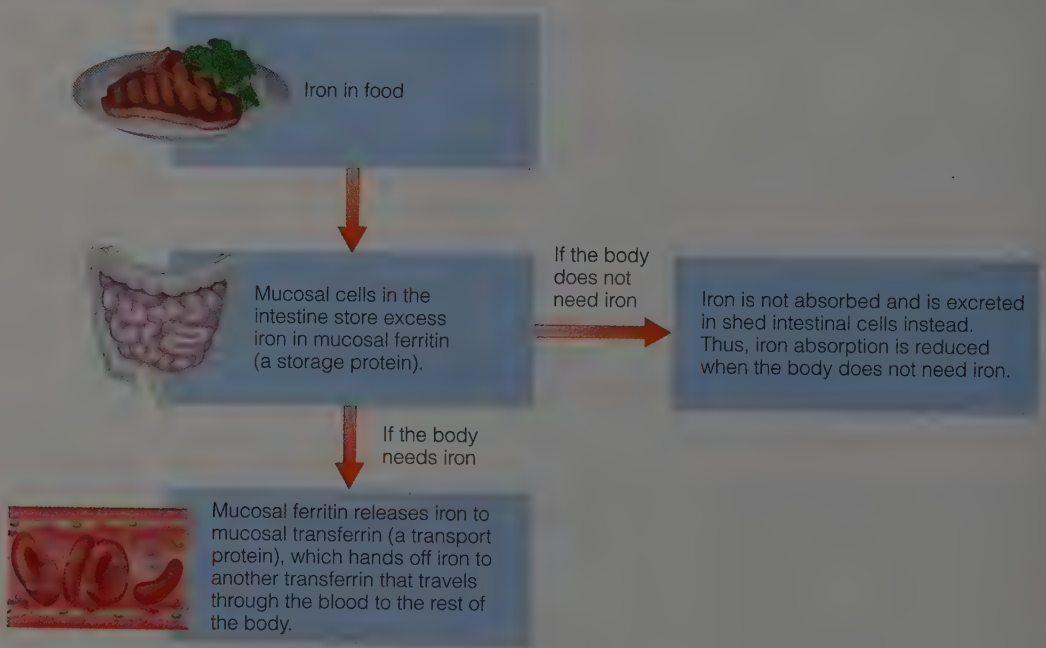
transferrin (trans-FAIR-in): the iron transport protein.

heme (HEEM) **iron:** the iron in foods that is bound to the hemoglobin and myoglobin proteins; found only in meat, fish, and poultry.

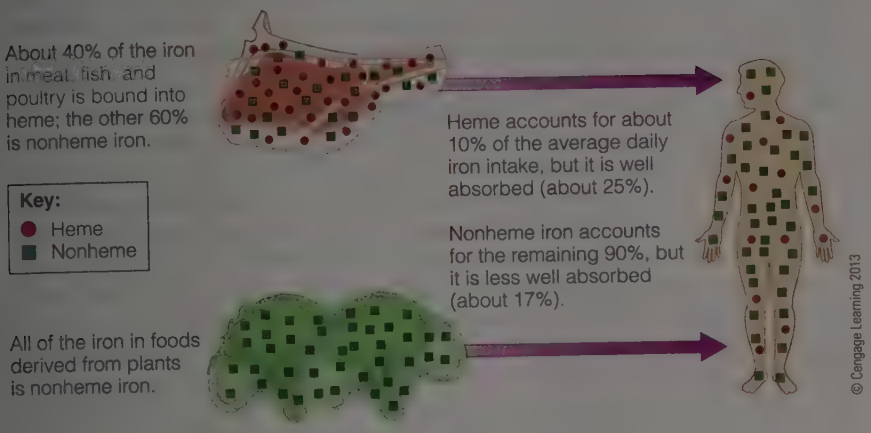
nonheme iron: the iron in foods that is not bound to proteins; found in both plant-derived and animal-derived foods.

*The iron-containing electron carriers of the electron transport chain are known as *cytochromes*. See Appendix C for details on the electron transport chain.

> **FIGURE 13-3 Iron Absorption**



> **FIGURE 13-4** Heme and Nonheme Iron in Foods



Heme iron has a high bioavailability and is not influenced by dietary factors. In contrast, several dietary factors enhance nonheme iron absorption. ♦ Meat, fish, and poultry contain not only the well-absorbed heme iron, but also a peptide (sometimes called the MFP factor) that promotes the absorption of nonheme iron from other foods eaten at the same meal. Vitamin C also enhances nonheme iron absorption from foods eaten at the same meal by capturing the iron and keeping it in the reduced ferrous form, ready for absorption. Some acids and sugars also enhance nonheme iron absorption.

Some dietary factors bind with nonheme iron, inhibiting absorption. ♦ These factors include the phytates in legumes, whole grains, and rice; the vegetable proteins in soybeans, other legumes, and nuts; the calcium in milk; and the polyphenols (such as tannic acid) in tea, coffee, grain products, oregano, and red wine.

The many dietary enhancers, inhibitors, and their combined effects make it difficult to estimate iron absorption. Most of these factors exert a strong influence individually, but not when combined with the others in a meal. Furthermore, the impact of the combined effects diminishes when a diet is evaluated over several days. When multiple meals are analyzed together, three factors appear to be most relevant: MFP factor and vitamin C as enhancers and phytates as inhibitors.

Overall, about 18 percent of dietary iron is absorbed from mixed diets and only about 10 percent from vegetarian diets.[7] As you might expect, vegetarian diets do not have the benefit of easy-to-absorb heme iron or the help of the MFP factor in enhancing absorption. In addition to dietary influences, iron absorption also depends on an individual's health, stage in the life cycle, and iron status. Absorption can be as low as 2 percent in a person with GI disease or as high as 35 percent in a rapidly growing, healthy child. The body adapts to absorb more iron when a person's iron stores fall short or when the need increases for any reason (such as pregnancy). The body makes more ferritin to absorb more iron from the small intestine and more transferrin to carry more iron around the body. Similarly, when iron stores are sufficient, the body adapts to absorb less iron.

Iron Transport and Storage The blood transport protein transferrin delivers iron to the bone marrow and other tissues. The bone marrow uses large quantities of iron to make new red blood cells, whereas other tissues use less. Surplus iron is stored in the protein ferritin, primarily in the liver, but also in the bone marrow and spleen. When dietary iron has been plentiful, ferritin is constantly and rapidly made and broken down, providing an ever-ready supply of iron. When iron concentrations become abnormally high, the liver converts some ferritin into another storage protein called **hemosiderin.** Hemosiderin releases iron more slowly than ferritin does. Storing excess iron in hemosiderin protects the body against the damage that free iron can cause. Free iron acts as a free radical, attacking cell lipids, DNA, and protein. (See Highlight 11 for more information on free radicals and the damage they can cause.)

♦ Factors that *enhance* nonheme iron absorption:
- MFP factor
- Vitamin C (ascorbic acid)
- Acids (citric and lactic)
- Sugars (fructose)

♦ Factors that *inhibit* nonheme iron absorption:
- Phytates (legumes, grains, and rice)
- Vegetable proteins (soybeans, legumes, nuts)
- Calcium (milk)
- Tannic acid (and other polyphenols in tea and coffee)


© haak78/Shutterstock.com

This chili dinner provides several factors that may enhance iron absorption: heme and nonheme iron and the MFP factor from meat, nonheme iron from legumes, and vitamin C from tomatoes.

MFP factor: a peptide released during the digestion of meat, fish, and poultry that enhances nonheme iron absorption.

hemosiderin (heem-oh-SID-er-in): an iron-storage protein primarily made in times of iron overload.

The average red blood cell lives about 4 months; then the spleen and liver cells remove it from the blood, take it apart, and prepare the degradation products for excretion or recycling. The iron is salvaged: the liver attaches it to transferrin, which transports it back to the bone marrow to be reused in making new red blood cells. Thus, although red blood cells live for only about 4 months, the iron recycles through each new generation of cells (see Figure 13-5). The body loses some iron daily via the GI tract and, if bleeding occurs, in blood. Only tiny amounts of iron are lost in urine, sweat, and shed skin. Iron excretion differs for men and women.[8] On average, men and women lose about 1.0 milligram of iron per day, with women losing additional iron in menses; menstrual losses vary considerably, but over a month, they average about 0.5 milligram per day.

Maintaining iron balance depends on the careful regulation of iron absorption, transport, storage, recycling, and losses. The hormone **hepcidin** is central to the regulation of iron balance.[9] Produced by the liver, hepcidin helps to maintain blood iron within the normal range by limiting absorption from the small intestine and controlling release from the liver, spleen, and bone marrow. Hepcidin production increases in iron overload and decreases in iron deficiency.[10]

Iron Deficiency Worldwide, **iron deficiency** is the most common nutrient deficiency, with **iron-deficiency anemia** affecting more than 1.6 billion people—mostly preschool children and pregnant women.[11] In the United States, iron deficiency is less prevalent, but it still affects about 10 percent of toddlers, adolescent girls, and women of childbearing age. Iron deficiency is also relatively common among overweight children and adolescents compared with those who are normal weight.[12] The association between iron deficiency and obesity has yet to be explained, but researchers are currently examining the relationships between the inflammation that develops with excess body fat and reduced iron absorption.[13] The increased production of hepcidin in obesity may also help to explain the relationship between obesity and iron deficiency.[14] Preventing and correcting iron deficiency are high priorities.

Some stages of life ♦ demand more iron but provide less, making deficiency likely.[15] Women in their reproductive years are especially prone to iron deficiency because of repeated blood losses during menstruation. Pregnancy demands additional

♦ High risk for iron deficiency:
- Women in their reproductive years
- Pregnant women
- Infants and young children
- Adolescents

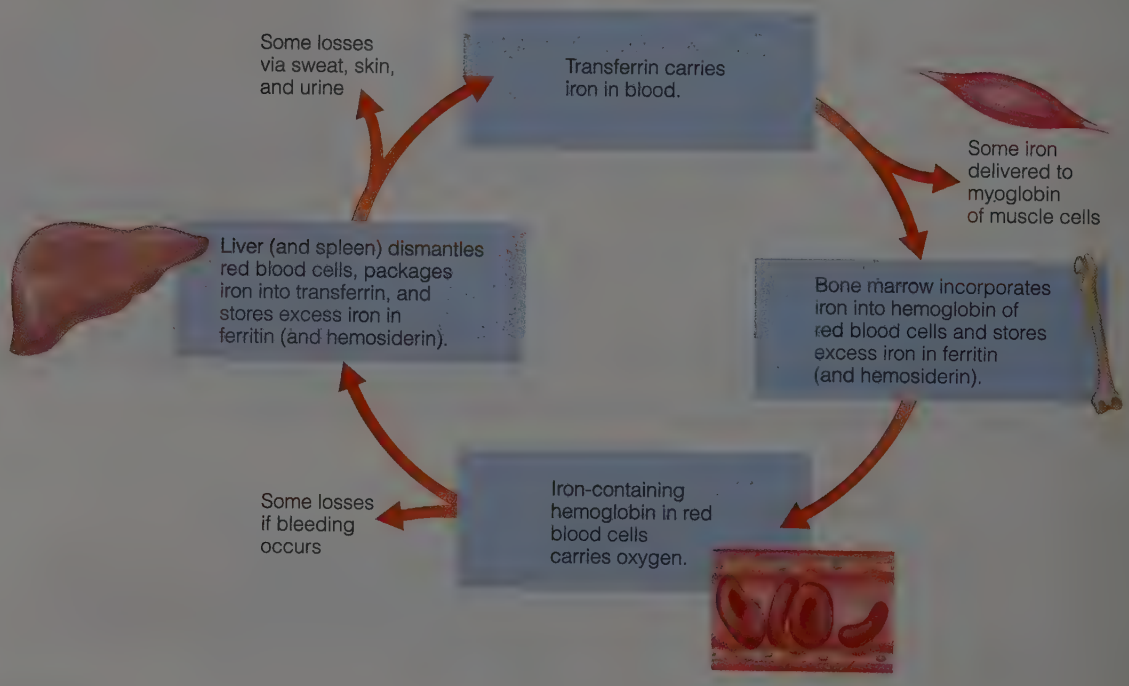
hepcidin: a hormone produced by the liver that regulates iron balance.

iron deficiency: the state of having depleted iron stores.

iron-deficiency anemia: severe depletion of iron stores that results in low hemoglobin and small, pale red blood cells. Anemias that impair hemoglobin synthesis are *microcytic* (small cell).
- **micro** = small
- **cytic** = cell

> FIGURE 13-5 ***Animated*** **Iron Recycled in the Body**

Once iron enters the body, most of it is recycled. Some is lost with body tissues and must be replaced by eating iron-containing foods.



iron to support the added blood volume, growth of the fetus, and blood loss during childbirth. Infants and young children receive little iron from their high-milk diets, yet need extra iron to support their rapid growth and brain development.[16]* Iron deficiency among toddlers in the United States is common. The rapid growth of adolescence, especially for males, and the menstrual losses of females also demand extra iron that a typical teen diet may not provide. An adequate iron intake is especially important during these stages of life.

Bleeding from any site incurs iron losses.** In some cases, such as an active ulcer, the bleeding may not be obvious, but even small chronic blood losses significantly deplete iron reserves. In developing countries, blood loss is often brought on by malaria and parasitic infections of the GI tract. People who donate blood regularly also incur losses and may benefit from iron supplements. As mentioned, menstrual losses can be considerable as they tap women's iron stores regularly.

Assessment of Iron Deficiency Iron deficiency develops in stages. ♦ This section provides a brief overview of how to detect these stages, and Appendix E provides more details. In the first stage of iron deficiency, iron stores diminish. Measures of serum ferritin (in the blood) reflect iron stores and are most valuable in assessing iron status at this earliest stage.[17] Unfortunately, serum ferritin increases with infections, which interferes with an accurate diagnosis and estimate of prevalence.[18]

♦ Stages of iron deficiency:
- Iron stores diminish
- Transport iron decreases
- Hemoglobin production declines

The second stage of iron deficiency is characterized by a decrease in transport iron: serum iron falls, and the iron-carrying protein transferrin *increases* (an adaptation that enhances iron absorption). Together, measurements of serum iron and transferrin can determine the severity of the deficiency—the more transferrin and the less iron in the blood, the more advanced the deficiency is. Transferrin saturation—the percentage of transferrin that is saturated with iron—decreases as iron stores decline.

The third stage of iron deficiency occurs when the lack of iron limits hemoglobin production. Now the hemoglobin precursor, **erythrocyte protoporphyrin**, begins to accumulate as hemoglobin and **hematocrit** values decline. Hemoglobin and hematocrit tests are easy, quick, and inexpensive, so they are the tests most commonly used in evaluating iron status. Their usefulness in detecting iron deficiency is limited, however, because they are late indicators. Furthermore, other nutrient deficiencies and medical conditions can influence their values.

Iron Deficiency and Anemia Notice that iron deficiency and iron-deficiency anemia are not the same: people may be iron deficient without being anemic. The term *iron deficiency* refers to depleted body iron stores without regard to the degree of depletion or to the presence of anemia. The term *iron-deficiency anemia* refers to the severe depletion of iron stores that results in a low hemoglobin concentration. In iron-deficiency anemia, hemoglobin synthesis decreases, resulting in red blood cells that are pale (hypochromic) and small (microcytic), ♦ as shown in Figure 13-6, p. 410. Without adequate iron, these cells can't carry enough oxygen from the lungs to the tissues. Energy metabolism in the cells falters. The result is fatigue, weakness, headaches, apathy, pallor, and poor resistance to cold temperatures. Because hemoglobin is the bright red pigment of the blood, the skin of a fair person who is anemic may become noticeably pale. In a dark-skinned person, the tongue and eye lining, normally pink, is very pale.

♦ Iron-deficiency anemia is a *microcytic* (my-cro-SIT-ic) *hypochromic* (high-po-KROME-ic) *anemia*.
- **micro** = small
- **cytic** = cell
- **hypo** = too little
- **chrom** = color

The fatigue that accompanies iron-deficiency anemia differs from the tiredness a person experiences from a simple lack of sleep. People with anemia feel fatigue only when they exert themselves. Iron supplementation can relieve the fatigue and improve the body's response to physical activity. (The iron needs of physically active people and the special iron deficiency known as sports anemia are discussed in Chapter 14.)

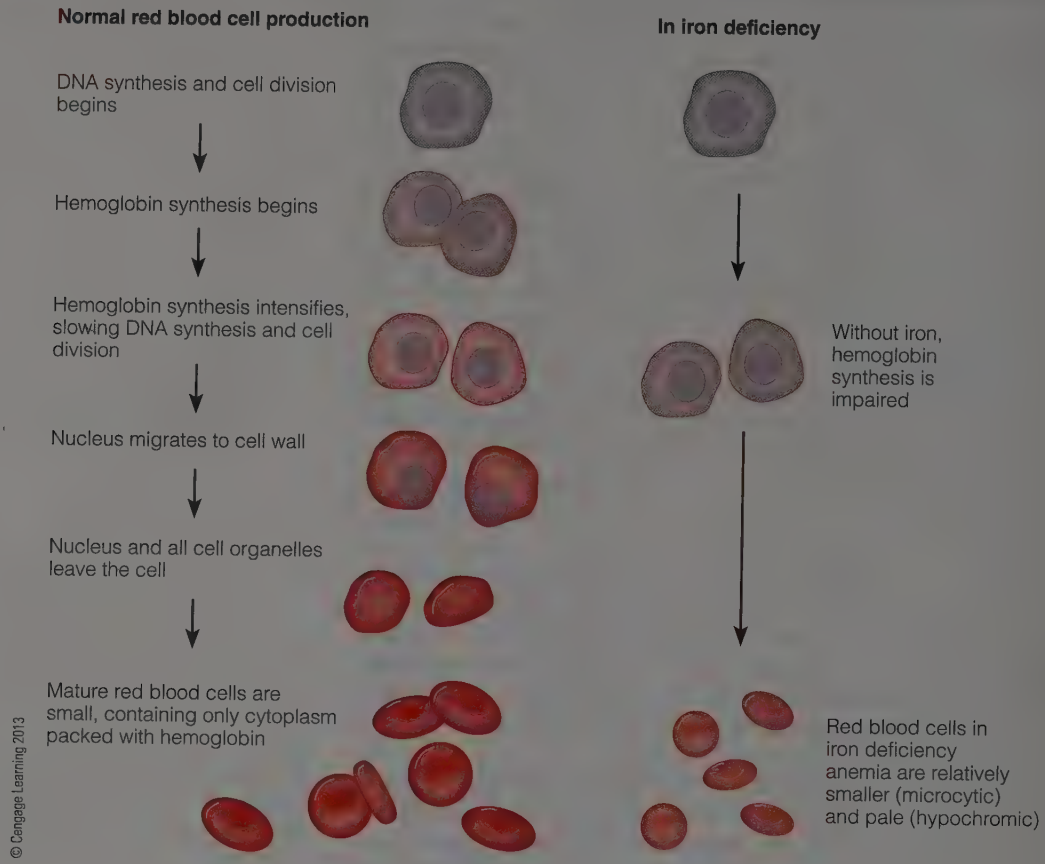
*The condition of developing iron-deficiency anemia because iron-poor milk displaces iron-rich foods in the diet is called *milk anemia*.

**The iron content of blood is about 0.5 miligram/100 milliliters blood. A person donating a pint of blood (approximately 500 millileters) loses about 2.5 milligrams of iron.

erythrocyte protoporphyrin (PRO-toe-PORE-fe-rin) a precursor to hemoglobin.

hematocrit (hee-MAT-oh-krit): the percentage of total blood volume that consists of red blood cells.

> **FIGURE 13-6 Normal Blood Cells and Blood Cells in Iron Deficiency Anemia Compared**



© Cengage Learning 2013

Iron Deficiency and Behavior Long before the red blood cells are affected and anemia is diagnosed, a developing iron deficiency affects behavior.[19] Even at slightly lowered iron levels, energy metabolism is impaired and neurotransmitter synthesis is altered, reducing physical work capacity and mental productivity.[20] Without the physical energy and mental alertness to work, plan, think, play, sing, or learn, people simply do less. They have no obvious deficiency symptoms; they just appear unmotivated, apathetic, and less physically fit. Work productivity and voluntary activities decline.

Many of the symptoms associated with iron deficiency are easily mistaken for behavioral or motivational problems. A restless child who fails to pay attention in class might be thought contrary. An apathetic homemaker who has let housework pile up might be thought lazy. No responsible dietitian would ever claim that all behavioral problems are caused by nutrient deficiencies, but poor nutrition is always a possible contributor to problems like these. When investigating a behavioral problem, check the adequacy of the diet and seek a routine physical examination before undertaking more expensive, and possibly more harmful, treatment options. Treatment with iron supplements may improve mood, cognitive skills, and physical performance.[21] The effects of iron deficiency on children's behavior are discussed further in Chapter 16.

Iron Deficiency and Pica A curious behavior seen in some iron-deficient people, especially in women and children of low-income groups, is **pica**—the craving and consumption of ice, chalk, starch, and other nonfood substances. These substances contain no iron and cannot remedy a deficiency; in fact, clay actually

pica (PIE-ka): a craving for and consumption of nonfood substances. Pica is known as *geophagia* (gee-oh-FAY-gee-uh) when referring to eating clay, baby powder, chalk, ash, ceramics, paper, paint chips, or charcoal; *pagophagia* (pag-oh-FAY-gee-uh) when referring to eating large quantities of ice; and *amylophagia* (AM-ee-low-FAY-gee-ah) when referring to eating uncooked starch (flour, laundry starch, or raw rice).

inhibits iron absorption, which may explain the iron deficiency that accompanies such behavior. Pica is poorly understood. Its cause is unknown, but researchers hypothesize that it may be motivated by hunger, nutrient deficiencies, or an attempt to protect against toxins or microbes.[22] The consequence of pica is anemia.

Iron Overload As mentioned earlier, iron is closely regulated and absorption normally decreases when iron stores are full. Even a diet that includes fortified foods usually poses no risk for most people, but some individuals are vulnerable to excess iron. Once considered rare, **iron overload** has emerged as an important disorder of iron metabolism and regulation.

The iron overload disorder known as **hemochromatosis** is caused by a genetic failure to prevent unneeded iron in the diet from being absorbed.[23] Research suggests that just as insulin supports normal glucose homeostasis and its absence or ineffectiveness causes diabetes, the hormone hepcidin supports iron homeostasis and its deficiency or (rarely) resistance causes hemochromatosis.[24]

Hereditary hemochromatosis is the most common genetic disorder in the United States, affecting some 1.5 million people. Other causes of iron overload include repeated blood transfusions (which bypass the intestinal defense), massive doses of supplementary iron (which overwhelm the intestinal defense), and other rare metabolic disorders. Excess iron overload is characterized by a toxic accumulation of iron in the liver, heart, joints, and other tissues.[25]

Some of the signs and symptoms of iron overload are similar to those of iron deficiency: apathy, lethargy, and fatigue. Therefore, taking iron supplements before assessing iron status is clearly unwise; hemoglobin tests alone would fail to make the distinction because excess iron accumulates in storage. Iron overload assessment tests measure transferrin saturation and serum ferritin.

Iron overload is characterized by free-radical tissue damage, especially in iron-storing organs such as the liver.[26] Infections are likely because viruses and bacteria thrive on iron-rich blood.[27] Symptoms are most severe in alcohol abusers because alcohol damages the small intestine, further impairing its defenses against absorbing excess iron. Untreated iron overload increases the risks of diabetes, liver cancer, heart disease, and arthritis.[28] Treatment involves chelation therapy, which uses a **chelate** to form a complex with iron and promote its excretion.[29]

Iron overload is much more common in men than in women and is twice as prevalent among men as iron deficiency.[30] The widespread fortification of foods with iron makes it difficult for people with hemochromatosis to follow a low-iron diet, and greater dangers lie in the indiscriminate use of iron and vitamin C supplements. Vitamin C not only enhances iron absorption, but also releases iron from ferritin, allowing free iron to wreak the damage typical of free radicals. Thus vitamin C acts as a *pro*xidant when taken in high doses. (See Highlight 11 for a discussion of free radicals and their effects on disease development.)

Iron and Chronic Diseases Some research suggests a link between heart disease and excess iron.[31] Limited evidence suggests an association between iron and some cancers. Explanations for how iron might be involved in contributing to these chronic diseases focus on its free-radical activity. One of the benefits of a high-fiber diet may be that the accompanying phytates bind iron, making it less available for such reactions.

Iron Poisoning Large doses of iron supplements cause GI distress, including constipation, nausea, vomiting, and diarrhea. These effects may not be as serious as other consequences of iron toxicity, but they are consistent enough to establish a UL of 45 milligrams per day for adults.

Ingestion of iron-containing supplements is a common cause of accidental poisoning in young children.[32] Symptoms of toxicity include nausea, vomiting, diarrhea, a rapid heartbeat, a weak pulse, dizziness, shock, and confusion. As few as five iron tablets containing as little as 200 milligrams of iron have caused death in young children. The exact cause of death is uncertain, but excessive free-radical damage is thought to play a role in heart failure and respiratory distress. Autopsy reports reveal iron deposits and cell death in the stomach, small intestine, liver,

iron overload: toxicity from excess iron.

hemochromatosis (HE-moh-KRO-ma-toe-sis): a genetically determined failure to prevent absorption of unneeded dietary iron that is characterized by iron overload and tissue damage.

chelate (KEY-late): a substance that can grasp the positive ions of a mineral.

- **chele** = claw

>How To

Estimate the Recommended Daily Intake for Iron

To calculate the recommended daily iron intake, the DRI Committee considers a number of factors. For example, for a woman of childbearing age (19 to 50):

- Losses from feces, urine, sweat, and shed skin: 1.0 milligram
- Losses through menstruation: 0.5 milligram (about 14 milligrams total averaged over 28 days)

These losses reflect an average daily need (total) of 1.5 milligrams of *absorbed iron.*

An estimated average requirement is determined based on the daily need and the assumption that an average of 18 percent of ingested iron is absorbed:

1.5 mg iron (needed)
÷ 0.18 (percent iron absorbed)
= 8 mg iron (estimated average requirement)

Then, a margin of safety is added to cover the needs of essentially all women of childbearing age, and the RDA is set at 18 milligrams.

TRY IT Calculate how many slices of whole-wheat bread, cups of broccoli, ounces of hamburger meat, and cups of milk it takes to provide 18 milligrams of iron.

and blood vessels (which can cause internal bleeding). As with medicines and other potentially toxic substances, keep iron-containing tablets out of the reach of children. If you suspect iron poisoning, call the nearest poison control center or a physician immediately.

Iron Recommendations The usual diet in the United States provides about 6 to 7 milligrams of iron for every 1000 kcalories. The recommended daily intake for men is 8 milligrams, and because most men eat more than 2000 kcalories a day, they can meet their iron needs with little effort. Women in their reproductive years, however, need 18 milligrams a day. The accompanying "How To" feature explains how to calculate the recommended intake.

Because women have higher iron needs and lower energy needs, they sometimes have trouble obtaining enough iron. On average, women receive only 12 to 13 milligrams of iron per day, which is not enough iron for women until after menopause. To meet their iron needs from foods, premenopausal women need to select iron-rich foods at every meal.



> DIETARY GUIDELINES FOR AMERICANS 2010

Women capable of becoming pregnant should choose foods that supply heme iron, which is more readily absorbed by the body, additional iron sources, and enhancers of iron absorption such as vitamin C. If pregnant, women should take an iron supplement, as recommended by a health-care provider.

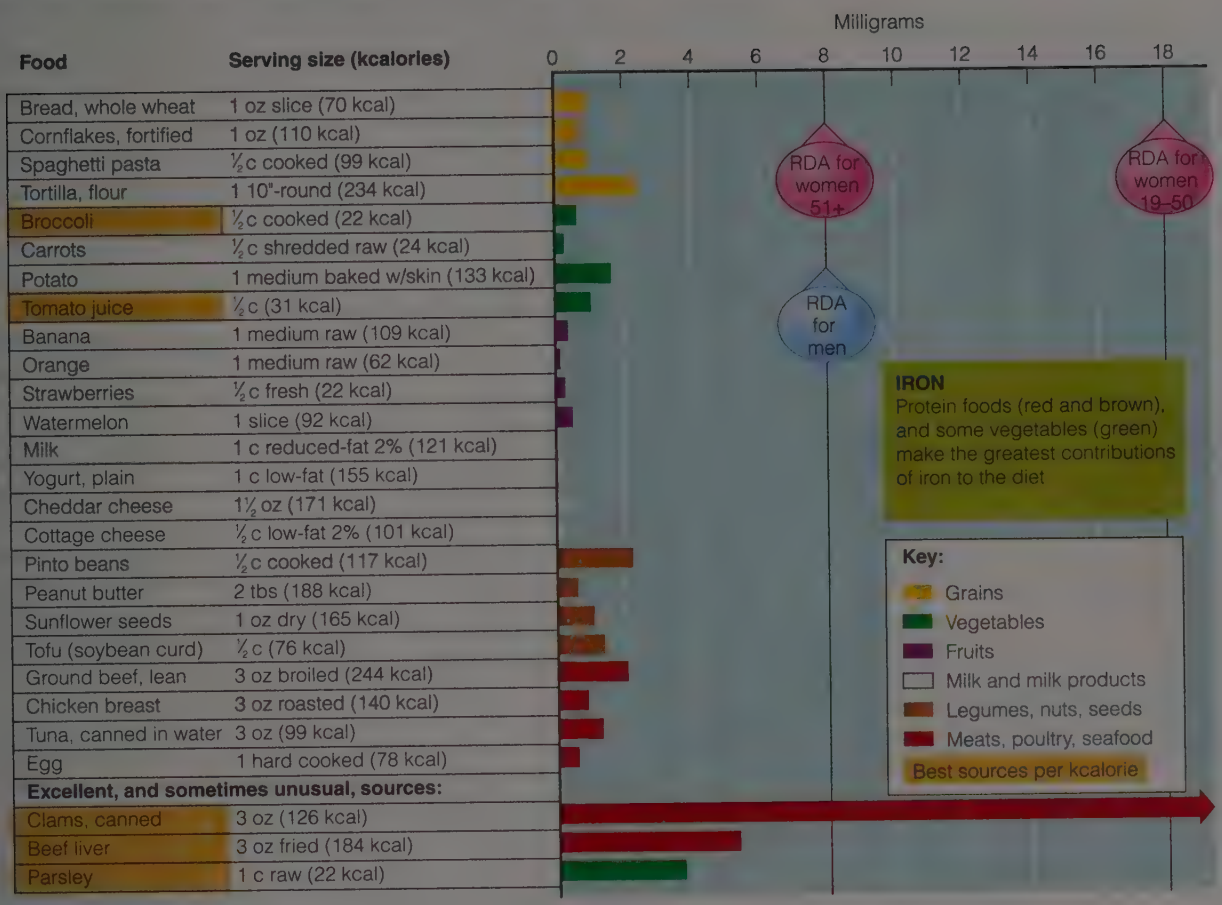
♦ To calculate the RDA for vegetarians, multiply by 1.8:
- 8 mg × 1.8 = 14 mg/day (vegetarian men)
- 18 mg × 1.8 = 32 mg/day (vegetarian women, 19 to 50 yr)

Vegetarians need 1.8 times as much iron ♦ to make up for the low bioavailability typical of their diets.[33] To maximize iron absorption, vegetarians should incorporate iron-rich foods into a diet that is low in inhibitors (foods such as leavened breads and fermented soy products such as miso and tempeh) and high in enhancers (foods rich in vitamin C and the organic acids found in fruits and vegetables). Good vegetarian sources of iron include soy foods (such as soybeans and tofu), legumes (such as lentils and kidney beans), nuts (such as cashews and almonds), seeds (such as pumpkin seeds and sunflower seeds), cereals (such as cream of wheat and oatmeal), dried fruit (such as apricots and raisins), vegetables (such as mushrooms and potatoes), and blackstrap molasses.

Iron Food Sources To obtain enough iron, people must first select iron-rich foods—both naturally occurring and enriched or fortified—and then take advantage of factors that maximize iron absorption. This discussion begins by identifying iron-rich foods and then reviews the factors affecting absorption. Figure 13-7 shows

> FIGURE 13-7 Iron in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.



Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	½ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Clams, canned	3 oz (126 kcal)
Beef liver	3 oz fried (184 kcal)
Parsley	1 c raw (22 kcal)

the amounts of iron in selected foods. Meats, fish, and poultry contribute the most iron per serving; other protein-rich foods such as legumes and eggs are also good sources. Although an indispensable part of the diet, foods in the milk group are notoriously poor in iron. Grain products vary, with whole-grain, enriched, and fortified breads and cereals contributing significantly to iron intakes. Finally, dark greens (such as broccoli) and dried fruits (such as raisins) contribute some iron.

The FDA does not mandate iron enrichment, but most states require manufacturers to enrich flour and grain products with iron.* One serving of enriched bread or cereal provides only a little iron, but because people eat many servings of these foods, the contribution can be significant. Iron added to foods is nonheme iron, which is not absorbed as well as heme iron, but when eaten with absorption-enhancing foods, enrichment iron can increase iron stores and reduce iron deficiency. In cases of iron overload, enrichment may exacerbate the problem.

In general, the bioavailability of iron is high in meats, fish, and poultry, intermediate in grains and legumes, and low in most vegetables, especially those containing oxalates such as spinach. As mentioned earlier, the amount of iron ultimately absorbed from a meal depends on the combined effects of several enhancing and inhibiting factors. For maximum absorption of nonheme iron, eat meat for the MFP factor and fruits or vegetables for vitamin C. The iron of baked beans, for example, will be enhanced by the MFP factor in a piece of pork served with them. The iron of bread will be enhanced by the vitamin C in a slice of tomato on a sandwich.



© Craig M. Moore

When the label on a grain product says "enriched," it means iron and several B vitamins have been added to meet FDA standards.

*Each pound of enriched flour contains at least 20 milligrams of iron.

♦ Increase in iron content (mg) for selected foods (3 oz) after cooking in iron skillet:

Beef stew	0.66→3.40
Chili	0.96→6.27
Cornbread	0.67→0.86
Hamburger	1.49→2.29
Pancake	0.63→1.31
Rice	0.67→1.97
Scrambled egg	1.49→4.76
Spaghetti sauce	0.61→5.77



© Polara Studios, Inc.

An old-fashioned iron skillet adds iron to foods.

Iron Contamination In addition to the iron from foods, **contamination iron** from nonfood sources of inorganic iron salts can contribute to the day's intakes. Foods cooked in iron cookware take up iron salts. The more acidic the food and the longer it is cooked in iron cookware, the higher the iron content. ♦ The iron content of eggs can triple in the time it takes to scramble them in an iron pan. Admittedly, the absorption of this iron may be poor (perhaps only 1 to 2 percent), but every little bit helps a person who is trying to increase iron intake.

Iron Supplementation People can also get iron from supplements. People who are iron deficient may need supplements as well as an iron-rich, absorption-enhancing diet. Many physicians routinely recommend iron supplements to pregnant women, infants, and young children. Iron from supplements is less well absorbed than that from food, so the doses must be high. The absorption of iron taken as ferrous sulfate is better than that from other iron supplements. Absorption also improves when supplements are taken between meals, at bedtime on an empty stomach, and with liquids (other than milk, tea, or coffee, which inhibit absorption). Taking iron supplements in a single dose instead of several doses per day is equally effective and may improve a person's willingness to take it regularly.

There is no benefit to taking iron supplements with orange juice because vitamin C does not enhance absorption from supplements as it does from foods. Vitamin C enhances iron absorption by converting insoluble ferric iron in foods to the more soluble ferrous iron, and supplemental iron is already in the ferrous form. Constipation is a common side effect of iron supplementation; drinking plenty of water may help to relieve this problem. The best strategy to ensure compliance is to individualize the dose, formulation, and schedule.[34] Most importantly, iron supplements should be taken only when prescribed by a physician who has assessed an iron deficiency.

REVIEW IT

Most of the body's iron is in hemoglobin and myoglobin, where it carries oxygen for use in energy metabolism; some iron is also required for enzymes involved in a variety of reactions. Special proteins assist with iron absorption, transport, and storage—all helping to maintain an appropriate balance—because both too little and too much iron can be damaging. Iron deficiency is most common among infants and young children, teenagers, women of childbearing age, and pregnant women. Symptoms include fatigue and anemia. Iron overload is most common in men. Heme iron, which is found only in meat, fish, and poultry, is better absorbed than nonheme iron, which occurs in most foods. Nonheme iron absorption is improved by eating iron-containing foods with foods containing the MFP factor and vitamin C; absorption is limited by phytates and oxalates. The accompanying table provides a summary of iron.

Iron

RDA	Significant Sources
Men: 8 mg/day Women: 18 mg/day (19–50 yr) 8 mg/day (51+)	Red meats, fish, poultry, shellfish, eggs, legumes, dried fruits
Upper Level	**Deficiency Symptoms**
Adults: 45 mg/day	Anemia: weakness, fatigue, headaches; impaired work performance and cognitive function; impaired immunity; pale skin, nail beds, mucous membranes, and palm creases; concave nails; inability to regulate body temperature; pica
Chief Functions in the Body	**Toxicity Symptoms**
Part of the protein hemoglobin, which carries oxygen in the blood; part of the protein myoglobin in muscles, which makes oxygen available for muscle contraction; necessary for the utilization of energy as part of the cells' metabolic machinery	GI distress Iron overload: infections, fatigue, joint pain, skin pigmentation, organ damage

♦ Metalloenzymes that require zinc:
- Synthesize parts of the genetic materials DNA and RNA
- Manufacture heme for hemoglobin
- Convert retinol to retinal and alcohol to acetaldehyde
- Influence carbohydrate metabolism
- Regulate protein synthesis
- Digest proteins and folate
- Dispose of damaging free radicals
- Dispose of carbon dioxide

contamination iron: iron found in foods as the result of contamination by inorganic iron salts from iron cookware, iron-containing soils, and the like.

zinc: an essential trace mineral that is part of many enzymes and a constituent of insulin.

metalloenzymes (meh-TAL-oh-EN-zimes): enzymes that contain one or more minerals as part of their structures.

Zinc

Zinc is a versatile trace element required as a cofactor by more than 100 enzymes. Virtually all cells contain zinc, but the highest concentrations are found in muscle and bone.

Zinc Roles in the Body Zinc supports the work of numerous proteins in the body, such as the **metalloenzymes,** ♦ which are involved in a variety of metabolic processes,

including the regulation of gene expression.* In addition, zinc stabilizes cell membranes and DNA, helping to strengthen antioxidant defenses against free-radical attacks.[35] Zinc also assists in immune function and in growth and development.[36] Zinc participates in the synthesis, storage, and release of the hormone insulin in the pancreas, although it does not appear to play a direct role in insulin's action. Zinc interacts with platelets in blood clotting, affects thyroid hormone function, and influences behavior and learning performance. It is needed to produce the active form of vitamin A (retinal) in visual pigments and the retinol-binding protein that transports vitamin A. It is essential to normal taste perception, wound healing, sperm production, and fetal development. A zinc deficiency impairs all these and other functions, underlining the vast importance of zinc in supporting the body's proteins.

Zinc Absorption The body's handling of zinc resembles that of iron in some ways and differs in others. A key difference is the circular passage of zinc from the small intestine to the body and back again.

The rate of zinc absorption varies from about 15 to 40 percent, depending on the amount of zinc consumed—as zinc intake increases, the rate of absorption decreases, and as zinc intake decreases, the rate of absorption increases.[37] Like iron, dietary factors such as phytates influence absorption, limiting its bioavailability.[38]

Upon absorption into an intestinal cell, zinc has two options. Zinc may participate in the metabolic functions of the intestinal cell itself, or it may be retained within the intestinal cells by **metallothionein** until the body needs zinc. Metallothionein plays a key role in storing and distributing zinc throughout the body.[39]

Zinc Transport Some zinc eventually reaches the pancreas, where it is incorporated into many of the digestive enzymes that the pancreas releases into the small intestine at mealtimes. The small intestine thus receives two doses of zinc with each meal—one from foods and the other from the zinc-rich pancreatic juices. The recycling of zinc in the body from the pancreas to the small intestine and back to the pancreas is referred to as the **enteropancreatic circulation** of zinc. Each time zinc circulates through the small intestine, it may be excreted in shed intestinal cells or reabsorbed into the body (see Figure 13-8). The body loses zinc

*Among the metalloenzymes requiring zinc are carbonic anhydrase, deoxythymidine kinase, DNA and RNA polymerase, and alkaline phosphatase.

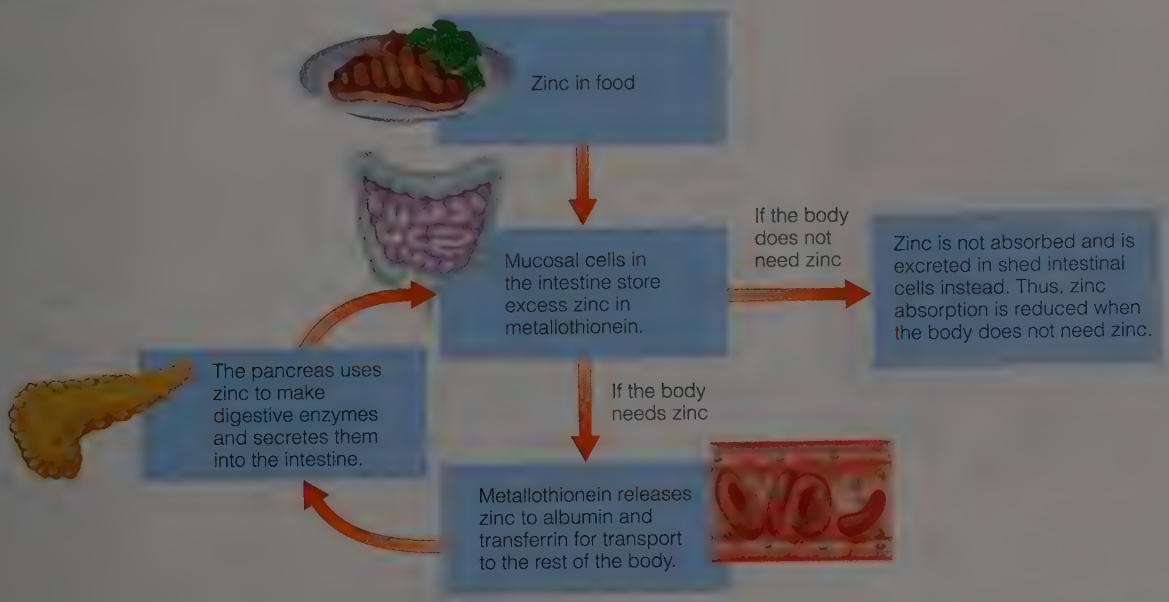
metallothionein (meh-TAL-oh-THIGH-oh-neen): a sulfur-rich protein that avidly binds with and transports metals such as zinc.

- **metallo** = containing a metal
- **thio** = containing sulfur
- **ein** = a protein

enteropancreatic (EN-ter-oh-PAN-kree-AT-ik) **circulation:** the circulatory route from the pancreas to the small intestine and back to the pancreas.

> FIGURE 13-8 ***Animated*** **Enteropancreatic Circulation of Zinc**

Some zinc from food is absorbed by the small intestine and sent to the pancreas to be incorporated into digestive enzymes that return to the small intestine. This cycle is called the *enteropancreatic circulation* of zinc.



© Cengage Learning 2013

> FIGURE 13-9 Zinc-Deficiency Symptom—The Stunted Growth of Dwarfism

The growth retardation, known as dwarfism, is rightly ascribed to zinc deficiency because it is partially reversible when zinc is restored to the diet.



© H. Sanstead, University of Texas at Galveston

The Egyptian man on the right is an adult of average height. The Egyptian boy on the left is 17 years old but is only 4 feet tall, like a 7-year-old in the United States. His genitalia are like those of a 6-year-old.



© Polara Studios, Inc.

Zinc is highest in protein-rich foods such as oysters, beef, poultry, legumes, and nuts.

primarily in feces. Smaller losses occur in urine, shed skin, hair, sweat, menstrual fluids, and semen.

Numerous proteins participate in zinc transport.[40] Zinc's main transport vehicle in the blood is the protein albumin. Some zinc also binds to transferrin—the same transferrin that carries iron in the blood.

Zinc Deficiency Severe zinc deficiency is not widespread in developed countries, but it is responsible for an estimated 1 out of 20 childhood deaths in Africa, Asia, and Latin America.[41] Human zinc deficiency was first reported in the 1960s in children and adolescent boys in Egypt, Iran, and Turkey. Children have especially high zinc needs because they are growing rapidly and synthesizing many zinc-containing proteins, and the native diets among those populations were not meeting these needs. Middle Eastern diets are traditionally low in the richest zinc source, meats. Furthermore, the staple foods in these diets are legumes, unleavened breads, and other whole-grain foods—all high in fiber and phytates, which inhibit zinc absorption.*

Figure 13-9 shows the severe growth retardation and mentions the immature sexual development characteristic of zinc deficiency.[42] In addition, zinc deficiency hinders digestion and absorption, causing diarrhea, which worsens malnutrition not only for zinc, but for other nutrients as well. It also impairs the immune response, making infections likely—among them, pneumonia and GI tract infections, which worsen malnutrition, including zinc malnutrition (a classic downward spiral of events).[43] Chronic zinc deficiency damages the central nervous system and brain and may lead to poor motor development and cognitive performance. Because zinc deficiency directly impairs vitamin A metabolism, vitamin A–deficiency symptoms often appear. Zinc deficiency also disturbs thyroid function and the metabolic rate. It alters taste, causes loss of appetite, and slows wound healing—in fact, its symptoms are so pervasive that generalized malnutrition and sickness are more likely to be the diagnosis than simple zinc deficiency.

Zinc Toxicity High doses (more than 50 milligrams) of zinc may cause vomiting, diarrhea, headaches, exhaustion, and other symptoms. The UL for adults was set at 40 milligrams based on zinc's interference in copper metabolism—an effect that, in animals, leads to degeneration of the heart muscle.

Zinc Recommendations and Sources Figure 13-10 shows zinc amounts in selected foods per serving. Zinc is highest in protein-rich foods such as shellfish (especially oysters), meats, poultry, milk, and cheese. Legumes and whole-grain products are good sources of zinc if eaten in large quantities; in typical US diets, the phytate content of grains is not high enough to impair zinc absorption. Vegetables vary in zinc content depending on the soil in which they are grown. Average zinc intakes in the United States are slightly higher than recommendations.

Zinc Supplementation In developed countries, most people obtain enough zinc from the diet without resorting to supplements. In developing countries, zinc supplementation plays a major role in the treatment of childhood infectious diseases.[44] Zinc supplements effectively reduce the incidence of disease and death associated with diarrhea in children.[45] Similarly, zinc supplements may reduce the incidence of pneumonia and associated deaths in older adults.[46]

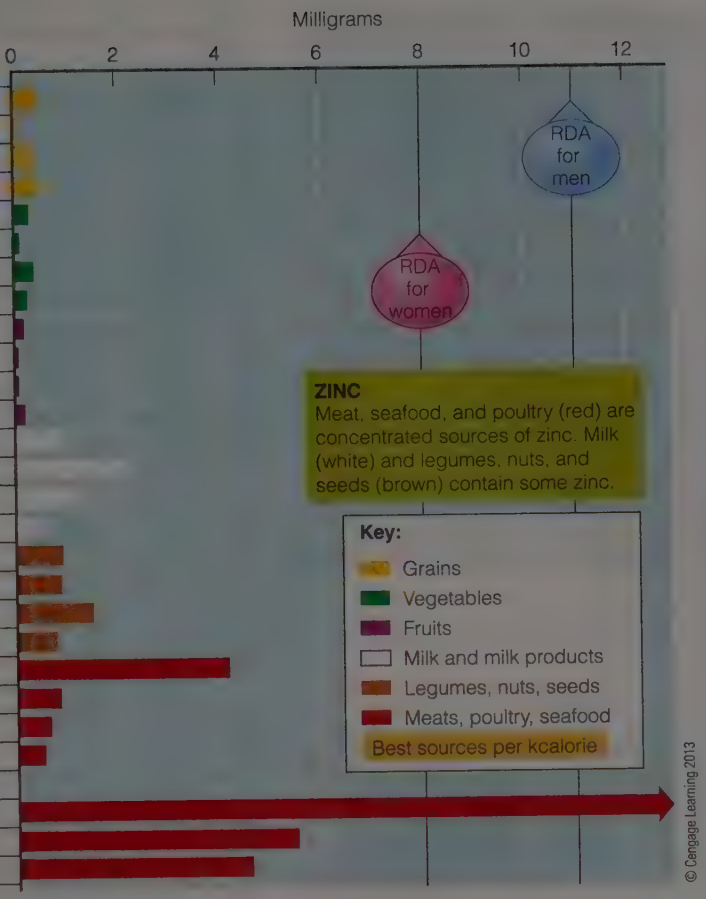
The use of zinc lozenges to treat the common cold has been controversial and inconclusive, with some studies finding them effective and others not.[47] The different study results may reflect the effectiveness of various zinc compounds. Some studies using zinc gluconate report shorter duration of cold symptoms, whereas most studies using other combinations of zinc report no effect. Common side effects of zinc lozenges include nausea and bad taste reactions.

*Unleavened bread contains no yeast, which normally breaks down phytates during fermentation.

> FIGURE 13-10 Zinc in Selected Foods

See the "How To" feature on p. 302 for more information on using this figure.

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Oysters	3 oz cooked (139 kcal)
Sirloin steak, lean	3 oz broiled (172 kcal)
Crab	3 oz cooked (94 kcal)



© Cengage Learning 2013

REVIEW IT

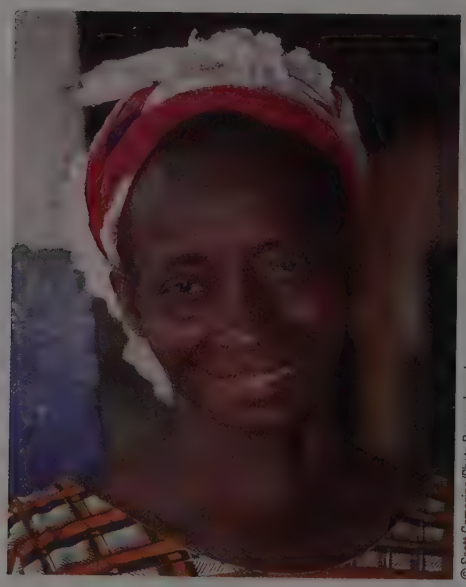
Zinc-requiring enzymes participate in a multitude of reactions affecting growth, vitamin A activity, and pancreatic digestive enzyme synthesis, among others. After a meal, both dietary zinc and zinc-rich pancreatic secretions (via enteropancreatic circulation) are absorbed. Absorption is regulated by a special binding protein (metallothionein) in the small intestine. Protein-rich foods derived from animals are the best sources of bioavailable zinc. Fiber and phytates in cereals bind zinc, limiting absorption. Growth retardation and sexual immaturity are hallmark symptoms of zinc deficiency. The accompanying table provides a summary of zinc.

Zinc

RDA	Significant Sources
Men: 11 mg/day Women: 8 mg/day	Protein-containing foods: red meats, shellfish, whole grains; some fortified cereals
Upper Level	**Deficiency Symptoms[a]**
Adults: 40 mg/day	Growth retardation, delayed sexual maturation, impaired immune function, hair loss, eye and skin lesions, loss of appetite
Chief Functions in the Body	**Toxicity Symptoms**
Part of many enzymes; associated with the hormone insulin; involved in making genetic material and proteins, immune reactions, transport of vitamin A, taste perception, wound healing, the making of sperm, and the normal development of the fetus	Loss of appetite, impaired immunity, low HDL, copper and iron deficiencies

[a]A rare inherited disease of zinc malabsorption, *acrodermatitis* (AK-roh-der-ma-TIE-tis) *enteropathica* (EN-teroh- PATH-ick-ah), causes additional and more severe symptoms.

> **FIGURE 13-11 Iodine-Deficiency Symptom—The Enlarged Thyroid of Goiter**



© Scott Camazine/Photo Researchers, Inc.

In iodine deficiency, the thyroid gland enlarges—a condition known as simple goiter. Iodine toxicity also enlarges the thyroid gland, creating a similar-looking goiter.

♦ Examples of goitrogen-containing foods:
- Cabbage, spinach, radishes, rutabagas
- Soybeans, peanuts
- Peaches, strawberries

♦ For perspective, most foods provide 3 to 75 µg iodine per serving.

iodine: an essential trace mineral that is needed for the synthesis of thyroid hormones.

goiter (GOY-ter): an enlargement of the thyroid gland due to an iodine deficiency, malfunction of the gland, or overconsumption of a goitrogen. Goiter caused by iodine deficiency is sometimes called *simple goiter.*

goitrogen (GOY-troh-jen): a substance that enlarges the thyroid gland and causes *toxic goiter.* Goitrogens occur naturally in such foods as cabbage, kale, brussels sprouts, cauliflower, broccoli, and kohlrabi.

cretinism (CREE-tin-ism): a congenital disease characterized by mental and physical retardation and commonly caused by maternal iodine deficiency during pregnancy.

Iodine

Traces of the **iodine** ion (called iodide) are indispensable to life. In the GI tract, iodine from foods becomes iodide. This chapter uses the term *iodine* when referring to the nutrient in foods and *iodide* when referring to it in the body. Iodide occurs in the body in minuscule amounts, but its principal role in the body and its requirement are well established.

Iodide Roles in the Body

Iodide is an integral part of the thyroid hormones that regulate body temperature, metabolic rate, reproduction, growth, blood cell production, nerve and muscle function, and more.* By controlling the rate at which the cells use oxygen, these hormones influence the amount of energy released during basal metabolism.

Iodine Deficiency

The hypothalamus regulates thyroid hormone production by controlling the release of the pituitary's thyroid-stimulating hormone (TSH).** With iodine deficiency, thyroid hormone production declines, and the body responds by secreting more TSH in a futile attempt to accelerate iodide uptake by the thyroid gland. If a deficiency persists, the cells of the thyroid gland enlarge to trap as much iodide as possible. Sometimes the gland enlarges until it makes a visible lump in the neck, a **goiter** (shown in Figure 13-11).

Goiter afflicts about 200 million people the world over, many of them in South America, Asia, and Africa. In all but 4 percent of these cases, the cause is iodine deficiency. As for the 4 percent (8 million), most have goiter because they regularly eat excessive amounts of foods ♦ that contain an antithyroid substance **(goitrogen)** whose effect is not counteracted by dietary iodine. The goitrogens present in plants remind us that even natural components of foods can cause harm when eaten in excess.

Goiter may be the earliest and most obvious sign of iodine deficiency, but the most tragic and prevalent damage occurs in the brain. Iodine deficiency is the most common cause of *preventable* mental retardation and brain damage in the world. Children with even a mild iodine deficiency typically have goiters and perform poorly in school. With sustained treatment, however, mental performance in the classroom as well as thyroid function improves.[48]

A severe iodine deficiency during pregnancy causes the extreme and irreversible mental and physical retardation known as **cretinism.***** Cretinism affects approximately six million people worldwide and can be averted by the early diagnosis and treatment of maternal iodine deficiency.[49] A worldwide effort to provide iodized salt to people living in iodine-deficient areas has been dramatically successful. An estimated 70 percent of all households in developing countries have access to iodized salt.[50] Because iron deficiency is common among people with iodine deficiency and because iron deficiency reduces the effectiveness of iodized salt, dual fortification with both iron and iodine may be most beneficial.

Iodine Toxicity

Excessive intakes of iodine can interfere with thyroid function and enlarge the gland, just as deficiency can. During pregnancy, exposure to excessive iodine from foods, prenatal supplements, or medications is especially damaging to the developing infant. An infant exposed to toxic amounts of iodine during gestation may develop a goiter so severe as to block the airways and cause suffocation. The UL is 1100 micrograms ♦ per day for an adult—several times higher than average or recommended intakes (review Figure 13-1 on p. 404).

Iodine Recommendations and Sources

The ocean is the world's major source of iodine. In coastal areas, kelp, seafood, water, and even iodine-containing sea mist are dependable iodine sources. Further inland, the amount of iodine in foods is variable and generally reflects the amount present in the soil in which plants are grown or on which animals graze. Landmasses that were once under the ocean

*The thyroid gland releases tetraiodothyronine (T_4), commonly known as *thyroxine* (thigh-ROCKS-in), to its target tissues. Upon reaching the cells, T_4 loses one iodine, becoming triiodothyronine (T_3), which is the active form of the hormone.
**Thyroid-stimulating hormone is also called *thyrotropin.*
***The underactivity of the thyroid gland is known as *hypothyroidism* and may be caused by iodine deficiency or any number of other causes. Without treatment, an infant with *congenital hypothyroidism* will develop the physical and mental retardation of *cretinism.*

have soils rich in iodine; those in flood-prone areas where water leaches iodine from the soil are poor in iodine. In the United States and Canada, the iodization of salt ♦ has eliminated the widespread misery caused by iodine deficiency during the 1930s, but iodized salt is not available in many parts of the world. Some countries add iodine to bread, fish paste, or drinking water instead. Families who do not use iodized foods have a higher prevalence of child malnutrition and mortality.[51]

♦ Iodized salt contains about 60 µg iodine per gram salt.

Although average consumption of iodine in the United States exceeds recommendations, it falls below toxic levels. Some of the excess iodine in the US diet stems from fast foods, which use iodized salt liberally. Some iodine comes from bakery products and from milk. The baking industry uses iodates (iodine salts) as dough conditioners, and most dairies feed cows iodine-containing medications and use iodine to disinfect milking equipment. Now that these sources have been identified, food industries have reduced their use of these compounds, but the sudden emergence of this problem points to a need for continued surveillance of the food supply. Processed foods in the United States use regular salt, not iodized salt.

The recommended intake of iodine for adults is a minuscule amount. The need for iodine is easily met by consuming seafood, vegetables grown in iodine-rich soil, and iodized salt. ♦ In the United States, labels indicate whether salt is iodized; in Canada, all table salt is iodized.

♦ On average, ½ tsp iodized salt provides the RDA for iodine.

REVIEW IT

Iodide, the ion of the mineral iodine, is an essential component of the thyroid hormones. An iodine deficiency can lead to simple goiter (enlargement of the thyroid gland) and can impair fetal development, causing cretinism. Iodization of salt has largely eliminated iodine deficiency in the United States and Canada. The accompanying table provides a summary of iodine.

Iodine

RDA	**Deficiency Disease**
Adults: 150 µg/day	Simple goiter, cretinism
Upper Level	**Deficiency Symptoms**
1100 µg/day	Underactive thyroid gland, goiter, mental and physical retardation in infants (cretinism)
Chief Functions in the Body	**Toxicity Symptoms**
A component of two thyroid hormones that help to regulate growth, development, and metabolic rate	Underactive thyroid gland, elevated TSH, goiter
Significant Sources	
Iodized salt, seafood, bread, dairy products, plants grown in iodine-rich soil and animals fed those plants	



© Craig M. Moore

Only "iodized salt" has had iodine added.

Selenium The essential mineral **selenium** shares some of the chemical characteristics of the mineral sulfur. This similarity allows selenium to substitute for sulfur in the amino acids methionine, cysteine, and cystine.

Selenium Roles in the Body Selenium is one of the body's antioxidant nutrients, ♦ working primarily as a part of proteins—most notably, the enzyme glutathione peroxidase.[52] Glutathione peroxidase and vitamin E work in tandem. Glutathione peroxidase prevents free-radical formation, thus blocking the chain reaction before it begins; if free radicals do form and a chain reaction starts, vitamin E stops it. (Highlight 11 describes free-radical formation, chain reactions, and antioxidant action in detail.) Other selenium-containing enzymes selectively activate or inactivate the thyroid hormones.[53]

♦ Key antioxidant nutrients:
- Vitamin C, vitamin E, beta-carotene
- Selenium

Selenium Deficiency Selenium deficiency is associated with **Keshan disease**—a heart disease that is prevalent in regions of China where the soil and foods lack selenium.[54] Although the primary cause of this heart disease is probably a virus or toxin, selenium deficiency appears to predispose people to it, and adequate selenium seems to prevent it.[55]

selenium (se-LEEN-ee-um): an essential trace mineral that is part of an antioxidant enzyme.

Keshan (KESH-an or ka-SHAWN) **disease:** the heart disease associated with selenium deficiency; named for one of the provinces of China where it was first studied. Keshan disease is characterized by heart enlargement and insufficiency; fibrous tissue replaces the muscle tissue that normally composes the middle layer of the walls of the heart.

Selenium and Cancer Limited research suggests that the antioxidant action of selenium may protect against some types of cancers.[56] Selenium supplements, however, have not proved effective in preventing cancer and may in fact damage DNA and cause harm.[57]

Selenium Recommendations and Sources Selenium is found in the soil, and therefore in the crops grown for consumption. People living in regions with selenium-poor soil may still get enough selenium, partly because they eat vegetables and grains transported from other regions and partly because they eat meats, milk, and eggs, which are reliable sources of selenium. Eating as few as two Brazil nuts a day effectively improves selenium status.[58] Average intakes in the United States and Canada exceed the RDA, which is based on the amount needed to maximize glutathione peroxidase activity.

Selenium Toxicity Because high doses of selenium are toxic, a UL has been set. Selenium toxicity causes loss and brittleness of hair and nails, garlic breath odor, and nervous system abnormalities.

REVIEW IT

Selenium is an antioxidant nutrient that works closely with the glutathione peroxidase enzyme and vitamin E. Selenium is found in association with protein in foods. Deficiencies are associated with a predisposition to a type of heart abnormality known as Keshan disease. The accompanying table provides a summary of selenium.

Selenium

RDA	Deficiency Symptoms
Adults: 55 µg/day	Predisposition to heart disease characterized by cardiac tissue becoming fibrous (Keshan disease)
Upper Level	**Toxicity Symptoms**
Adults: 400 µg/day	Loss and brittleness of hair and nails; skin rash, fatigue, irritability, and nervous system disorders; garlic breath odor
Chief Functions in the Body	
Defends against oxidation; regulates thyroid hormone	
Significant Sources	
Seafood, meat, whole grains, fruits, and vegetables (depending on soil content)	

Copper The body contains about 100 milligrams of **copper** in a variety of cells and tissues. Copper balance and transport depend on a system of proteins.[59]

Copper Roles in the Body Copper serves as a constituent of several enzymes. The copper-containing enzymes have diverse metabolic roles with one common characteristic: all involve reactions that consume oxygen or oxygen radicals. For example, copper-containing enzymes catalyze the oxidation of ferrous iron to ferric iron, which allows iron to bind to transferrin. Copper's role in iron metabolism makes it a key factor in hemoglobin synthesis. Copper- and zinc-containing enzymes participate in the body's natural defenses against the oxidative damage of free radicals. Still other copper enzymes help to manufacture collagen, inactivate histamine, and degrade serotonin. Copper, like iron, is needed in many of the metabolic reactions involved in the release of energy.

Copper Deficiency and Toxicity Typical US diets provide adequate amounts of copper and deficiency is rare. In animals, copper deficiency raises blood cholesterol and damages blood vessels, raising questions about whether low dietary copper might contribute to cardiovascular disease in humans.

Some genetic disorders create a copper toxicity, but excessive intakes from foods are unlikely. Excessive intakes from supplements may cause liver damage, and therefore a UL has been set.

Two rare genetic disorders affect copper status in opposite directions.[60] In **Menkes disease**, the intestinal cells absorb copper, but cannot release it into

copper: an essential trace mineral that is part of many enzymes.

Menkes disease: a genetic disorder of copper transport that creates a copper deficiency and results in mental retardation, poor muscle tone, seizures, brittle kinky hair, and failure to thrive.

circulation, causing a life-threatening deficiency. Treatment involves giving copper intravenously. In **Wilson's disease**, copper accumulates in the liver and brain, creating a life-threatening toxicity. Wilson's disease can be controlled by reducing copper intake, using chelating agents such as penicillamine, and taking zinc supplements, which interfere with copper absorption.

Copper Recommendations and Sources The richest food sources of copper are legumes, whole grains, nuts, shellfish, and seeds. More than half of the copper from foods is absorbed, and the major route of elimination appears to be bile. Water may also provide copper, depending on the type of plumbing pipe and the hardness of the water.

REVIEW IT

Copper is a component of several enzymes, all of which are involved in some way with oxygen or oxidation. Some act as antioxidants; others are essential to iron metabolism. Legumes, whole grains, and shellfish are good sources of copper. The accompanying table provides a summary of copper.

Copper

RDA	Significant Sources
Adults: 900 µg/day	Seafood, nuts, whole grains, seeds, legumes
Upper Level	**Deficiency Symptoms**
Adults: 10,000 µg/day (10 mg/day)	Anemia, bone abnormalities
Chief Functions in the Body	**Toxicity Symptoms**
Necessary for the absorption and use of iron in the formation of hemoglobin; part of several enzymes	Liver damage

Manganese

The human body contains a mere 20 milligrams of **manganese**. Most of it can be found in the bones and metabolically active organs such as the liver, kidneys, and pancreas.

Manganese Roles in the Body Manganese acts as a cofactor for many enzymes that facilitate the metabolism of carbohydrate, lipids, and amino acids. In addition, manganese-containing metalloenzymes assist in bone formation and the conversion of pyruvate to a TCA cycle compound.

Manganese Deficiency and Toxicity Manganese requirements are low, and many plant foods contain significant amounts of this trace mineral, so deficiencies are rare. As is true of other trace minerals, however, dietary factors such as phytates inhibit its absorption. In addition, high intakes of iron and calcium limit manganese absorption, so people who use supplements of those minerals regularly may impair their manganese status.

Toxicity is more likely to occur from an environment contaminated with manganese than from dietary intake. Miners who inhale large quantities of manganese dust on the job over prolonged periods show symptoms of a brain disease, along with abnormalities in appearance and behavior. Still, a UL has been established based on intakes from food, water, and supplements.

Manganese Recommendations and Sources Grain products make the greatest contribution of manganese to the diet. With insufficient information to establish an RDA, an AI was set based on average intakes.

REVIEW IT

Manganese-dependent enzymes are involved in bone formation and various metabolic processes. Because manganese is widespread in plant foods, deficiencies are rare, although regular use of calcium and iron supplements may limit manganese absorption. The table on p. 422 provides a summary of manganese.

Wilson's disease: a genetic disorder of copper metabolism that creates a copper toxicity and results in neurologic symptoms such as tremors, impaired speech, inappropriate behaviors, and personality changes.

manganese: an essential trace mineral that acts as a cofactor for many enzymes.

REVIEW IT *(continued)*

Manganese

AI	Significant Sources
Men: 2.3 mg/day Women: 1.8 mg/day	Nuts, whole grains, leafy vegetables, tea
Upper Level	**Deficiency Symptoms**
Adults: 11 mg/day	Rare
Chief Functions in the Body	**Toxicity Symptoms**
Cofactor for several enzymes; bone formation	Nervous system disorders

Fluoride Fluoride is present in virtually all soils, water supplies, plants, and animals. The body contains only a trace of fluoride, but with this amount, the crystalline deposits in teeth are larger and more perfectly formed.

♦ Key bone nutrients:
- Vitamin D, vitamin K, vitamin A
- Calcium, phosphorus, magnesium, fluoride

Fluoride Roles in the Body As Chapter 12 explains, during the mineralization of bones ♦ and teeth, calcium and phosphorus form crystals called hydroxyapatite. Then fluoride replaces the hydroxyl (OH) portions of the hydroxyapatite crystal, forming **fluorapatite,** which makes the teeth stronger and more resistant to decay.

Dental caries ranks as the nation's most widespread health problem: an estimated 95 percent of the population have decayed, missing, or filled teeth. These dental problems can quickly lead to a multitude of nutrition problems by interfering with a person's ability to chew and eat a wide variety of foods. Where fluoride is lacking, dental decay is common.

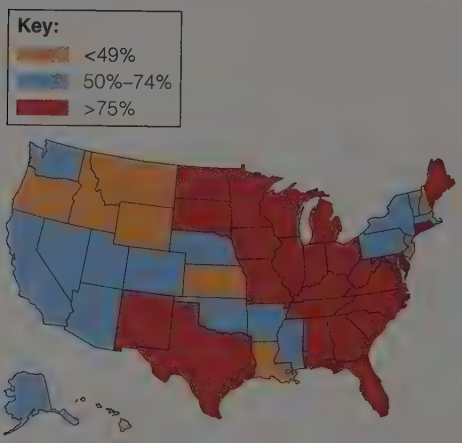
Drinking water is usually the best source of fluoride, and most of the US population served by public water systems receives optimal levels of fluoride (see Figure 13-12).[61] Fluoridation of drinking water (to raise the concentration to one part fluoride per one million parts water) offers the greatest protection against dental caries at virtually no risk of toxicity.[62] By fluoridating the drinking water, a community offers its residents, particularly the children, a safe, economical, practical, and effective way to defend against dental caries. Most bottled waters lack fluoride.

♦ To prevent fluorosis:
- Monitor the fluoride content of the local water supply.
- Supervise toddlers when they brush their teeth—using only a little toothpaste (pea-size amount).
- Use fluoride supplements only as prescribed by a physician.

Fluoride Toxicity Too much fluoride can damage the teeth, causing **fluorosis.**[63] For this reason, a UL has been established. In mild cases, the teeth develop small white flecks; in severe cases, the enamel becomes pitted and permanently stained (as shown in Figure 13-13). Fluorosis occurs only during tooth development and cannot be reversed, making its prevention ♦ a high priority. To limit fluoride ingestion, take care not to swallow fluoride-containing dental products such as toothpaste and mouthwash.

Fluoride Recommendations and Sources As mentioned earlier, much of the US population has access to water with an optimal fluoride concentration, which typically delivers about 1 milligram per person per day. Fish and most teas contain appreciable amounts of natural fluoride.

> **FIGURE 13-12 US Population with Access to Fluoridated Water through Public Water Systems**



fluoride: an essential trace mineral that makes teeth stronger and more resistant to decay.

fluorapatite (floor-APP-uh-tite): the stabilized form of bone and tooth crystal, in which fluoride has replaced the hydroxyl groups of hydroxyapatite.

fluorosis (floor-OH-sis): discoloration and pitting of tooth enamel caused by excess fluoride during tooth development.

REVIEW IT

Fluoride makes teeth stronger and more resistant to decay. Fluoridation of public water supplies can significantly reduce the incidence of dental caries, but excess fluoride during tooth development can cause fluorosis—discolored and pitted tooth enamel. The accompanying table provides a summary of fluoride.

Fluoride

AI	Significant Sources
Men: 4 mg/day Women: 3 mg/day	Drinking water (if fluoride containing or fluoridated), tea, seafood
Upper Level	**Deficiency Symptoms**
Adults: 10 mg/day	Susceptibility to tooth decay
Chief Functions in the Body	**Toxicity Symptoms**
Strengthens teeth; helps to make teeth resistant to decay	Fluorosis (pitting and discoloration of teeth)

Chromium Chromium is an essential mineral that participates in carbohydrate and lipid metabolism. Like iron, chromium assumes different charges. In chromium, the Cr^{+++} ion is the most stable and most commonly found in foods.

Chromium Roles in the Body Chromium helps maintain glucose homeostasis by enhancing the activity of the hormone insulin.* When chromium is lacking, a diabetes-like condition may develop with elevated blood glucose and impaired glucose tolerance, insulin response, and glucagon response. Some research suggests that chromium supplements lower blood glucose or improve insulin responses in type 2 diabetes, but findings have not been consistent.[64]

Chromium Recommendations and Sources Chromium is present in a variety of foods. The best sources are unrefined foods, particularly liver, brewer's yeast, and whole grains. The more refined foods people eat, the less chromium they ingest.

Chromium Supplements Supplement advertisements have succeeded in convincing consumers that they can lose fat and build muscle by taking chromium picolinate. Whether chromium supplements (either picolinate or plain) reduce body fat or improve muscle strength remains controversial. (Highlight 14 discusses chromium picolinate and other supplements athletes use in the hopes of improving their performance.)

REVIEW IT

Chromium enhances insulin's action. A deficiency can impair glucose homeostasis. Chromium is widely available in unrefined foods including brewer's yeast, whole grains, and liver. The accompanying table provides a summary of chromium.

Chromium

AI	Significant Sources
Men: 35 µg/day	Meats (especially liver), whole grains, brewer's yeast
Women: 25 µg/day	**Deficiency Symptoms**
Chief Functions in the Body	Diabetes-like condition
Enhances insulin action and may improve glucose tolerance	**Toxicity Symptoms**
	None reported

Molybdenum Molybdenum acts as a working part of several metalloenzymes. Dietary deficiencies of molybdenum are unknown because the amounts needed are minuscule—as little as 0.1 part per million parts of body tissue. Legumes, breads and other grain products, leafy green vegetables, milk, and liver are molybdenum-rich foods. Average daily intakes fall within the suggested range of intakes.

Molybdenum toxicity in people is rare. It has been reported in animal studies, and a UL has been established. Characteristics of molybdenum toxicity include kidney damage and reproductive abnormalities.

REVIEW IT

Molybdenum is found in a variety of foods and participates in several metabolic reactions. The table on p. 424 provides a summary of molybdenum.

*Small organic compounds that enhance insulin's actions are called *glucose tolerance factors (GTF)*. Some glucose tolerance factors contain chromium.v

> **FIGURE 13-13** Fluoride-Toxicity Symptom—The Mottled Teeth of Fluorosis



© Dr. P. Marazzi/Science Photo Library/ Photo Researchers, Inc.

chromium (KRO-mee-um): an essential trace mineral that enhances the activity of insulin.

molybdenum (mo LIB duh-num): an essential trace mineral that acts as a cofactor for many enzymes.

Molybdenum

RDA	Significant Sources
Adult: 45 µg/day	Legumes, cereals, nuts
Upper Level	**Deficiency Symptoms**
Adults: 2 mg/day	Unknown
Chief Functions in the Body	**Toxicity Symptoms**
Cofactor for several enzymes	None reported; reproductive effects in animals

13.3 Contaminant Minerals

LEARN IT Describe how contaminant minerals disrupt body processes and impair nutrition status.

Chapter 12 and this chapter explain the many ways minerals serve the body—maintaining fluid and electrolyte balance, providing structural support to the bones, transporting oxygen, and assisting enzymes. In contrast to the essential minerals that the body requires, contaminant minerals impair the body's growth, work capacity, and general health. Contaminant minerals include the **heavy metals** lead, mercury, and cadmium, which enter the food supply by way of soil, water, and air pollution. This section focuses on lead poisoning because it is a serious environmental threat to young children and because reducing blood lead levels in children is a goal of the Healthy People initiative. Much of the information on lead applies to the other contaminant minerals as well—they all disrupt body processes and impair nutrition status similarly.

Like other minerals, lead is indestructible; the body cannot change its chemistry. Chemically similar to nutrient minerals such as iron, calcium, and zinc (cations with two positive charges), lead displaces them from some of the metabolic sites they normally occupy so they are then unable to perform their roles. For example, lead competes with iron in heme, but it cannot carry oxygen. Similarly, lead competes with calcium in the brain, but it cannot signal messages from nerve cells. Excess lead in the blood also deranges the structure of red blood cell membranes, making them leaky and fragile. Lead interacts with white blood cells, too, impairing their ability to fight infection, and it binds to antibodies, thwarting their effort to resist disease.

Children with iron deficiency are particularly vulnerable to lead toxicity.[65] Chapter 16 examines the damaging effects of iron deficiency and lead toxicity on a child's growth and development.[66]

REVIEW IT Describe how contaminant minerals disrupt body processes and impair nutrition status.

Lead typifies the ways all heavy metals behave in the body: they interfere with nutrients that are trying to do their jobs. The "good guy" nutrients are shoved aside by the "bad guy" contaminants. Then, when the contaminants cannot perform the roles of the nutrients, health diminishes. To safeguard our health, we must defend ourselves against contamination by eating nutrient-rich foods and preserving a clean environment.

This chapter completes the introductory lessons on the nutrients. Each nutrient from the amino acids to zinc has been described rather thoroughly—its chemistry, roles in the body, sources in the diet, symptoms of deficiency and toxicity, and influences on health and disease. Such a detailed examination is informative, but it can also be misleading. It is important to step back from the detailed study of the individual nutrients to look at them as a whole. After all, people eat foods, not nutrients, and most foods deliver dozens of nutrients. Furthermore, nutrients work cooperatively with one another in the body; their actions are most often *inter*actions. This chapter alone mentioned how iron depends on vitamin C to keep it in its active form and copper to incorporate it into hemoglobin, how zinc is needed to activate and transport vitamin A, and how both iodine and selenium are needed for the synthesis of thyroid hormone. The accompanying table provides a summary of the trace minerals for your review. Highlight 13 explores the benefits of phytochemicals.

heavy metals: mineral ions such as mercury and lead, so called because they are of relatively high atomic weight. Many heavy metals are poisonous.

REVIEW IT The Trace Minerals

Mineral and Chief Functions	Deficiency Symptoms	Toxicity Symptoms[a]	Significant Sources
Iron Part of the protein hemoglobin, which carries oxygen in the blood; part of the protein myoglobin in muscles, which makes oxygen available for muscle contraction; necessary for energy metabolism	Anemia: weakness, fatigue, headaches; impaired work performance; impaired immunity; pale skin, nail beds, mucous membranes, and palm creases; concave nails; inability to regulate body temperature; pica	GI distress; iron overload: infections, fatigue, joint pain, skin pigmentation, organ damage	Red meats, fish, poultry, shellfish, eggs, legumes, dried fruits
Zinc Part of insulin and many enzymes; involved in making genetic material and proteins, immune reactions, transport of vitamin A, taste perception, wound healing, the making of sperm, and normal fetal development	Growth retardation, delayed sexual maturation, impaired immune function, hair loss, eye and skin lesions, loss of appetite	Loss of appetite, impaired immunity, low HDL, copper and iron deficiencies	Protein-containing foods: red meats, fish, shellfish, poultry, whole grains; fortified cereals
Iodine A component of the thyroid hormones that help to regulate growth, development, and metabolic rate	Underactive thyroid gland, goiter, mental and physical retardation (cretinism)	Underactive thyroid gland, elevated TSH, goiter	Iodized salt; seafood; plants grown in iodine-rich soil and animals fed those plants
Selenium Part of an enzyme that defends against oxidation; regulates thyroid hormone	Associated with Keshan disease	Nail and hair brittleness and loss; fatigue, irritability, and nervous system disorders, skin rash, garlic breath odor	Seafoods, organ meats; other meats, whole grains, fruits, and vegetables (depending on soil content)
Copper Helps form hemoglobin; part of several enzymes	Anemia, bone abnormalities	Liver damage	Seafood, nuts, legumes, whole grains, seeds
Manganese Cofactor for several enzymes; bone formation	Rare	Nervous symptom disorders	Nuts, whole grains, leafy vegetables, tea
Fluoride Maintains health of bones and teeth; confers decay resistance on teeth	Susceptibility to tooth decay	Fluorosis (pitting and discoloration) of teeth	Drinking water (if fluoridated), tea, seafood
Chromium Enhances insulin action, may improve glucose intolerance	Diabetes-like condition	None reported	Meats (liver), whole grains, brewer's yeast
Molybdenum Cofactor for several enzymes	Unknown	None reported	Legumes, cereals, nuts

[a]Acute toxicities of many minerals cause abdominal pain, nausea, vomiting, and diarrhea.

Nutrition Portfolio

Trace minerals from a variety of foods, especially those in the protein foods group, support many of your body's activities. Go to Diet Analysis Plus and choose one of the days on which you tracked your diet for an entire day. Select the Intake vs. Goals report and then consider the following questions. Remember that scoring 100 percent on this report means you met your goal.

- Your Intake vs. Goals report may only display your intake for two of the trace minerals: iron and zinc. How was your intake for these two trace minerals?

Now look at the Intake Spreadsheet report and consider the following questions:

- Examine the variety in your food intake, taking particular notice of how often you include meats, seafood, poultry, legumes, and enriched or fortified grain products weekly. These foods often contain trace minerals.

- Describe the advantages of using iodized salt.
- Determine whether your community provides fluoridated water.

Diet Analysis PLUS To complete this exercise, go to your Diet Analysis Plus at **www.cengagebrain.com.**

STUDY IT To review the key points of this chapter and take a practice quiz, go to the study cards at the end of the book.

REFERENCES

1. L. H. Allen, Limitations of current indicators of micronutrient status, *Nutrition Reviews* 67 (2009): S21–S23.
2. F. H. Nielsen, Is boron nutritionally relevant? *Nutrition Reviews* 66 (2008): 183–191.
3. M. S. Tallman, What is the role of arsenic in newly diagnosed APL? *Best Practice and Research Clinical Haematology* 21 (2008): 659–666.
4. M. Muñoz, J. A. García-Erce, and A. F. Remacha, Disorders of iron metabolism. Part 1: Molecular basis of iron homeostasis, *Journal of Clinical Pathology* 64 (2011): 281–286; M. D. Knutson, Iron-sensing proteins that regulate hepcidin and enteric iron absorption, *Annual Review of Nutrition* 30 (2010): 149–171.
5. P. A. Sharp, Intestinal iron absorption: Regulation by dietary & systematic factors, *International Journal for Vitamin and Nutrition Research* 80 (2010): 231–242; Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc* (Washington, D.C.: National Academies Press, 2001), p. 315.
6. P. Thankachan and coauthors, Iron absorption in young Indian women: The interaction of iron status with the influence of tea and ascorbic acid, *American Journal of Clinical Nutrition* 87 (2008): 881–886.
7. Committee on Dietary Reference Intakes, 2001, p. 351.
8. J. R. Hunt, C. A. Zito, and L. K. Johnson, Body iron excretion by healthy men and women, *American Journal of Clinical Nutrition* 89 (2009): 1792–1798.
9. T. Ganz and E. Nemeth, Hepcidin and disorders of iron metabolism, *Annual Review of Medicine* 62 (2011): 347–360; M. Wessling-Resnick, Iron homeostasis and the inflammatory response, *Annual Review of Nutrition* 30 (2010): 105–122; D. M. Frazer and G. J. Anderson, Hepcidin compared with prohepcidin: An absorbing story, *American Journal of Clinical Nutrition* 89 (2009): 475–476; M. D. Knutson, Into the matrix: Regulation of the iron regulatory hormone hepcidin by matriptase-2, *Nutrition Reviews* 67 (2009): 284–288; M. A. Roe and coauthors, Plasma hepcidin concentrations significantly predict interindividual variation in iron absorption in healthy men, *American Journal of Clinical Nutrition* 89 (2009): 1088–1091; M. F. Young and coauthors, Serum hepcidin is significantly associated with iron absorption from food and supplemental sources in healthy young women, *American Journal of Clinical Nutrition* 89 (2009): 533–538; M. U. Muckenthaler, B. Galy, and M. W. Hentze, Systemic iron homeostasis and the iron-responsive element/iron-regulatory protein (IRE/IRP) regulatory network, *Annual Review of Nutrition* 28 (2008): 197–213.
10. T. Ganz, Hepcidin and iron regulation: 10 years later, *Blood* 117 (2011): 4425–4433; J. Kaplan, D. M. Ward, and I. De Domenico, The molecular basis of iron overload disorders and iron-linked anemias, *International Journal of Hematology* 93 (2011): 14–20; A. Pietrangelo, Hereditary hemochromatosis: Pathogenesis, diagnosis, and treatment, *Gastroenterology* 139 (2010): 393–408; B. Borch-Iohnsen and coauthors, Regulation of the iron metabolism, *Journal of the Norwegian Medical Association* 129 (2009): 858–862.
11. S. R. Lynch, Why nutritional iron deficiency persists as a worldwide problem, *Journal of Nutrition* 141 (2011): 763S–768S; Worldwide prevalence of anaemia 1993–2005: WHO Global Database on Anaemia, 2008, **www.who.org.**
12. L. M. Tussing-Humphreys and coauthors, Excess adiposity, inflammation, and iron-deficiency in female adolescents, *Journal of the American Dietetic Association* 109 (2009): 297–302.
13. A. C. Cepeda-Lopez and coauthors, Sharply higher rates of iron deficiency in obese Mexican women and children are predicted by obesity-related inflammation rather than by differences in dietary iron intake, *American Journal of Clinical Nutrition* 93 (2011): 975–983; J. P. McClung and J. P. Karl, Iron deficiency and obesity: The contribution of inflammation and diminished iron absorption, *Nutrition Reviews* 67 (2008): 100–104.
14. E. M. del Giudice and coauthors, Hepcidin in obese children as a potential mediator of the association between obesity and iron deficiency, *Journal of Endocrinology and Metabolism* 94 (2009): 5102–5107.
15. N. Milman, Anemia: Still a major health problem in many parts of the world, *Annals of Hematology* 90 (2011): 369–377.
16. J. L. Beard, Why iron deficiency is important in infant development, *Journal of Nutrition* 138 (2008): 2534–2536.
17. Z. Yang and coauthors, Comparison of plasma ferritin concentration with the ratio of plasma transferrin receptor to ferritin in estimating body iron stores: Results of 4 intervention trials, *American Journal of Clinical Nutrition* 87 (2008): 1892–1898.
18. D. I. Thurnham and coauthors, Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: A meta-analysis, *American Journal of Clinical Nutrition* 92 (2010): 546–555; M. A. Ayoya and coauthors, α_1-Acid glycoprotein, hepcidin, C-reactive protein, and serum ferritin are correlated in anemic schoolchildren with *Schistosoma haematobium*, *American Journal of Clinical Nutrition* 91 (2010): 1784–1790.
19. L. E. Murray-Kolb, Iron status and neuropsychological consequences in women of reproductive age: What do we know and where are we headed? *Journal of Nutrition* 141 (2011): 747S–755S; K. Kordas, Iron, lead, and children's behavior and cognition, *Annual Review of Nutrition* 30 (2010): 123–148.
20. B. Lozoff, Early iron deficiency has brain and behavior effects consistent with dopaminergic dysfunction, *Journal of Nutrition* 141 (2011): 740S–746S.
21. J. P. McClung and coauthors, Randomized, double-blind, placebo-controlled trial of iron supplementation in female soldiers during military training: Effects on iron status, physical performance, and mood, *American Journal of Clinical Nutrition* 90 (2009): 124–131; L. E. Murray-Kolb and J. L. Beard, Iron treatment normalizes cognitive functioning in young women, *American Journal of Clinical Nutrition* 85 (2007): 778–787.
22. S. L. Young, Pica in pregnancy: New ideas about an old condition, *Annual Review of Nutrition* 30 (2010): 403–422.
23. P. Brissot and coauthors, Molecular diagnosis of genetic iron-overload disorders, *Expert Review of Molecular Diagnostics* 10 (2010): 755–763.
24. C. Camaschella and E. Poggiali, Inherited disorders of iron metabolism, *Current Opinion in Pediatrics* 23 (2011): 14–20.
25. O. K. Fix and K. V. Kowdley, Hereditary hemochromatosis, *Minerva Medica* 99 (2008): 605–617.
26. G. A. Ramm and R. G. Ruddell, Iron homeostasis, hepatocellular injury, and fibrogenesis in hemochromatosis: The role of inflammation in a non-inflammatory liver disease, *Seminars in Liver Disease* 30 (2010): 271–287; S. Lekawanvijit and N. Chattipakorn, Iron overload thalassemic cardiomyopathy: Iron status assessment and mechanisms of mechanical and electrical disturbance due to iron toxicity, *Canadian Journal of Cardiology* 25 (2009): 213–218.
27. H. Drakesmith and A. Prentice, Viral infection and iron metabolism, *Nature Reviews. Microbiology* 6 (2008): 541–552; A. M. Prentice, Iron

metabolism, malaria, and other infections: What is all the fuss about? *Journal of Nutrition* 138 (2008): 2537–2541.
28. Q. Liu and coauthors, Role of iron deficiency and overload in the pathogenesis of diabetes and diabetic complications, *Current Medicinal Chemistry* 16 (2009): 113–129.
29. G. M. Brittenham, Iron-chelating therapy for transfusional iron overload, *New England Journal of Medicine* 364 (2011): 146–156; F. Dreyfus, The deleterious effects of iron overload in patients with myelodysplastic syndromes, *Blood Reviews* 22 (2008): S29–S34.
30. K. J. Allen and coauthors, Iron-overload: Related disease in *HFE* hereditary hemochromatosis, *New England Journal of Medicine* 358 (2008): 221–230.
31. N. Ahluwalia and coauthors, Iron status is associated with carotid atherosclerotic plaques in middle-aged adults, *Journal of Nutrition* 140 (2010): 812–816.
32. A. C. Bronstein and coauthors, 2009 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 27th Annual Report, *Clinical Toxicology* 28 (2010): 979–1178.
33. Committee on Dietary Reference Intakes, 2001, p. 351.
34. M. Alleyne, M. K. Horne, and J. L. Miller, Individualized treatment for iron-deficiency anemia in adults, *American Journal of Medicine* 121 (2008): 943–948.
35. Y. Song and coauthors, Dietary zinc restriction and repletion affects DNA integrity in healthy men, *American Journal of Clinical Nutrition* 90 (2009): 321–328.
36. H. Haase and L. Rink, Functional significance of zinc-related signaling pathways in immune cells, *Annual Review of Nutrition* 29 (2009): 133–152.
37. J. R. Hunt, Algorithms for iron and zinc bioavailability: Are they accurate? *International Journal of Vitamin and Nutrition Research* 80 (2010): 257–262; J. C. King, Does zinc absorption reflect zinc status? *International Journal of Vitamin and Nutrition Research* 80 (2010): 300–306.
38. K. M. Hambidge and coauthors, Zinc bioavailability and homeostasis, *American Journal of Clinical Nutrition* 91 (2010): 1478S–1483S; J. R. Hunt, J. M. Beiseigel, and L. K. Johnson, Adaptation in human zinc absorption as influenced by dietary zinc and bioavailability, *American Journal of Clinical Nutrition* 87 (2008): 1336–1345.
39. S. G. Bell and B. L. Vallee, The metallothionein/thionein system: An oxidoreductive metabolic zinc link, *European Journal of Chemical Biology* 10 (2009): 55–62.
40. L. A. Lichten and R. J. Cousins, Mammalian zinc transporters: Nutritional and physiologic regulation, *Annual Review of Nutrition* 29 (2009): 153–176.
41. C.L.F. Walker, M. Ezzati, and R. E. Black, Global and regional child mortality and burden of disease attributable to zinc deficiency, *European Journal of Clinical Nutrition* 63 (2009): 591–597.
42. C. R. Cole and F. Lifshitz, Zinc nutrition and growth retardation, *Pediatric Endocrinology Reviews* 5 (2008): 889–896.
43. J. B. Barnett, D. H. Hamer, and S. N. Meydani, Low zinc status: A new risk factor for pneumonia in the elderly? *Nutrition Reviews* 68 (2010): 30–37.
44. D. E. Roth and coauthors, Acute lower respiratory infections in childhood: Opportunities for reducing the global burden through nutritional interventions, *Bulletin of the World Health Organization* 86 (2008): 321–416.
45. Walker, Ezzati, and Black, 2009; M. Lukacik, R. L. Thomas, and J. V. Aranda, A meta-analysis of the effects of oral zinc in the treatment of acute and persistent diarrhea, *Pediatrics* 121 (2008): 326–336; S. E. Wuehler, F. Sempértegui, and K. H. Brown, Dose-response trial of prophylactic zinc supplements, with or without copper, in young Ecuadorian children at risk of zinc deficiency, *American Journal of Clinical Nutrition* 87 (2008): 723–733.
46. Barnett, Hamer, and Meydani, 2010.
47. T. J. Caruso, C. G. Prober, and J. M. Gwaltney, Jr., Treatment of naturally acquired common colds with zinc: A structured review, *Clinical Infectious Disease* 45 (2007): 569–574.
48. R. C. Gordon and coauthors, Iodine supplementation improves cognition in mildly iodine-deficient children, *American Journal of Clinical Nutrition* 90 (2009): 1264–1271.
49. M. B. Zimmerman, Iodine deficiency in pregnancy and the effects of maternal iodine supplementation on the offspring: A review, *American Journal of Clinical Nutrition* 89 (2009): 668S–672S.
50. GAIN-UNICEF Universal Salt Iodization Partnership Program, 2011, **www.gainhealth.gov/programs/usi.**
51. R. D. Semba and coauthors, Child malnutrition and mortality among families not utilizing adequately iodized salt in Indonesia, *American Journal of Clinical Nutrition* 87 (2008): 438–444.
52. F. P. Bellinger and coauthors, Regulation and function of selenoproteins in human disease, *Biochemical Journal* 422 (2009): 11–22.
53. D. L. St. Germain, V. A. Galton, and A. Hernandez, Minireview: Defining the roles of the iodothyronine deiodinases: Current concepts and challenges, *Endocrinology* 150 (2009): 1097–1107.
54. C. Lei and coauthors, Is selenium deficiency really the cause of Keshan disease? *Environmental Geochemistry and Health* 33 (2011): 183–188; J. Yang and coauthors, Selenium level surveillance for the year 2007 of Keshan disease in endemic areas and analysis on surveillance results between 2003 and 2007, *Biological Trace Element Research* 138 (2010): 53–59.
55. S. Sun, Chronic exposure to cereal mycotoxin likely citreoviridin may be a trigger for Keshan disease mainly through oxidative stress mechanism, *Medical Hypotheses* 74 (2010): 841–842.
56. G. Dennert and coauthors, Selenium for preventing cancer, *Cochrane Database of Systematic Reviews* 5 (2011): CD005195; S. J. Fairweather-Tait and coauthors, Selenium in human health and disease, *Antioxidants and Redox Signaling* 14 (2011): 1337–1383.
57. B. K. Dunn and coauthors, A nutrient approach to prostate cancer prevention: The Selenium and Vitamin E Cancer Prevention Trial (SELECT), *Nutrition and Cancer* 62 (2010): 896–918; J. Brozmanová and coauthors, Selenium: A double-edged sword for defense and offence in cancer, *Archives of Toxicology* 84 (2010): 919–938.
58. C. D. Thomson and coauthors, Brazil nuts: An effective way to improve selenium status, *American Journal of Clinical Nutrition* 87 (2008): 379–384.
59. J. R. Prohaska, Role of copper transporters in copper homeostasis, *American Journal of Clinical Nutrition* 88 (2008): 826S–829S.
60. D. L. de Romaña and coauthors, Risks and benefits of copper in light of new insights of copper homeostasis, *Journal of Trace Elements in Medicine and Biology* 25 (2011): 3–13.
61. 2008 Water Fluoridation Statistics, **www.cdc.gov/fluoridation/statistics/2008stats.htm**, updated October 22, 2010.
62. Position of the American Dietetic Association: The impact of fluoride on health, *Journal of the American Dietetic Association* 105 (2005): 1620–1628.
63. E. D. Beltrán-Aguilar, L. Barker, and B. A. Dye, Prevalence and severity of dental fluorosis in the United States, *NCHS Data Brief* 53 (2010): 1–8.
64. F. C. Lau and coauthors, Nutrigenomic basis of beneficial effects of chromium (III) on obesity and diabetes, *Molecular and Cellular Biochemistry* 317 (2008): 1–10; Z. Q. Wang and W. T. Cefalu, Current concepts about chromium supplementation in type 2 diabetes and insulin resistance, *Current Diabetes Reports* 10 (2010): 145–151; H. E. Bartlett and F. Eperjesi, Nutritional supplements for type 2 diabetes: A systematic review, *Ophthalmic & Physiological Optics* 28 (2008): 503–523.
65. Kordas, 2010.
66. C. Warniment, K. Tsang, and S. S. Galazka, Lead poisoning in children, *American Family Physician* 81 (2010): 751–757.

LEARN IT Define *phytochemicals* and explain how they might defend against chronic diseases.



Phytochemicals and Functional Foods

Chapter 13 completes the introductory lessons on the six classes of nutrients—carbohydrates, lipids, proteins, vitamins, minerals, and water. In addition to these nutrients, foods contain thousands of other compounds, including the **phytochemicals.** Chapter 1 introduces the phytochemicals as compounds found in plant-derived foods (*phyto* means plant) that have biological activity in the body. Research on phytochemicals is unfolding daily, adding to our knowledge of their roles in human health, but there are still many questions and only tentative answers. Just a few of the tens of thousands of phytochemicals have been researched at all, and only a sampling are mentioned in this highlight—enough to illustrate their wide variety of food sources and roles in supporting health.

The concept that foods provide health benefits beyond those of the nutrients emerged from numerous epidemiological studies showing the protective effects of plant-based diets on cancer and heart disease. People have been using foods to maintain health and prevent disease for years, but now these foods have been given a name—they are called **functional foods.**[1] (The accompanying glossary defines this and other terms.) As Chapter 1 explains, functional foods include all foods (whole, fortified, or modified foods) that have a potentially beneficial effect on health.[2] Much of this text touts the benefits of nature's functional foods—whole grains rich in dietary fibers, oily fish rich in omega-3 fatty acids, and fresh fruits rich in phytochemicals, for example. This highlight begins with a look at some of these familiar functional foods, the phytochemicals they contain, and their roles in disease prevention. Then the discussion turns to examine the most controversial of functional foods—novel foods to which phytochemicals have been added to promote health. How these foods fit into a healthy diet is still unclear.

The Phytochemicals

In foods, phytochemicals impart tastes, aromas, colors, and other characteristics. They give hot peppers their burning sensation, garlic its pungent flavor, and tomatoes their red color. In the body, phytochemicals can have profound physiological effects—acting as antioxidants, mimicking hormones, stimulating enzymes, interfering with DNA replication, suppressing inflammation, destroying bacteria, and binding to cell walls. Any of these actions may prevent the development of chronic diseases, depending in part on how genetic factors interact with the phytochemicals.[3] Phytochemicals might also have adverse effects when consumed in excess. Table H13-1 presents the names, possible effects, and food sources of some of the better-known phytochemicals.

Defending against Cancer

A variety of phytochemicals from a variety of foods appear to protect against DNA damage and defend the body against cancer. A few examples follow.

Soy may protect against breast and prostate cancers and reduce the risk of death and recurrence.[4] Soybeans—as well as other legumes, **flaxseeds,** whole grains, fruits, and vegetables—are a rich source of an array of phytochemicals, among them the **phytoestrogens.** Because the chemical structure of phytoestrogens is similar to the steroid hormone estrogen, they can weakly mimic or modulate the effects of estrogen in the body. They also have antioxidant activity that appears to slow the growth of some cancers. Soy foods appear to be most

GLOSSARY

carotenoids (kah-ROT-eh-noyds): pigments commonly found in plants and animals, some of which have vitamin A activity. The carotenoid with the greatest vitamin A activity is beta-carotene.

flavonoids (FLAY-von-oyds): yellow pigments in foods; phytochemicals that may exert physiological effects on the body.

flaxseeds: the small brown seeds of the flax plant; valued in nutrition as a source of fiber, lignans, and omega-3 fatty acids.

functional foods: whole, fortified, or modified foods that contain bioactive compounds that provide health benefits beyond their nutrient contributions; sometimes called *designer foods* and *nutraceuticals.*

lignans: phytochemicals present in flaxseed, that are converted to phytosterols by intestinal bacteria and are under study as possible anticancer agents.

lutein (LOO-teen): a plant pigment of yellow hue; a phytochemical believed to play roles in eye functioning and health.

lycopene (LYE-koh-peen): a pigment responsible for the red color of tomatoes and other red-hued vegetables; a phytochemical that may act as an antioxidant in the body.

phytochemicals: nonnutrient compounds found in plants that confer taste, color, and other characteristics. Some phytochemicals have biological activity in the body.

phytoestrogens: phytochemicals structurally similar to human estrogen that weakly mimic or modulate estrogen's action in the body. Phytoestrogens include the isoflavones *genistein, daidzein,* and *glycitein.*

plant sterols: phytochemicals that have structural similarities to cholesterol and lower blood cholesterol by interfering with cholesterol absorption. Plant sterols include *sterol esters* and *stanol esters.*

TABLE H13-1 Phytochemicals—Their Food Sources and Actions

Name	Possible Effects	Food Sources
Alkylresorcinols (phenolic lipids)	May contribute to the protective effect of grains in reducing the risks of diabetes, heart disease, and some cancers.	Whole-grain wheat and rye
Allicin (organosulfur compound)	Antimicrobial that may reduce ulcers; may lower blood cholesterol.	Chives, garlic, leeks, onions, scallions
Capsaicin	Modulates blood clotting, possibly reducing the risk of fatal clots in heart and artery disease.	Hot peppers
Carotenoids (include beta-carotene, lycopene, lutein, zeaxanthin, and hundreds of related compounds)	Act as antioxidants, possibly reducing risks of cancer and other diseases.	Deeply pigmented fruits and vegetables (apricots, broccoli, cantaloupe, carrots, pink grapefruit, pumpkin, spinach, sweet potatoes, tomatoes, red peppers, watermelon)
Curcumin (polyphenol)	Acts as an antioxidant and anti-inflammatory agent; may reduce blood clot formation; may inhibit enzymes that activate carcinogens.	Turmeric, a yellow-colored spice common in curry powder
Flavonoids (include anthocyanins, flavones, flavonols, isoflavones, catechins, and others)	Act as antioxidants; scavenge carcinogens; bind to nitrates in the stomach, preventing conversion to nitrosamines; inhibit cell proliferation.	Berries, black tea, celery, citrus fruits, green tea, olives, onions, oregano, purple grapes, purple grape juice, soybeans and soy products, vegetables, whole wheat, wine
Genistein and daidzein (isoflavonoids)	Phytoestrogens that inhibit cell replication in GI tract; may reduce risk of breast, colon, ovarian, prostate, and other estrogen-sensitive cancers; may reduce cancer cell survival; may reduce risk of osteoporosis.	Soybeans, soy flour, soy milk, tofu, textured vegetable protein, other legume products
Indoles (organosulfur compound)	May trigger production of enzymes that block DNA damage from carcinogens; may inhibit estrogen action.	Cruciferous vegetables such as bok choy, broccoli, brussels sprouts, cabbage, cauliflower, collard greens, mustard greens, kale, swiss chard, watercress
Isothiocyanates (organosulfur compounds, including sulforaphane)	Act as antioxidants; inhibit enzymes that activate carcinogens; activate enzymes that detoxify carcinogens; may reduce risk of breast cancer, prostate cancer.	Cruciferous vegetables such as bok choy, broccoli, brussels sprouts, cabbage, cauliflower, collard greens, mustard greens, kale, swiss chard, watercress
Lignans (polyphenol)	Phytoestrogens that block estrogen activity in cells possibly reducing the risk of cancer of the breast, colon, ovaries, and prostate.	Flaxseed, whole grains
Monoterpenes (including limonene)	May trigger enzyme production to detoxify carcinogens; inhibit cancer promotion and cell proliferation.	Citrus fruits, cherries
Phenolic acids (including ellagic acid)	May trigger enzyme production to make carcinogens water soluble, facilitating excretion.	Coffee beans, fruits (apples, blueberries, cherries, grapes, oranges, pears, prunes), oats, potatoes, soybeans
Phytic acid (phenolic acid)	Binds to minerals, preventing free-radical formation, possibly reducing cancer risk.	Whole grains
Resveratrol (flavonoid)	Acts as an antioxidant; may inhibit cancer growth; reduce inflammation, LDL oxidation, and blood clot formation.	Red wine, peanuts, grapes, raspberries
Saponins (glucosides)	May interfere with DNA replication, preventing cancer cells from multiplying; stimulate immune response.	Alfalfa sprouts, other sprouts, green vegetables, potatoes, tomatoes
Tannins (flavonoid)	Act as antioxidants; may inhibit carcinogen activation and cancer promotion.	Black-eyed peas, grapes, lentils, red and white wine, tea

© Cengage Learning 2013

effective when consumed in moderation early and throughout life.[5] Importantly, soy concentrates or the use of phytoestrogen supplements are ill-advised—especially for women with breast cancer and those with high risk factors—as phytoestrogens may stimulate the growth of estrogen-dependent cancers (such as breast cancer).[6] The American Cancer Society recommends that women with breast cancer should consume only *moderate* amounts of soy as part of a healthy plant-based diet and should not intentionally ingest high levels of soy or supplements of phytoestrogens.

Limited evidence suggests that tomatoes may offer protection against some cancers.[7] Among the phytochemicals thought to be responsible for this effect is **lycopene,** one of the many **carotenoids**.[8] Lycopene is the pigment that gives apricots, guava, papaya, pink grapefruits, and watermelon their red color—and it is especially abundant in tomatoes and cooked tomato products. Lycopene is a powerful antioxidant that seems to inhibit the growth of cancer cells.[9] Importantly, the benefits of lycopene have been seen when people have eaten *foods* containing lycopene; lycopene supplements may interfere with cancer treatments.[10]

Soybeans and tomatoes are only two of the many fruits and vegetables credited with providing anticancer activity. Strong and convincing evidence shows that the risk of many cancers, and perhaps of cancer in general, decreases when diets include an abundance of fruits and vegetables.[11] To that end, current recommendations urge consumers to eat five to nine servings of fruits and vegetables a day.

Defending against Heart Disease

Diets based primarily on unprocessed foods appear to support heart health better than those founded on highly refined foods—perhaps because of the abundance of nutrients, fiber, or phytochemicals such as the **flavonoids.** Flavonoids, a large group of phytochemicals known for their health-promoting qualities, are found in whole grains, legumes, soy, vegetables, fruits, herbs, spices, teas, chocolate, nuts, olive oil, and red wines.[12] Flavonoids are powerful antioxidants that may help to protect LDL cholesterol against oxidation, minimize inflammation, and reduce blood platelet stickiness, thereby slowing the progression of atherosclerosis and making blood clots less likely.[13] Whereas an abundance of flavonoid-containing *foods* in the diet may lower the risks of chronic diseases, no claims can be made for flavonoids themselves as the protective factor, particularly when they are extracted from foods and sold as supplements. In fact, purified flavonoids may even be harmful.[14]

In addition to flavonoids, fruits and vegetables are rich in carotenoids such as beta-carotene and **lutein.** Studies suggest that a diet rich in carotenoids is associated with a lower risk of hypertension and heart disease.[15]

The **plant sterols** of soybeans and the **lignans** of flaxseed may also protect against heart disease.[16] These cholesterol-like molecules are naturally found in all plants and inhibit cholesterol absorption in the body. As a result, blood cholesterol levels decline.[17] These phytochemicals also seem to protect against heart disease by reducing inflammation and lowering blood pressure.[18]

Defending against Other Diseases

Most research on phytochemicals has focused on cancer and heart disease, but phytochemicals defend against other diseases as well. The orange-yellow pigment curcumin, commonly found in curry powder, may help reverse insulin resistance, inflammation, and other symptoms associated with obesity.[19] The carotenoids lutein and zeaxanthin may protect the eyes and skin from ultraviolet light damage and the bones from mineral loss.[20]

The Phytochemicals in Perspective

Because foods deliver thousands of phytochemicals in addition to dozens of nutrients, researchers must be careful in giving credit for particular health benefits to any one compound. Diets rich in whole grains, legumes, vegetables, fruits, and nuts seem to protect against heart disease and cancer, but identifying *the* specific foods or components of foods that are responsible is difficult. Each food possesses a unique array of phytochemicals—citrus fruits provide monoterpenes; grapes, resveratrol; and flaxseed, lignans. (Review Table H13-1, p. 429, for the possible effects and other food sources of these phytochemicals.) Broccoli may contain as many as 10,000 different phytochemicals—each with the potential to influence some action in the body. Beverages such as wine, spices such as oregano, and oils such as olive oil (especially virgin olive oil) contain many phytochemicals that may explain, in part, why people who eat a traditional Mediterranean diet have reduced risks of heart disease and cancer.[21] Phytochemicals might also explain why the DASH diet is so effective in lowering blood pressure and blood lipids. Even identifying all of the phytochemicals and their effects doesn't answer all the questions because the actions of phytochemicals may be complementary or overlapping—which reinforces the principle of variety in diet planning. For an appreciation of the array of phytochemicals offered by a variety of foods, see Figure H13-1.

Functional Foods

Because foods naturally contain thousands of phytochemicals that are biologically active in the body, virtually all of them have some value in supporting health.[22] In other words, even simple, whole foods, in reality, are functional foods.[23] Cranberries may help prevent urinary tract infections; garlic may lower blood cholesterol; grapes may reduce inflammation; and green tea may inhibit ulcer infections, just to name a few examples.[24] Functional foods rich in phytochemicals are easy to find in the produce section of grocery stores. Just look for the colorful fruits and vegetables (see Table H13-2, p. 432). But food manufacturers continue to create new functional foods as well. The creation of more functional foods has become the fastest-growing trend and the greatest influence transforming the global food supply.[25]

Many processed foods become functional foods when they are fortified with nutrients or enhanced with phytochemicals or herbs (calcium-fortified orange juice, for example). Less frequently, an entirely new food is created, as in the case of a meat substitute made of mycoprotein—a protein derived from a fungus.* This functional food not only provides dietary fiber, polyunsaturated fats, and high-quality protein, but it lowers LDL cholesterol, raises HDL cholesterol, improves glucose response, and prolongs satiety after a meal. Such a novel functional food raises the question—is it a food or a drug?

Foods as Pharmacy

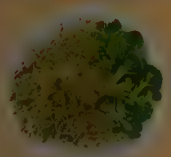
Not too long ago, most of us could agree on what was a food and what was a drug. Today, functional foods blur the distinctions.[26] They have characteristics similar to both foods and drugs, but do not fit neatly into either category. Consider margarine, for example.

Eating nonhydrogenated margarine sparingly instead of butter generously may lower blood cholesterol slightly over several months and clearly falls into the food category. Taking a statin drug, on the other hand, lowers blood cholesterol significantly within weeks and clearly falls into the drug category. But margarine enhanced with a plant sterol that lowers blood cholesterol is in a gray area between the two. The margarine looks and tastes like a food, but it acts like a drug.

The use of functional foods as drugs creates a whole new set of diet-planning challenges. Not only must foods provide an adequate intake of all the nutrients to support good health, but they must also

*This mycoprotein product is marketed under the trade name Quorn (pronounced KWORN).

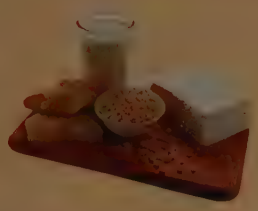
> **FIGURE H13-1 An Array of Phytochemicals in a Variety of Fruits and Vegetables**



Broccoli and broccoli sprouts (and brussels sprouts, bok choy, cabbage, cauliflower, kale, collard greens, swiss chard, turnips, and watercress) contain an abundance of the cancer-fighting phytochemicals sulforaphane and indoles.



An apple a day—rich in phenolic acids—may protect against heart disease.



The phytoestrogens of soybeans seem to starve cancer cells and inhibit tumor growth; the plant sterols may lower blood cholesterol and protect cardiac arteries.



Garlic (and chives, leeks, onions, and scallions), with its abundant organosulfur compounds, may lower blood cholesterol and blood pressure and protect against stomach cancer.



The phytochemical resveratrol found in grapes (and nuts) protects against cancer by inhibiting cell growth and against heart disease by limiting clot formation and inflammation.



The ellagic acid of strawberries (and blackberries, blueberries, raspberries, and grapes) may inhibit certain types of cancer and decrease cholesterol levels.



The monoterpenes of citrus fruits (and cherries) may protect the lungs.



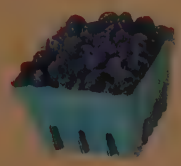
The flavonoids in black tea may protect against heart disease, whereas those in green tea may defend against cancer.



The flavonoids in cocoa and chocolate defend against oxidation and reduce the tendency of blood to clot.



Tomatoes (and pink grapefruit, red peppers, and watermelons), with their abundant lycopene, may defend against cancer and heart disease by protecting DNA from oxidative damage.



Blueberries (and cherries, plums, and strawberries), a rich source of anthocyanins, may protect against the effects of aging.



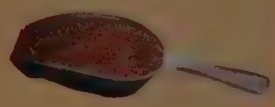
Spinach (and collard greens, corn, swiss chard, and winter squash) contains the carotenoids lutein and zeaxanthin, which help protect the eyes against macular degeneration.



Quercetins—commonly found in kale (and onions, pears, and grapes)—reduce inflammation from allergies, inhibit tumor growth, and protect the lungs.



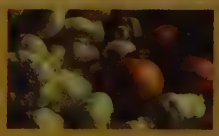
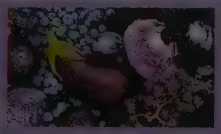
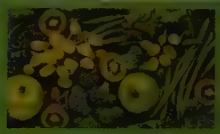
Colorful foods such as apricots (and cantaloupes, carrots, kale, kiwifruit, mangoes, papaya, pumpkins, spinach, sweet potatoes, and winter squash) contain beta-carotene, which may help slow aging, protect against some cancers, improve lung function, and reduce complications of diabetes.



Flaxseed, the richest source of lignans, may prevent the spread of cancer.

© Courtesy of Brassica Protection Products. © 2001 PhotoDisc. © Eye Wire. Inc. Courtesy of Flax Council of Canada. PhotoDisc/Getty Images. Matthew Farruggio; © Barbro Bergfeldt/Shutterstock.com; © Goncharuk/Shutterstock.com

TABLE H13-2 The Colors of Foods Rich in Phytochemicals

Red	White-Brown	Orange-Yellow	Blue-Purple	Green
				
Anthocyanins Lycopene	Allicin Allyl sulfides	Beta-carotene Limonene	Anthocyanins Ellagic acid Phenolics	Beta-carotene Lutein Indoles
Beets Cherries Cranberries Pink grapefruit Pomegranates Radicchio Radishes Raspberries Red apples Red peppers Red potatoes Rhubarb Strawberries Tomatoes Watermelon	Bananas Brown pears Cauliflower Chives Dates Garlic Ginger Leeks Mushrooms Onions Parsnips Shallots Turnips	Apricots Cantaloupe Carrots Lemons Mangoes Nectarines Oranges Papayas Peaches Persimmons Pineapple Pumpkin Rutabagas Squash Sweet potatoes Tangerines Yellow peppers	Black currants Blackberries Blueberries Dried plums Eggplant Elderberries Plums Purple figs Purple peppers Raisins Purple cabbage Purple grapes	Artichokes Arugula Asparagus Avocados Broccoli Brussels sprouts Cabbage Celery Cucumbers Endive Green apples Green beans Green grapes Green onions Green pears Green peppers Honeydew melon Kiwifruit Leafy greens Limes Okra Peas Snow peas Spinach Sugar snap peas Watercress Zucchini

© Cengage Learning 2013. Photos: red © foodfolio/Alamy; white-brown: © J.R. Bale/Alamy; orange-yellow: © D. Hurst/Alamy; blue-purple. © D. Hurst/Alamy; green: © D. Hurst/Alamy



© Craig M. Moore

Nature offers a variety of functional foods that provide us with many health benefits.

deliver druglike ingredients to protect against disease. Like drugs used to treat chronic diseases, functional foods may need to be eaten several times a day for several months or even years to have a beneficial effect. Sporadic users may be disappointed in the results. Margarine enriched with 2 to 3 grams of plant sterols may reduce cholesterol by up to 15 percent, much more than regular margarine does, but not nearly as much as the more than 30 percent reduction seen with cholesterol-lowering drugs. For this reason, functional foods may be more useful for prevention and mild cases of disease than for intervention and more severe cases.

Foods and drugs differ dramatically in cost as well. Functional foods such as fruits and vegetables incur no added costs, but foods that have been manufactured with added phytochemicals can be expensive, costing up to six times as much as their conventional counterparts.

The price of functional foods typically falls between that of traditional foods and medicines.

Unanswered Questions

To achieve a desired health effect, which is the better choice: to eat a novel functional food created to affect a specific body function or to adjust the diet? Does it make more sense to use a margarine enhanced with a plant sterol that lowers blood cholesterol or simply to limit the amount of butter eaten?* Is it smarter to eat eggs enriched with omega-3 fatty acids or to restrict egg consumption? Might functional foods offer a sensible solution for improving our nation's health—if done correctly? Perhaps so, but the problem is that the food industry is moving too fast for either scientists or the Food and Drug Administration to keep up. Consumers were able to buy soup with St. John's wort that claimed to enhance mood and fruit juice with echinacea that was supposed to fight colds while scientists were still conducting their studies on these ingredients. Research to determine the safety and effectiveness of these substances is still in progress. Until this work is complete, consumers are on their own in finding answers to the following questions:

- *Does it work?* Research is generally lacking and findings are often inconclusive.
- *How much does it contain?* Food labels are not required to list the quantities of added phytochemicals. Even if they were, consumers have no standard for comparison and cannot deduce whether the amounts listed are a little or a lot. Most importantly, until research is complete, food manufacturers do not know what amounts (if any) are most effective—or most toxic.
- *Is it safe?* Functional foods can act like drugs. They contain ingredients that can alter body functions and cause allergies, drug interactions, drowsiness, and other side effects. Yet, unlike drug labels, food labels do not provide instructions for the dosage, frequency, or duration of treatment.
- *Is it healthy?* Adding phytochemicals to a food does not magically make it a healthy choice. A candy bar fortified with phytochemicals is still made mostly of sugar and fat.

Critics suggest that the designation "functional foods" may be nothing more than a marketing tool. After all, even the most experienced researchers cannot yet identify the perfect combination of nutrients and phytochemicals to support optimal health. Yet manufacturers are freely experimenting with various concoctions as if they possessed that knowledge. Is it okay for them to sprinkle phytochemicals on fried snack foods or caramel candies and label them "functional," thus implying health benefits?



© Craig M. Moore

Functional foods currently on the market promise to "enhance mood," "promote relaxation and good karma," "increase alertness," and "improve memory," among other claims.

Future Foods

Nature has elegantly designed foods to provide us with a complex array of dozens of nutrients and thousands of additional compounds that may benefit health—most of which we have yet to identify or understand. Over the years, we have taken those foods, deconstructed them, and then reconstructed them in an effort to "improve" them. With new scientific understandings of how nutrients—and the myriad other compounds in foods—interact with genes, we may someday be able to design *specific* eating patterns to meet the *exact* health needs of *each* individual.[27] Indeed, our knowledge of the human genome and of human nutrition may well merge to allow specific recommendations for individuals based on their predisposition to diet-related diseases.

If the present trend continues, someday physicians may be able to prescribe the perfect foods to enhance your health, and farmers will be able to grow them. As Highlight 19 explains, scientists have already developed gene technology to alter the composition of food crops. They can grow rice enriched with vitamin A and tomatoes containing a hepatitis vaccine, for example. It seems quite likely that foods can be created to meet every possible human need. But then, in a sense, that was largely true 100 years ago when we relied on the bounty of nature.

*Margarine products that lower blood cholesterol contain either sterol esters from vegetable oils, soybeans, and corn or stanol esters from wood pulp.

REFERENCES

1. W. R. Kapsak and coauthors, Functional foods: Consumer attitudes, perceptions, and behaviors in a growing market, *Journal of the American Dietetic Association* 111 (2011): 804–810.
2. Position of the American Dietetic Association: Functional foods, *Journal of the American Dietetic Association* 109 (2009): 735–746.
3. J. W. Lampe, Interindividual differences in response to plant-based diets: Implications for cancer risk, *American Journal of Clinical Nutrition* 89 (2009): 1553S–1557S.
4. P. L. de Souza and coauthors, Clinical pharmacology of isoflavones and its relevance for potential prevention of prostate cancer, *Nutrition Reviews* 68 (2010): 542–555; S. A. Lee and coauthors, Adolescent and adult soy food intake and breast cancer risk: Results from the Shanghai Women's Health Study, *American Journal of Clinical Nutrition* 89 (2009): 1920–1926; X. O. Shu and coauthors, Soy food intake and breast cancer survival, *Journal of the American Medical Association* 302 (2009): 2437–2443; E. Cheung and coauthors, Diet

and prostate cancer risk reduction, *Expert Review of Anticancer Therapy* 8 (2008): 43–50.
5. L. Hilakivi-Clarke, J. E. Andrade, and W. Helferich, Is soy consumption good or bad for the breast? *Journal of Nutrition* 140 (2010): 2326S–2334S.
6. M. Messina and A. H. Wu, Perspectives on the soy-breast cancer relation, *American Journal of Clinical Nutrition* 89 (2009): 1673S–1679S.
7. N. P. Gullet and coauthors, Cancer prevention with natural compounds, *Seminars in Oncology* 37 (2010): 258–281.
8. J. Talvas and coauthors, Differential effects of lycopene consumed in tomato paste and lycopene in the form of a purified extract on target genes of cancer prostatic cells, *American Journal of Clinical Nutrition* 91 (2010): 1716–1724; J. R. Mein, F. Lian, and X. Wang, Biological activity of lycopene metabolites: Implications for cancer prevention, *Nutrition Reviews* 66 (2008): 667–683.
9. N. Khan, F. Afaq, and H. Mukhtar, Cancer chemoprevention through dietary antioxidants: Progress and promise, *Antioxidants and Redox Signaling* 10 (2008): 475–510.
10. B. Cassileth, Lycopene, *Oncology* 24 (2010): 296.
11. T. J. Key, Fruit and vegetables and cancer risk, *British Journal of Cancer* 104 (2011): 6–11; J. M. Matés and coauthors, Anticancer antioxidant regulatory functions of phytochemicals, *Current Medicinal Chemistry* 18 (2011): 2315–2338.
12. O. K. Chun and coauthors, Estimation of antioxidant intakes from diet and supplements in US adults, *Journal of Nutrition* 140 (2010): 317–324.
13. G. Williamson and coauthors, Functional foods for health promotion: State-of-the-science on dietary flavonoids. Extended abstracts from the 12th Annual Conference on Functional Foods for Health Promotion, April 2009, *Nutrition Reviews* 67 (2009): 736–743; R. di Giuseppe and coauthors, Regular consumption of dark chocolate is associated with low serum concentrations of C-reactive protein in a healthy Italian population, *Journal of Nutrition* 138 (2008): 1939–1945; I. Erlund and coauthors, Favorable effects of berry consumption on platelet function, blood pressure, and HDL cholesterol, *American Journal of Clinical Nutrition* 87 (2008): 323–331; L. Hooper and coauthors, Flavonoids, flavonoid-rich foods, and cardiovascular risk: A meta-analysis of randomized controlled trials, *American Journal of Clinical Nutrition* 88 (2008): 38–50; W. M. Loke and coauthors, Pure dietary flavonoids quercetin and (–)-epicatechin augment nitric oxide products and reduce endothelin-1 acutely in healthy men, *American Journal of Clinical Nutrition* 88 (2008): 1018–1025.
14. S. Egert and G. Rimbach, Which sources of flavonoids: Complex diets or dietary supplements? *Advances in Nutrition* 2 (2011): 8–14.
15. A. Hozawa and coauthors, Circulating carotenoid concentrations and incident hypertension: The Coronary Artery Risk Development in Young Adults (CARDIA) study, *Journal of Hypertension* 27 (2009): 237–242; G. Riccioni, Carotenoids and cardiovascular disease, *Current Atherosclerosis Reports* 11 (2009): 434–439.
16. A. Pan and coauthors, Meta-analysis of the effects of flaxseed interventions on blood lipids, *American Journal of Clinical Nutrition* 90 (2009): 288–297.
17. S. B. Racette and coauthors, Dose effects of dietary phytosterols on cholesterol metabolism: A controlled feeding study, *American Journal of Clinical Nutrition* 91 (2010): 32–38; J. H. van Ee, Soy constituents: Modes of action in low-density lipoprotein management, *Nutrition Reviews* 67 (2009): 222–234.
18. R. A. Othman and M. H. Moghadasian, Beyond cholesterol-lowering effects of plant sterols: Clinical and experimental evidence of anti-inflammatory properties, *Nutrition Reviews* 69 (2011): 371–382.
19. B. B. Aggarwal, Targeting inflammation-induced obesity and metabolic diseases by curcumin and other nutraceuticals, *Annual Review of Nutrition* 30 (2010): 173–199; L. Alappat and A. B. Awad, Curcumin and obesity: Evidence and mechanisms, *Nutrition Reviews* 68 (2010): 729–738.
20. R. L. Roberts, J. Green, and B. Lewis, Lutein and zeaxanthin in eye and skin health, *Clinics in Dermatology* 27 (2009): 195–201; S. Shivani and coauthors, Inverse association of carotenoid intakes with 4-y change in bone mineral density in elderly men and women: The Framingham Osteoporosis Study, *American Journal of Clinical Nutrition* 89 (2009): 416–424.
21. S. Granados-Principal and coauthors, Hydroxytyrosol: From laboratory investigations to future clinical trials, *Nutrition Reviews* 68 (2010): 191–206; D. M. Minich and J. S. Bland, Dietary management of the metabolic syndrome beyond macronutrients, *Nutrition Reviews* 66 (2008): 429–444.
22. A. S. Chang, B. Y. Yeong, and W. P. Koh, Symposium on plant polyphenols: Nutrition, health and innovations, June 2009, *Nutrition Reviews* 68 (2010): 246–252.
23. Position of the American Dietetic Association, 2009.
24. C. Chuang and M. K. McIntosh, Potential mechanisms by which polyphenol-rich grapes prevent obesity-mediated inflammation and metabolic diseases, *Annual Review of Nutrition* 31 (2011): 155–176; K. M. Reinhart and coauthors, The impact of garlic on lipid parameters: A systematic review and meta-analysis, *Nutrition Research Reviews* 22 (2009): 39–48; S. Y. Lee, Y. W. Shin, and K. B. Hahm, Phytoceuticals: Mighty but ignored weapons against *Helicobacter pylori* infection, *Journal of Digestive Diseases* 9 (2008): 129–139; Y. Liu and coauthors, Cranberry changes the physicochemical surface properties of *E. coli* and adhesion with uroepithelial cells, *Colloids and Surfaces. B: Biointerfaces* 65 (2008): 35–42.
25. A. E. Sloan, The top functional food trends, *Food Technology* 62 (2008): 24–44; I. Siró and coauthors, Functional food. Product development, marketing and consumer acceptance: A review, *Appetite* 51 (2008): 456–467.
26. P. J. Jones and K. A. Varady, Are functional foods redefining nutritional requirements? *Applied Physiology, Nutrition, and Metabolism* 33 (2008): 118–123.
27. L. R. Ferguson, Nutrigenomics approaches to functional foods, *Journal of the American Dietetic Association* 109 (2009): 452–458.



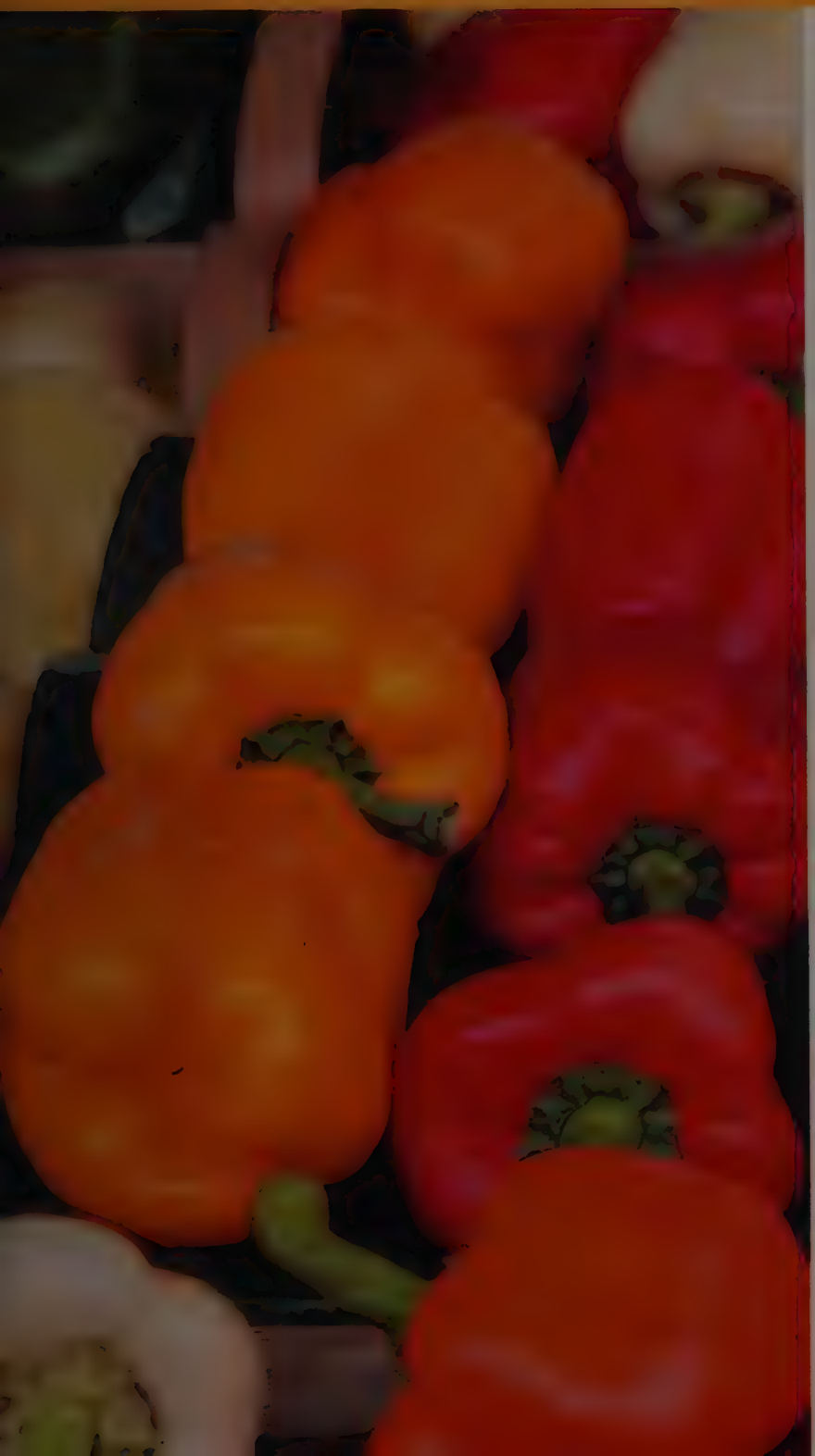


© Ammit/Shutterstock.com

CENGAGE LEARNING'S GLOBAL NUTRITION
GLOBAL NUTRITION RESOURCE CENTER

Good health depends on a well-balanced diet and regular exercise. Go to Fitness → Exercise to learn how a physically active body improves nutrient absorption.

Appendixes



© Kim D. French/Shutterstock.com

APPENDIX A
Cells, Hormones, and Nerves

APPENDIX B
Basic Chemistry Concepts

APPENDIX C
Biochemical Structures and Pathways

APPENDIX D
Measures of Protein Quality

APPENDIX E
Nutrition Assessment

APPENDIX F
Physical Activity and Energy Requirements

APPENDIX G
Exchange Lists for Diabetes

APPENDIX H
Table of Food Composition

APPENDIX I
WHO Nutrition Recommendations

APPENDIX J
Healthy People 2020

APPENDIX K
Aids to Calculation

Appendix A Cells, Hormones, and Nerves

CONTENTS

Cells
Hormones
Nerves
Putting It Together

This appendix is offered as an optional chapter for readers who want to enhance their understanding of how the body coordinates its activities. It presents a brief summary of the structure and function of the body's basic working unit (the cell) and of the body's two major regulatory systems (the hormonal system and the nervous system).

Cells

The body's organs are made up of millions of cells and of materials produced by them. Each **cell** is specialized to perform its organ's functions, but all cells have common structures (see the accompanying glossary and Figure A-1). Every cell is contained within a **cell membrane.** The cell membrane assists in moving materials into and out of the cell, and some of its special proteins act as "pumps" (described in Chapter 6). Some features of cell membranes, such as microvilli (Chapter 3), permit cells to interact with other cells and with their environments in highly specific ways.

Inside the membrane lies the **cytoplasm,** which is filled with **cytosol,** a jelly-like fluid. The cytoplasm contains much more than just cytosol, though. It is a highly organized system of fibers, tubes, membranes, particles, and subcellular **organelles** as complex as a city. These parts intercommunicate, manufacture and exchange materials, package and prepare materials for export, and maintain and repair themselves.

Within each cell is another membrane-enclosed body, the **nucleus.** Inside the nucleus are the **chromosomes,** which contain the genetic material, DNA. The DNA encodes all the instructions for carrying out the cell's activities. The role of DNA in coding for cell proteins is summarized in Figure 6-7 on p. 174. Chapter 6 also describes the variety of proteins produced by cells and some of the ways they perform the body's work.

Among the organelles within a cell are ribosomes, mitochondria, and lysosomes. Figure 6-7 briefly refers to the **ribosomes;** they assemble amino acids into proteins, following directions conveyed to them by RNA.

GLOSSARY OF CELL STRUCTURES

cell: the basic structural unit of all living things.

cell membrane: the thin layer of tissue that surrounds the cell and encloses its contents, made primarily of lipid and protein.

chromosomes: structures within the nucleus of a cell made of DNA and associated proteins. Human beings have 46 chromosomes in 23 pairs. Each chromosome has many genes.

cytoplasm (SIGH-toh-plazm): the cell contents, except for the nucleus.

cytosol: the fluid of cytoplasm that contains water, ions, nutrients, and enzymes.

endoplasmic reticulum (en-doh-PLAZ-mic reh-TIC-you-lum): a complex network of intracellular membranes. The *rough endoplasmic reticulum* is dotted with ribosomes, where protein synthesis takes place. The *smooth endoplasmic reticulum* bears no ribosomes.

Golgi (GOAL-gee) **apparatus:** a set of membranes within the cell where secretory materials are packaged for export.

lysosomes (LYE-so-zomes); cellular organelles; membrane-enclosed sacs of degradative enzymes.

mitochondria (my-toh-KON-dree-uh); singular *mitochondrion:* the cellular organelles that are made of membranes (lipid and protein) with enzymes mounted on them responsible for producing ATP aerobically.

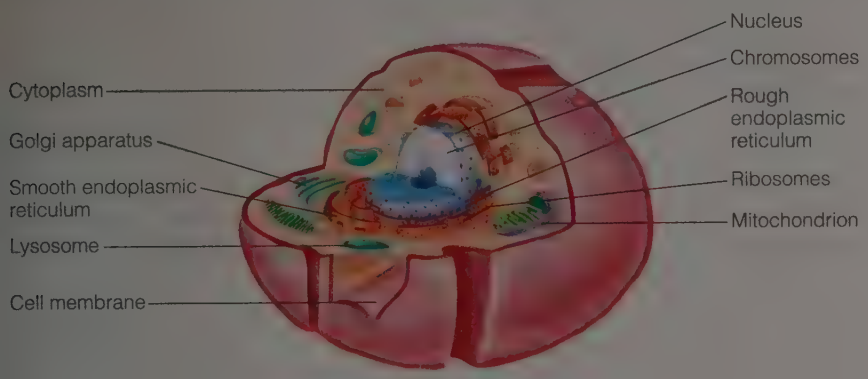
nucleus: a major membrane-enclosed body within cells, which contains the cell's genetic material (DNA) embedded in chromosomes.

organelles: subcellular structures such as ribosomes, mitochondria, and lysosomes.

ribosomes (RYE-boh-zomes): protein-making organelles in cells that are composed of RNA and protein.

> **FIGURE A-1 The Structure of a Typical Cell**

The cell shown might be one in a gland (such as the pancreas) that produces secretory products (enzymes) for export (to the intestine). The rough endoplasmic reticulum with its ribosomes produces the enzymes; the smooth reticulum conducts them to the Golgi region; the Golgi membranes merge with the cell membrane, where the enzymes can be released into the extracellular fluid.



The **mitochondria** are made of intricately folded membranes that bear thousands of highly organized sets of enzymes on their inner and outer surfaces. Mitochondria are crucial to energy metabolism (described in Chapter 7) and muscles conditioned to work aerobically are packed with them. Their presence is implied whenever the TCA cycle and electron transport chain are mentioned because the mitochondria house the needed enzymes.*

The **lysosomes** are membranes that enclose degradative enzymes. When a cell needs to self-destruct or to digest materials in its surroundings, its lysosomes free their enzymes. Lysosomes are active when tissue repair or remodeling is taking place—for example, in cleaning up infections, healing wounds, shaping embryonic organs, and remodeling bones.

Besides these and other cellular organelles, the cell's cytoplasm contains a highly organized system of membranes, the **endoplasmic reticulum.** The ribosomes may either float free in the cytoplasm or be mounted on these membranes. A membranous surface dotted with ribosomes looks speckled under the microscope and is called "rough" endoplasmic reticulum; such a surface without ribosomes is called "smooth." Some intracellular membranes are organized into tubules that collect cellular materials, merge with the cell membrane, and discharge their contents to the outside of the cell; these membrane systems are named the **Golgi apparatus,** after the scientist who first described them. The rough and smooth endoplasmic reticula and the Golgi apparatus are continuous with one another, so secretions produced deep in the interior of the cell can be efficiently transported to the outside and released. These and other cell structures enable cells to perform the multitudes of functions for which they are specialized.

The actions of cells are coordinated by both hormones and nerves, as the next sections show. Among the types of cellular organelles are receptors for the hormones delivering instructions that originate elsewhere in the body. Some hormones penetrate the cell and its nucleus and attach to receptors on chromosomes, where they activate certain genes to initiate, stop, speed up, or slow down synthesis of certain proteins as needed. Other hormones attach to receptors on the cell surface and transmit their messages from there. The hormones ♦ are described in the next section; the nerves, in the one following.

♦ The study of hormones and their effects is *endocrinology.*

*For the reactions of glycolysis, the TCA cycle, and the electron transport chain, see Chapter 7 and Appendix C. The reactions of glycolysis take place in the cytoplasm; the conversion of pyruvate to acetyl CoA takes place in the mitochondria, as do the TCA cycle and electron transport chain reactions. The mitochondria then release carbon dioxide, water, and ATP as their end products.

Hormones

Hormones are chemical messengers secreted by a variety of glands in response to altered conditions in the body. Each hormone travels in the blood to all parts of the body, but only its specific target tissues or organs possess receptors to accept it. Only then can the hormone elicit a response to restore homeostasis.

The hormones, the glands they originate in, their target organs, and their effects are described in this section. Many of the hormones you might be interested in are included, but only a few are discussed in detail. Figure A-2 identifies the glands that produce the hormones, and the accompanying glossary defines the hormones discussed in this section.

♦ The pituitary gland in the brain has two parts—the *anterior* (front) and the *posterior* (hind).

Hormones of the Pituitary Gland and Hypothalamus

The anterior pituitary gland ♦ produces the following hormones, each of which acts on one or more target organs and elicits a characteristic response:

- **Adrenocorticotropin (ACTH)** acts on the adrenal cortex, promoting the production and release of its hormones.
- **Thyroid-stimulating hormone** (TSH) acts on the thyroid gland, promoting the production and release of thyroid hormones.
- **Growth hormone (GH)** or **somatotropin** acts on all tissues, promoting growth, fat breakdown, and the formation of antibodies.
- **Follicle-stimulating hormone (FSH)** acts on the ovaries in the female, promoting their maturation, and on the testicles in the male, promoting sperm formation.
- **Luteinizing hormone (LH)** also acts on the ovaries, stimulating their maturation, the production and release of progesterone and estrogens, and ovulation; and on the testicles, promoting the production and release of testosterone.
- **Prolactin,** secreted in the female during pregnancy and lactation, acts on the mammary glands to stimulate their growth and the production of milk.

hormones: chemical messengers. Hormones are secreted by a variety of endocrine glands in response to altered conditions in the body. Each hormone travels to one or more specific target tissues or organs, where it elicits a specific response to maintain homeostasis.

GLOSSARY OF HORMONES

adrenocorticotropin (ad-REE-noh-KORE-tee-koh-TROP-in) or **ACTH:** a hormone, so named because it stimulates *(trope)* the adrenal cortex. The adrenal gland, like the pituitary, has two parts, in this case an outer portion *(cortex)* and an inner core *(medulla).* The release of ACTH is mediated by *corticotropin-releasing hormone (CRH).*

aldosterone: a hormone secreted by the adrenal glands that regulates blood pressure by increasing the reabsorption of sodium by the kidneys.

angiotensin: a hormone involved in blood pressure regulation.

antidiuretic hormone (ADH): a hormone produced by the pituitary gland in response to dehydration (or a high sodium concentration in the blood) that stimulates the kidneys to reabsorb more water and therefore to excrete less. In addition to its antidiuretic effect, ADH elevates blood pressure and so is also called *vasopressin* (VAS-oh-PRES-in).

calcitonin (KAL-see-TOH-nin): a hormone secreted by the thyroid gland that regulates calcium by lowering it when levels rise too high.

erythropoietin (eh-RITH-ro-POY-eh-tin): a hormone that stimulates red blood cell production.

estrogens: hormones responsible for the menstrual cycle and other female characteristics.

follicle-stimulating hormone (FSH): a hormone that stimulates maturation of the ovarian follicles in females and the production of sperm in males. (The ovarian follicles are part of the female reproductive system where the eggs are produced.) The release of FSH is mediated by *follicle-stimulating hormone releasing hormone (FSH–RH).*

glucocorticoids: hormones from the adrenal cortex that affect the body's management of glucose.

growth hormone (GH): a hormone secreted by the pituitary that regulates the cell division and protein synthesis needed for normal growth (also called *somatotropin).* The release of GH is mediated by *GH-releasing hormone (GHRH)* and *GH-inhibiting hormone (GHIH).*

luteinizing (LOO-tee-in-EYE-zing) **hormone (LH):** a hormone that stimulates ovulation and the development of the corpus luteum (the small tissue that develops from a ruptured ovarian follicle and secretes hormones). In men, LH stimulates testosterone secretion. The release of LH is mediated by *luteinizing hormone-releasing hormone (LH–RH).*

oxytocin (OCK-see-TOH-sin): a hormone that stimulates the mammary glands to eject milk during lactation and the uterus to contract during childbirth.

progesterone: the hormone of gestation (pregnancy).

prolactin (proh-LAK-tin): a hormone secreted from the anterior pituitary gland that acts on the mammary glands to promote the production of milk. The release of prolactin is mediated by *prolactin-inhibiting hormone (PIH).*

relaxin: the hormone of late pregnancy.

renin (REN-in): an enzyme from the kidneys that hydrolyzes the protein angiotensinogen to angiotensin, which results in the kidneys reabsorbing sodium.

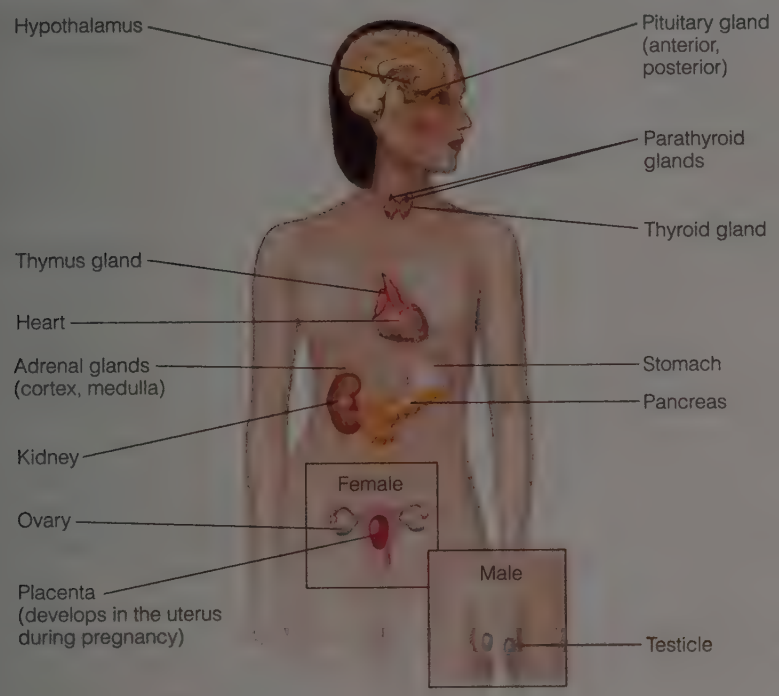
somatostatin (GHIH): a hormone that inhibits the release of growth hormone; the opposite of *somatotropin (GH).*

testosterone: a steroid hormone from the testicles, or testes. The steroids, as explained in Chapter 5, are chemically related to, and some are derived from, the lipid cholesterol.

thyroid-stimulating hormone (TSH): a hormone secreted by the pituitary that stimulates the thyroid gland to secrete its hormones—thyroxin and triiodothyronine. The release of TSH is mediated by *TSH-releasing hormone (TRH).*

> FIGURE A-2 The Endocrine System

These organs and glands release hormones that regulate body processes. An *endocrine gland* secretes its product directly into *(endo)* the blood; for example, the pancreas cells that produce insulin. An *exocrine gland* secretes its product(s) out *(exo)* to an epithelial surface either directly or through a duct; the sweat glands of the skin and the enzyme-producing glands of the pancreas are both examples. The pancreas is therefore both an endocrine and an exocrine gland.



Each of these hormones has one or more signals that turn it on and another (or others) that turns it off. ♦ Among the controlling signals are several hormones from the hypothalamus:

- **Corticotropin-releasing hormone (CRH)**, which promotes release of ACTH, is turned on by stress and turned off by ACTH when enough has been released.
- **TSH-releasing hormone (TRH)**, which promotes release of TSH, is turned on by large meals or low body temperature.
- **GH-releasing hormone (GHRH)**, which stimulates the release of growth hormone, is turned on by insulin.
- **GH-inhibiting hormone (GHIH** or **somatostatin)**, which inhibits the release of GH and interferes with the release of TSH, is turned on by hypoglycemia and/or physical activity and is rapidly destroyed by body tissues so that it does not accumulate.
- **FSH/LH-releasing hormone (FSH/LH-RH)** is turned on in the female by nerve messages or low estrogen and in the male by low testosterone.
- **Prolactin-inhibiting hormone (PIH)** is turned on by high prolactin levels and off by estrogen, testosterone, and suckling (by way of nerve messages).

Let's examine some of these controls. PIH, for example, responds to high prolactin levels (remember, prolactin promotes milk production). High prolactin levels ensure that milk is made and—by calling forth PIH—ensure that prolactin levels don't get too high. But when the infant is suckling—and creating a demand for milk—PIH is not allowed to work (suckling turns off PIH). The

♦ Hormones that are turned off by their own effects are said to be regulated by *negative feedback* (see Figure 3-12 on p. 84).

consequence: prolactin remains high, and milk production continues. Demand from the infant thus directly adjusts the supply of milk. The need is met through the interaction of the nerves and hormones.

As another example, consider CRH. Stress, perceived in the brain and relayed to the hypothalamus, switches on CRH. On arriving at the pituitary, CRH switches on ACTH. Then ACTH acts on its target organ, the adrenal cortex, which responds by producing and releasing stress hormones. The stress hormones trigger a cascade of events involving every body cell and many other hormones.

The numerous steps required to set the stress response in motion make it possible for the body to fine-tune the response; control can be exerted at each step. These two examples illustrate what the body can do in response to two different stimuli—producing milk in response to an infant's need and gearing up for action in an emergency.

The posterior pituitary gland produces two hormones, each of which acts on one or more target cells and elicits a characteristic response:

- **Antidiuretic hormone (ADH),** or **vasopressin,** acts on the arteries, promoting their contraction, and on the kidneys, preventing water excretion. ADH is turned on whenever the blood volume is low, the blood pressure is low, or the salt concentration of the blood is high (see Chapter 12). It is turned off by the return of these conditions to normal.
- **Oxytocin** acts during late pregnancy on the uterus, inducing contractions, and during lactation on the mammary glands, causing milk ejection. Oxytocin is produced in response to reduced progesterone levels, suckling, or the stretching of the cervix.

Hormones that Regulate Energy Metabolism Hormones produced by a number of different glands have effects on energy metabolism:

- Insulin from the pancreas beta cells is turned on by many stimuli, including high blood glucose. It acts on cells to increase glucose and amino acid uptake into them and to promote the secretion of GHRH.
- Glucagon from the pancreas alpha cells responds to low blood glucose and acts on the liver to promote the breakdown of glycogen to glucose, the conversion of amino acids to glucose, and the release of glucose into the blood.
- Thyroxin from the thyroid gland responds to TSH and acts on many cells to increase their metabolic rate, growth, and heat production.
- Norepinephrine and epinephrine ♦ from the adrenal medulla respond to stimulation by sympathetic nerves and produce reactions in many cells that facilitate the body's readiness for fight or flight: increased heart activity, blood vessel constriction, breakdown of glycogen and glucose, raised blood glucose levels, and fat breakdown. Norepinephrine and epinephrine also influence the secretion of the many hormones from the hypothalamus that exert control on the body's other systems.
- Growth hormone (GH) from the anterior pituitary (already mentioned).
- **Glucocorticoids** from the adrenal cortex become active during times of stress and carbohydrate metabolism.

♦ Norepinephrine and epinephrine were formerly called *noradrenalin* and *adrenalin,* respectively.

Every body part is affected by these hormones. Each different hormone has unique effects; and hormones that oppose each other are produced in carefully regulated amounts, so each can respond to the exact degree that is appropriate to the condition.

Hormones that Adjust Other Body Balances Hormones are involved in moving calcium into and out of the body's storage deposits in the bones:

- **Calcitonin** from the thyroid gland acts on the bones, which respond by storing calcium from the bloodstream whenever blood calcium rises above

the normal range. It also acts on the kidneys to increase excretion of both calcium and phosphorus in the urine. Calcitonin plays a major role in infants and young children, but is less active in adults.

- Parathyroid hormone (parathormone or PTH) from the parathyroid gland responds to the opposite condition—lowered blood calcium—and acts on three targets: the bones, which release stored calcium into the blood; the kidneys, which slow the excretion of calcium; and the intestine, which increases calcium absorption.
- Vitamin D from the skin and activated in the kidneys acts with parathyroid hormone and is essential for the absorption of calcium in the intestine.

Figure 12-12 on p. 386 diagrams the ways vitamin D and the hormones calcitonin and parathyroid hormone regulate calcium homeostasis.

Another hormone has effects on blood-making activity:

- **Erythropoietin** from the kidneys is responsive to oxygen depletion of the blood and to anemia. It acts on the bone marrow to stimulate the making of red blood cells.

Another hormone is special for pregnancy:

- **Relaxin** from the ovaries is secreted in response to the raised progesterone and estrogen levels of late pregnancy. This hormone acts on the cervix and pelvic ligaments to allow them to stretch so that they can accommodate the birth process without strain.

Other agents help regulate blood pressure:

- **Renin** (an enzyme), from the kidneys, in cooperation with **angiotensin** in the blood responds to a reduced blood supply experienced by the kidneys and acts in several ways to increase blood pressure. Renin and angiotensin also stimulate the adrenal cortex to secrete the hormone aldosterone.
- **Aldosterone**, a hormone from the adrenal cortex, targets the kidneys, which respond by reabsorbing sodium. The effect is to retain more water in the bloodstream—thus, again, raising the blood pressure. Figure 12-3 (on p. 372) in Chapter 12 provides more details.

The Gastrointestinal Hormones Several hormones are produced in the stomach and intestines in response to the presence of food or the components of food:

- Gastrin from the stomach and duodenum stimulates the production and release of gastric acid and other digestive juices and the movement of the GI contents through the system.
- Cholecystokinin from the duodenum signals the gallbladder and pancreas to release their contents into the intestine to aid in digestion.
- Secretin from the duodenum calls forth acid-neutralizing bicarbonate from the pancreas into the intestine and slows the action of the stomach and its secretion of acid and digestive juices.
- Gastric-inhibitory peptide from the duodenum and jejunum inhibits the secretion of gastric acid and slows the process of digestion.

These hormones are defined and discussed in Chapter 3.

The Sex Hormones There are three major sex hormones:

- **Testosterone** from the testicles is released in response to LH (described earlier) and acts on all the tissues that are involved in male sexuality, promoting their development and maintenance.
- **Estrogens** from the ovaries are released in response to both FSH and LH and act similarly in females.
- **Progesterone** from the ovaries' corpus luteum and from the placenta acts on the uterus and mammary glands, preparing them for pregnancy and lactation.

This brief description of the hormones and their functions should suffice to provide an awareness of the enormous impact these compounds have on body processes. The body's other overall regulating agency is the nervous system.

Nerves

The nervous system has a central control system that can evaluate information about conditions within and outside the body, and a vast system of wiring that receives information and sends instructions. The control unit is the brain and spinal cord, called the **central nervous system;** and the vast complex of wiring between the center and the parts is the **peripheral nervous system.** The smooth functioning that results from the systems' adjustments to changing conditions is homeostasis.

The nervous system has two general functions: it controls voluntary muscles in response to sensory stimuli from them, and it controls involuntary, internal muscles and glands in response to nerve-borne and chemical signals about their status. In fact, the nervous system is best understood as two systems that use the same or similar pathways to receive and transmit their messages. The **somatic nervous system** controls the voluntary muscles; the **autonomic nervous system** controls the internal organs.

When scientists were first studying the autonomic nervous system, they noticed that when something hurt one organ of the body, some of the other organs reacted as if in sympathy for the afflicted one. They therefore named the nerve network they were studying the sympathetic nervous system. The term is still used today to refer to that branch of the autonomic nervous system that responds to pain and stress. The other branch is called the parasympathetic nervous system. (Think of the sympathetic branch as the responder when homeostasis needs restoring and the parasympathetic branch as the commander of function during normal times.) Both systems transmit their messages through the brain and spinal cord. Nerves of the two branches travel side by side along the same pathways to transmit their messages, but they oppose each other's actions (see Figure A-3).

An example will show how the sympathetic and parasympathetic nervous systems work to maintain homeostasis. When you go outside in cold weather, your skin's temperature receptors send "cold" messages to the spinal cord and brain.

Your conscious mind may intervene at this point to tell you to zip your jacket, but let's say you have no jacket. Your sympathetic nervous system reacts to the external stressor, the cold. It signals your skin-surface capillaries to shut down so that your blood will circulate deeper in your tissues, where it will conserve heat. Your sympathetic nervous system also signals involuntary contractions of the small muscles just under the skin surface. The product of these muscle contractions is heat, and the visible result is goose bumps. If these measures do not raise your body temperature enough, then the sympathetic nerves signal your large muscle groups to shiver; the contractions of these large muscles produce still more heat. All of this activity helps to maintain your homeostasis (with respect to temperature) under conditions of external extremes (cold) that would throw it off balance. The cold was a stressor; the body's response was resistance.

GLOSSARY OF NERVOUS SYSTEM

autonomic nervous system: the division of the nervous system that controls the body's automatic responses. Its two branches are the *sympathetic* branch, which helps the body respond to stressors from the outside environment, and the *parasympathetic* branch, which regulates normal body activities between stressful times.

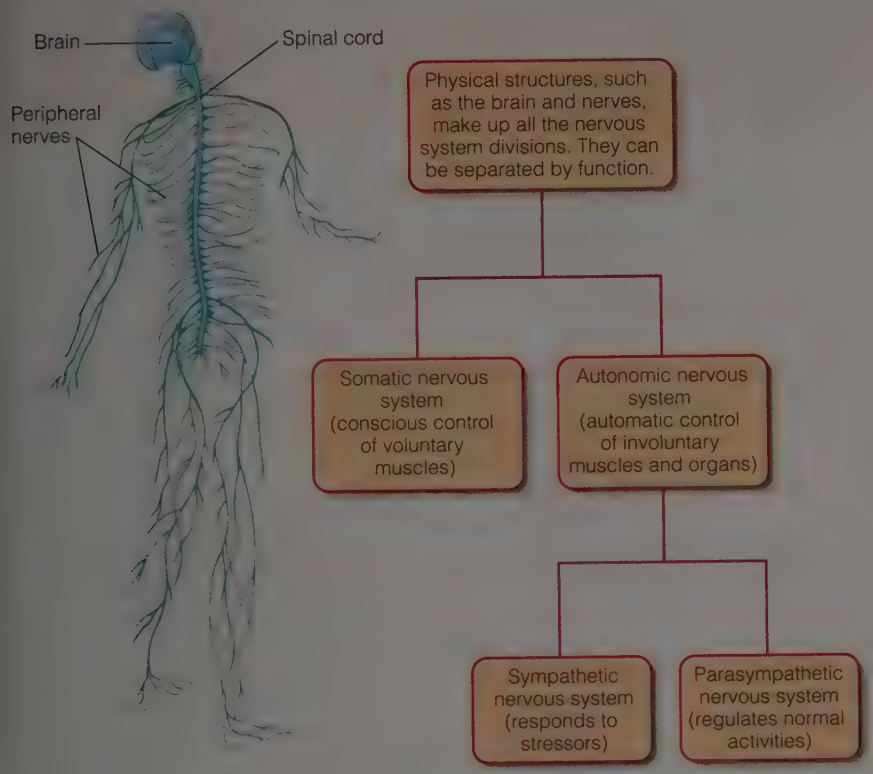
central nervous system: the central part of the nervous system; the brain and spinal cord.

peripheral (puh-RIFF-er-ul) **nervous system:** the peripheral (outermost) part of the nervous system; the vast complex of wiring that extends from the central nervous system to the body's outermost areas. It contains both *somatic* and *autonomic* components.

somatic (so-MAT-ick) **nervous system:** the division of the nervous system that controls the voluntary muscles, as distinguished from the autonomic nervous system, which controls involuntary functions.

> **FIGURE A-3 The Organization of the Nervous System**

The brain and spinal cord evaluate information about conditions within and outside the body, and the peripheral nerves receive information and send instructions.



Now let's say you come in and sit by a fire and drink hot cocoa. You are warm and no longer need all that sympathetic activity. At this point, your parasympathetic nerves take over; they signal your skin-surface capillaries to dilate again, your goose bumps to subside, and your muscles to relax. Your body is back to normal. This is recovery.

Putting It Together

The hormonal and nervous systems coordinate body functions by transmitting and receiving messages. The point-to-point messages of the nervous system travel through a central switchboard (the spinal cord and brain), whereas the messages of the hormonal system are broadcast over the airways (the bloodstream), and any organ with the appropriate receptors can pick them up. Nerve impulses travel faster than hormonal messages do—although both are remarkably swift. Whereas your brain's command to wiggle your toes reaches the toes within a fraction of a second and stops as quickly, a gland's message to alter a body condition may take several seconds or minutes to get started and may fade away equally slowly.

Together, the two systems possess every characteristic a superb communication network needs: varied speeds of transmission, along with private communication lines or public broadcasting systems, depending on the needs of the moment. The hormonal system, together with the nervous system, integrates the whole body's functioning so that all parts act smoothly together.

Appendix B Basic Chemistry Concepts

CONTENTS

Matter: The Properties of Atoms
Chemical Bonding
Formation of Ions
Water, Acids, and Bases
Chemical Reactions
Formation of Free Radicals

This appendix is intended to provide the background in basic chemistry you need to understand the nutrition concepts presented in this book. Chemistry is the branch of natural science that is concerned with the description and classification of **matter**, the changes that matter undergoes, and the **energy** associated with these changes. The accompanying glossary defines matter, energy, and other related terms.

Matter: The Properties of Atoms

Every substance has physical and chemical properties that distinguish it from all other substances and thus give it a unique identity. The physical properties include such characteristics as color, taste, texture, and odor, as well as the temperatures at which a substance changes its state (from a solid to a liquid or from a liquid to a gas) and the weight of a unit volume (its density). The chemical properties of a substance have to do with how it reacts with other substances or responds to a change in its environment so that new substances with different sets of properties are produced.

A physical change does not change a substance's chemical composition. The three physical states—ice, water, and steam—all consist of two hydrogen atoms and one oxygen atom bound together. In contrast, a chemical change occurs when an electric current passes through water. The water disappears, and two different substances are formed: hydrogen gas, which is flammable, and oxygen gas, which supports life.

Substances: Elements and Compounds The smallest part of a substance that can exist separately without losing its physical and chemical properties is a **molecule**. If a molecule is composed of **atoms** that are alike, the substance is an **element** (for example, O_2). If a molecule is **composed** of two or more different kinds of atoms, the substance is a **compound** (for example, H_2O).

Just over 100 elements are known, and these are listed in Table B-1 (p. B-1). A familiar example is hydrogen, whose molecules are composed only of hydrogen atoms linked together in pairs (H_2). On the other hand, more than a million compounds are known. An example is the sugar glucose. Each of its molecules is composed of 6 carbon, 6 oxygen, and 12 hydrogen atoms linked together in a specific arrangement (as described in Chapter 4).

The Nature of Atoms Atoms themselves are made of smaller particles. Within an atom's nucleus are protons (positively charged particles), and surrounding the nucleus are an equal number of electrons (negatively charged particles). The number of protons in the nucleus of an atom determines the atomic number. The positive charge on a proton is equal to the negative charge on an electron, so the charges cancel each other out and leave the atom neutral to its surroundings.

The nucleus may also include neutrons, subatomic particles that have no charge. Protons and neutrons are of equal mass, and together they give an atom its atomic mass. Electrons bond atoms together to make molecules, and they are involved in chemical reactions.

GLOSSARY

anion: a negatively changed ion.

atoms: the smallest components of an element that have all of the properties of the element.

cation: a positively changed ion.

compound: a substance composed of two or more different atoms—for example, water (H_2O).

covalent bonds: strong chemical bonds formed between atoms by sharing electrons.

element: a substance composed of atoms that are alike—for example, iron (Fe).

energy: the capacity to do work.

ion: an atom or group of atoms that have gained or lost one or more electrons and therefore have a negative or positive electrical charge.

matter: anything that takes up space and has mass.

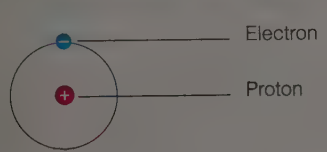
molecule: two or more atoms of the same or different elements joined by chemical bonds. Examples are molecules of the element oxygen, composed of two oxygen atoms (O_2), and molecules of the compound water, composed of two hydrogen atoms and one oxygen atom (H_2O).

TABLE B-1 The Elements

Number of Protons (Atomic Number)	Element	Number of Electrons in Outer Shell
1	Hydrogen (H)	1
2	Helium (He)	2
3	Lithium (Li)	1
4	Beryllium (Be)	2
5	Boron (B)	3
6	Carbon (C)	4
7	Nitrogen (N)	5
8	Oxygen (O)	6
9	Fluorine (F)	7
10	Neon (Ne)	8
11	Sodium (Na)	1
12	Magnesium (Mg)	2
13	Aluminum (Al)	3
14	Silicon (Si)	4
15	Phosphorus (P)	5
16	Sulfur (S)	6
17	Chlorine (Cl)	7
18	Argon (Ar)	8
19	Potassium (K)	1
20	Calcium (Ca)	2
21	Scandium (Sc)	2
22	Titanium (Ti)	2
23	Vanadium (V)	2
24	Chromium (Cr)	1
25	Manganese (Mn)	2
26	Iron (Fe)	2
27	Cobalt (Co)	2
28	Nickel (Ni)	2
29	Copper (Cu)	1
30	Zinc (Zn)	2
31	Gallium (Ga)	3
32	Germanium (Ge)	4
33	Arsenic (As)	5
34	Selenium (Se)	6
35	Bromine (Br)	7
36	Krypton (Kr)	8
37	Rubidium (Rb)	1
38	Strontium (Sr)	2
39	Yttrium (Y)	2
40	Zirconium (Zr)	2
41	Niobium (Nb)	1
42	Molybdenum (Mo)	1
43	Technetium (Tc)	1
44	Ruthenium (Ru)	1
45	Rhodium (Rh)	1
46	Palladium (Pd)	—
47	Silver (Ag)	1
48	Cadmium (Cd)	2
49	Indium (In)	3
50	Tin (Sn)	4
51	Antimony (Sb)	5
52	Tellurium (Te)	6
53	Iodine (I)	7
54	Xenon (Xe)	8
55	Cesium (Cs)	1
56	Barium (Ba)	2
57	Lanthanum (La)	2
58	Cerium (Ce)	2
59	Praseodymium (Pr)	2
60	Neodymium (Nd)	2
61	Promethium (Pm)	2
62	Samarium (Sm)	2
63	Europium (Eu)	2
64	Gadolinium (Gd)	2
65	Terbium (Tb)	2
66	Dysprosium (Dy)	2
67	Holmium (Ho)	2
68	Erbium (Er)	2
69	Thulium (Tm)	2
70	Ytterbium (Yb)	2
71	Lutetium (Lu)	2
72	Hafnium (Hf)	2
73	Tantalum (Ta)	2
74	Tungsten (W)	2
75	Rhenium (Re)	2
76	Osmium (Os)	2
77	Iridium (Ir)	2
78	Platinum (Pt)	1
79	Gold (Au)	1
80	Mercury (Hg)	2
81	Thallium (Tl)	3
82	Lead (Pb)	4
83	Bismuth (Bi)	5
84	Polonium (Po)	6
85	Astatine (At)	7
86	Radon (Rn)	8
87	Francium (Fr)	1
88	Radium (Ra)	2
89	Actinium (Ac)	2
90	Thorium (Th)	2
91	Protactinium (Pa)	2
92	Uranium (U)	2
93	Neptunium (Np)	2
94	Plutonium (Pu)	2
95	Americium (Am)	2
96	Curium (Cm)	2
97	Berkelium (Bk)	2
98	Californium (Cf)	2
99	Einsteinium (Es)	2
100	Fermium (Fm)	2
101	Mendelevium (Md)	2
102	Nobelium (No)	2
103	Lawrencium (Lr)	2
104	Rutherfordium (Rf)	2
105	Dubnium (Db)	2
106	Seaborgium (Sg)	2
107	Bohrium (Bh)	2
108	Hassium (Hs)	2
109	Meitnerium (Mt)	2
110	Darmstadtium (Ds)	2

Key
- Elements found in energy-yielding nutrients, vitamins, and water
- Major minerals
- Trace minerals

Each element has a characteristic number of protons in its atom's nucleus. For example, the hydrogen atom (the simplest of all) possesses a single proton, with a single electron associated with it:

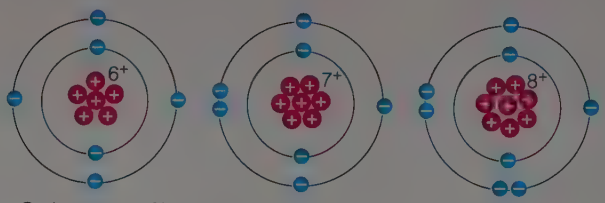


Hydrogen atom (H), atomic number 1

Just as hydrogen always has one proton, helium always has two, lithium three, and so on. The atomic number of each element is the number of protons in the nucleus of that atom, and this never changes in a chemical reaction; it gives the atom its identity. The atomic numbers for the known elements are listed in Table B-1.

In addition to hydrogen, the atoms most common in living things are carbon (C), nitrogen (N), and oxygen (O), whose atomic numbers are 6, 7, and 8, respectively. Their structures are more complicated than that of hydrogen, but each of them

possesses the same number of electrons as there are protons in the nucleus. These electrons are found in orbits, or shells (shown below).



Carbon atom (C), atomic number 6 | Nitrogen atom (N), atomic number 7 | Oxygen atom (O), atomic number 8

In these and all diagrams of atoms that follow, only the protons and electrons are shown. The neutrons, which contribute only to atomic weight, not to charge, are omitted.

The most important structural feature of an atom for determining its chemical behavior is the number of electrons in its outermost shell. The first, or innermost, shell is full when it is occupied by two electrons; so an atom with two or more electrons has a filled first shell. When the first shell is full, electrons begin to fill the second shell.

The second shell is completely full when it has eight electrons. A substance that has a full outer shell tends not to enter into chemical reactions. Atomic number 10, neon, is a chemically inert substance because its outer shell is complete. Fluorine, atomic number 9, has a great tendency to draw an electron from other substances to complete its outer shell, and thus it is highly reactive. Carbon has a half-full outer shell, which helps explain its great versatility; it can combine with other elements in a variety of ways to form a large number of compounds.

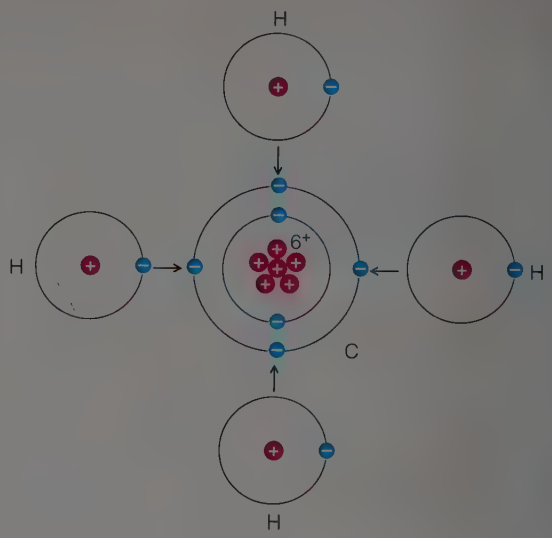
Atoms seek to reach a state of maximum stability or of lowest energy in the same way that a ball will roll down a hill until it reaches the lowest place. An atom achieves a state of maximum stability:

- By gaining or losing electrons to either fill or empty its outer shell.
- By sharing its electrons with other atoms and thereby completing its outer shell.

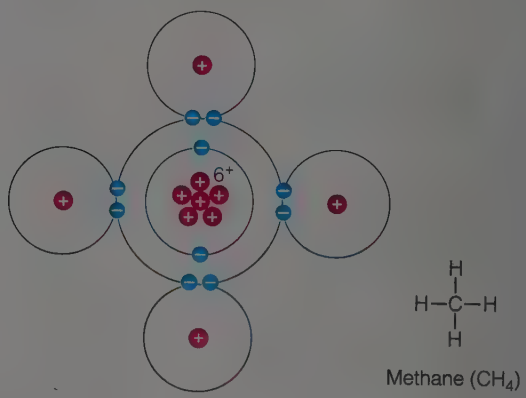
The number of electrons determines how the atom will chemically react with other atoms.

Chemical Bonding

Atoms often complete their outer shells by sharing electrons with other atoms. In order to complete its outer shell, a carbon atom requires four electrons. A hydrogen atom requires one. Thus, when a carbon atom shares electrons with four hydrogen atoms, each completes its outer shell (as shown below). Electron sharing binds the atoms together and satisfies the conditions of maximum stability for the molecule. The outer shell of each atom is complete because hydrogen effectively has the required 2 electrons in its first (outer) shell, and carbon has 8 electrons in its second (outer) shell; and the molecule is electrically neutral, with a total of 10 protons and 10 electrons.



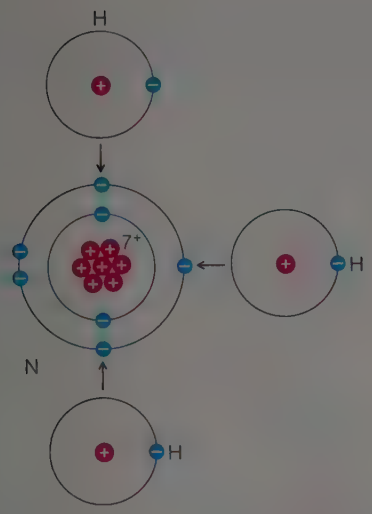
When a carbon atom shares electrons with four hydrogen atoms, a methane molecule is made.



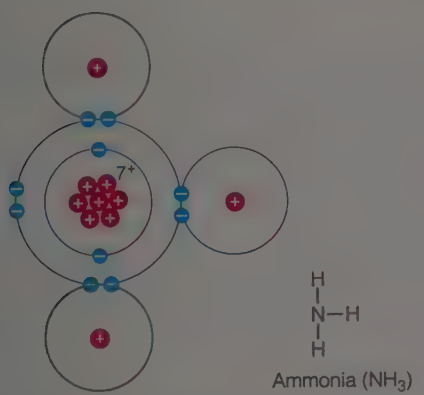
The chemical formula for methane is CH_4. Note that by sharing electrons, every atom achieves a filled outer shell.

Bonds that involve the sharing of electrons, like the bonds between carbon and the four hydrogens, are the most stable kind of association that atoms can form with one another. These bonds are called **covalent bonds**, and the resulting combination of atoms is called a molecule. A single pair of shared electrons forms a single bond. A simplified way to represent a single bond is with a single line.

Similarly, one nitrogen atom and three hydrogen atoms can share electrons to form one molecule of ammonia (NH_3):



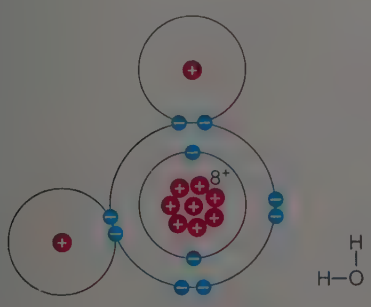
When a nitrogen atom shares electrons with three hydrogen atoms, an ammonia molecule is made.



Ammonia (NH_3)

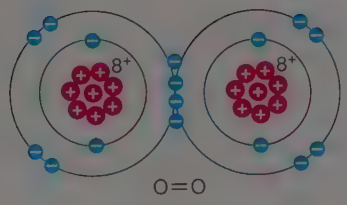
The chemical formula for ammonia is NH_3. Count the electrons in each atom's outer shell to confirm that it is filled.

One oxygen atom may be bonded to two hydrogen atoms to form one molecule of water (H_2O):



Water molecule (H_2O)

When two oxygen atoms form a molecule of oxygen, they must share two pairs of electrons. This double bond may be represented as two single lines:



Oxygen molecule (O_2)

Small atoms form the tightest, most stable bonds. H, O, N, and C are the smallest atoms capable of forming one, two, three, and four electron-pair bonds, respectively. This is the basis for the statement in Chapter 4 that in drawings of compounds containing these atoms, hydrogen must always have one, oxygen two, nitrogen three, and carbon four bonds radiating to other atoms:



The stability of the associations between these small atoms and the versatility with which they can combine make them very common in living things. Interestingly all cells—whether they come from animals, plants, or bacteria—contain the same elements in very nearly the same proportions. The elements commonly found in living things are shown in Table B-2.

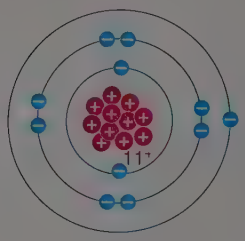
TABLE B-2 Elemental Composition of the Human Body

Element	Chemical Symbol	By Weight (%)
Oxygen	O	65.0
Carbon	C	18.0
Hydrogen	H	10.0
Nitrogen	N	3.0
Calcium	Ca	1.5
Phosphorus	P	1.0
Potassium	K	0.4
Sulfur	S	0.3
Sodium	Na	0.2
Chloride	Cl	0.1
Magnesium	Mg	0.1
Total		99.6[a]

[a]The remaining 0.4 percent by weight is contributed by the trace elements: chromium (Cr), copper (Cu), zinc (Zn), selenium (Se), molybdenum (Mo), fluorine (F), iodine (I), manganese (Mn), and iron (Fe). Cells may also contain variable traces of some of the following: boron (B), cobalt (Co), Lithium (Li), strontium (Sr), aluminum (AL), silicon (Si), Lead (Pb), vanadium (V), arsenic (As), bromine (Br), and others.

Formation of Ions

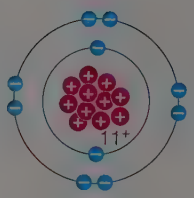
An atom such as sodium (Na, atomic number 11) cannot easily fill its outer shell by sharing. Sodium possesses a filled first shell of two electrons and a filled second shell of eight; there is only one electron in its outermost shell:



Sodium atom (Na)
11 + charges
11 – charges

0 net charge with one reactive electron in the outer shell

Loss of 1 electron

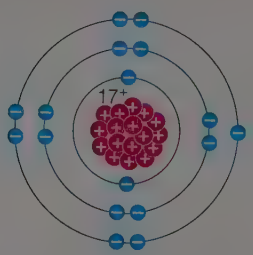


Sodium ion (Na^+)
11 + charges
10 – charges

1 + net charge and a filled outer shell

If sodium loses this electron, it satisfies one condition for stability: a filled outer shell (now its second shell counts as the outer shell). However, it is not electrically neutral. It has 11 protons (positive) and only 10 electrons (negative). It therefore has a net positive charge. An atom or molecule that has lost or gained one or more electrons and so is electrically charged is called an **ion**.

An atom such as chlorine (Cl, atomic number 17), with seven electrons in its outermost shell, can share electrons to fill its outer shell, or it can gain one electron to complete its outer shell and thus give it a negative charge:

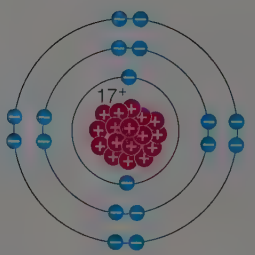


Chlorine atom (Cl)

17 + charges
17 – charges

0 net charge but lacks one electron to fill outer shell

Gain of 1 electron

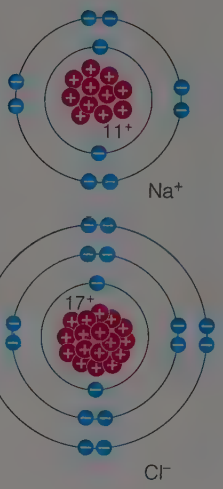


Chloride ion (Cl^-)

17 + charges
18 – charges

1 – net charge and a filled outer shell

A positively charged ion such as sodium ion (Na^+) is called a **cation**; a negatively charged ion such as a chloride ion (Cl^-) is called an **anion**. Cations and anions attract one another to form salts:



Sodium chloride (Na^+Cl^-)

28 + charges
28 – charges

0 net charge and filled outer shells

With all its electrons, sodium is a shiny, highly reactive metal; chlorine is the poisonous greenish yellow gas that was used in World War I. But after sodium and chlorine have transferred electrons, they form the stable white salt familiar to you as table salt, or sodium chloride (Na^+Cl^-). The dramatic difference illustrates how profoundly the electron arrangement can influence the nature of a substance. The wide distribution of salt in nature attests to the stability of the union between the ions. Each meets the other's needs (a good marriage).

When dry, salt exists as crystals; its ions are stacked very regularly into a lattice, with positive and negative ions alternating in a three-dimensional checkerboard structure. In water, however, the salt quickly dissolves, and its ions separate from one another, forming an electrolyte solution in which they move about freely. Covalently bonded molecules rarely dissociate like this in a water solution. The most common exception is when they behave like acids and release H^+ ions, as discussed in the next section.

An ion can also be a group of atoms bound together in such a way that the group has a net charge and enters into reactions as a single unit. Many such groups are active in the fluids of the body. The bicarbonate ion is composed of five atoms—one H, one C, and three Os—and has a net charge of −1 (HCO_3^-). Another important ion of this type is a phosphate ion with one H, one P, and four O, and a net charge of −2 (HPO_4^{-2}).

Whereas many elements have only one configuration in the outer shell and thus only one way to bond with other elements, some elements have the possibility of varied configurations. Iron is such an element. Under some conditions iron loses two electrons, and under other circumstances it loses three. If iron loses two electrons, it then has a net charge of +2, and we call it ferrous iron (Fe^{++}). If it donates three electrons to another atom, it becomes the +3 ion, or ferric iron (Fe^{+++}).

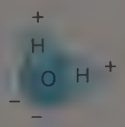
Ferrous iron (Fe^{++})	Ferric iron (Fe^{+++})
(had 2 outer-shell electrons but has lost them)	(had 3 outer-shell electrons but has lost them)
26 + charges	26 + charges
24 − charges	23 − charges
2 + net charge	3 + net charge

Remember that a positive charge on an ion means that negative charges—electrons—have been lost and not that positive charges have been added to the nucleus.

Water, Acids, and Bases

Water The water molecule is electrically neutral, having equal numbers of protons and electrons. When a hydrogen atom shares its electron with oxygen, however, that electron will spend most of its time closer to the positively charged oxygen nucleus. This leaves the positive proton (nucleus of the hydrogen atom) exposed on the outer part of the water molecule. We know, too, that the two hydrogens both bond toward the same side of the oxygen. These two facts explain why water molecules are polar: they have regions of more positive and more negative charge.

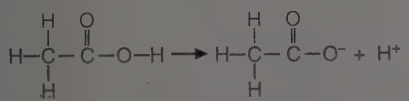
Polar molecules like water are drawn to one another by the attractive forces between the positive polar areas of one and the negative poles of another. These attractive forces, sometimes known as polar bonds or hydrogen bonds, occur among many molecules and also within the different parts of single large molecules. Although very weak in comparison with covalent bonds, polar bonds may occur in such abundance that they become exceedingly important in determining the structure of such large molecules as proteins and DNA.



This diagram of the polar water molecule shows displacement of electrons toward the O nucleus; thus the negative region is near the O and the positive regions are near the H atoms.

Water molecules have a slight tendency to ionize, separating into positive (H^+) and negative (OH^-) ions. In pure water, a small but constant number of these ions is present, and the number of positive ions exactly equals the number of negative ions.

Acids An acid is a substance that releases H^+ ions (protons) in a water solution. Hydrochloric acid (HCl^-) is such a substance because it dissociates in a water solution into H^+ and Cl^- ions. Acetic acid is also an acid because it dissociates in water to acetate ions and free H^+:

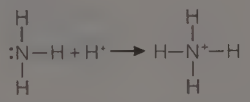


Acetic acid dissociates into an acetate ion and a hydrogen ion.

The more H^+ ions released, the stronger the acid.

Chemists define degrees of acidity by means of the pH scale, which runs from 0 to 14. The pH expresses the concentration of H^+ ions: a pH of 1 is extremely acidic, 7 is neutral, and 13 is very basic. There is a tenfold difference in the concentration of H^+ ions between points on this scale. A solution with pH 3, for example, has 10 times as many H^+ ions as a solution with pH 4. At pH 7, the concentrations of free H^+ and OH^- are exactly the same—1/10,000,000 moles per liter.* At pH 4, the concentration of free H^+ ions is 1/10,000 moles per liter. This is a higher concentration of H^+ ions, and the solution is therefore acidic. Figure 3-6 on p. 75 presents the pH scale.

Bases A base is a substance that can combine with H^+ ions, thus reducing the acidity of a solution. The compound ammonia is such a substance. The ammonia molecule has two electrons that are not shared with any other atom; a hydrogen ion (H^+) is just a proton with no shell of electrons at all. The proton readily combines with the ammonia molecule to form an ammonium ion; thus a free proton is withdrawn from the solution and no longer contributes to its acidity. Many compounds containing nitrogen are important bases in living systems. Acids and bases neutralize each other to produce substances that are neither acid nor base.



Ammonia captures a hydrogen ion from water. The two dots here represent the two electrons not shared with another atom. These dots are ordinarily not shown in chemical structure drawings. Compare this drawing with the earlier diagram of an ammonia molecule (p. B-3).

Chemical Reactions

A chemical reaction results in the breakdown or formation of substances. Almost all such reactions involve a change in the bonding of atoms. Old bonds are broken, and new ones are formed. The nuclei of atoms are never involved in chemical reactions—only their outer-shell electrons participate. At the end of a chemical reaction, the number of atoms of each type is always the same as at the beginning. For example, two hydrogen molecules ($2H_2$) can react with one oxygen molecule (O_2) to form two water molecules ($2H_2O$). In this reaction two substances (hydrogen and oxygen) disappear, and a new one (water) is formed, but at the end of the reaction there are still four H atoms and two O atoms, just as there were at the beginning. Because the atoms are now linked in a different way, their characteristics or properties have changed.

In many instances chemical reactions involve not the relinking of molecules but the exchanging of electrons or protons among them. In such reactions the molecule that gains one or more electrons (or loses one or more hydrogen ions) is said to be reduced; the molecule that loses electrons (or gains protons) is oxidized. A hydrogen ion is equivalent to a proton.

*A mole is a certain number (about 6×10^{23}) of molecules. The pH of a solution is defined as the negative logarithm of the hydrogen ion concentration of the solution. Thus, if the concentration is 10^{-2} (moles per liter), the pH is 2; if 10^{-8}, the pH is 8; and so on.

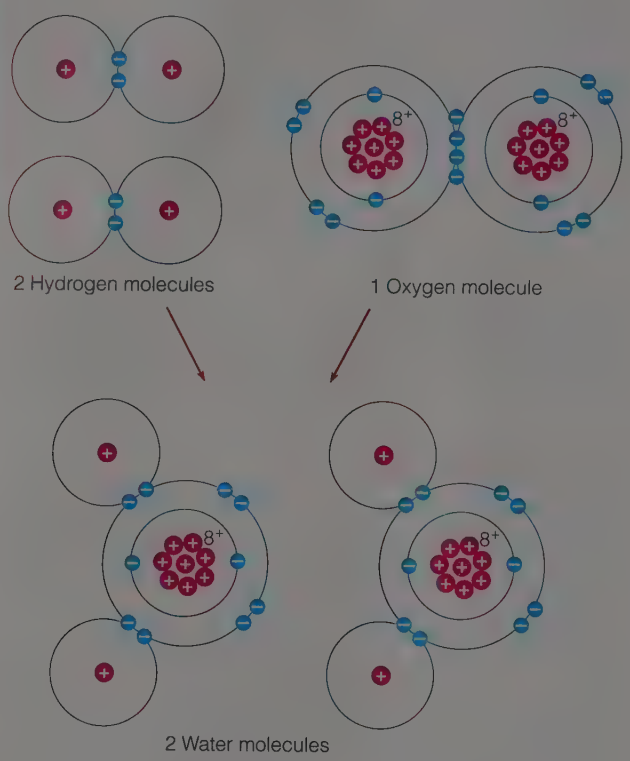
Oxidation and reduction reactions take place simultaneously because an electron or proton that is lost by one molecule is accepted by another. The addition of an atom of oxygen is also oxidation because oxygen (with six electrons in the outer shell) accepts two electrons in becoming bonded. Oxidation, then, is loss of electrons, gain of protons, or addition of oxygen (with six electrons); reduction is the opposite—gain of electrons, loss of protons, or loss of oxygen. The addition of hydrogen atoms to oxygen to form water can thus be described as the reduction of oxygen *or* the oxidation of hydrogen.

If a reaction results in a net increase in the energy of a compound, it is called an endergonic, or "uphill," reaction (energy *erg,* is added into, *endo,* the compound). An example is the chief result of photosynthesis, the making of sugar in a plant from carbon dioxide and water using the energy of sunlight. Conversely, the oxidation of sugar to carbon dioxide and water is an exergonic, or "downhill," reaction because the end products have less energy than the starting products. Oftentimes, but not always, reduction reactions are endergonic, resulting in an increase in the energy of the products. Oxidation reactions often, but not always, are exergonic.

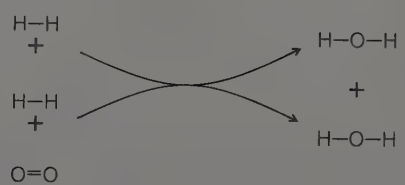
Chemical reactions tend to occur spontaneously if the end products are in a lower energy state and therefore are more stable than the reacting compounds. These reactions often give off energy in the form of heat as they occur. The generation of heat by wood burning in a fireplace and the maintenance of human body warmth both depend on energy-yielding chemical reactions. These downhill reactions occur easily although they may require some activation energy to get them started, just as a ball requires a push to start rolling.

Uphill reactions, in which the products contain more energy than the reacting compounds started with, do not occur until an energy source is provided. An example of such an energy source is the sunlight used in photosynthesis, where carbon dioxide and water (low-energy compounds) are combined to form the sugar glucose (a higher-energy compound). Another example is the use of the energy in glucose to combine two low-energy compounds in the body into the high-energy compound ATP (see Chapter 7). The energy in ATP may be used to power many other energy-requiring, uphill reactions. Clearly, any of many different molecules can be used as a temporary storage place for energy.

Diagrams:



Structures:

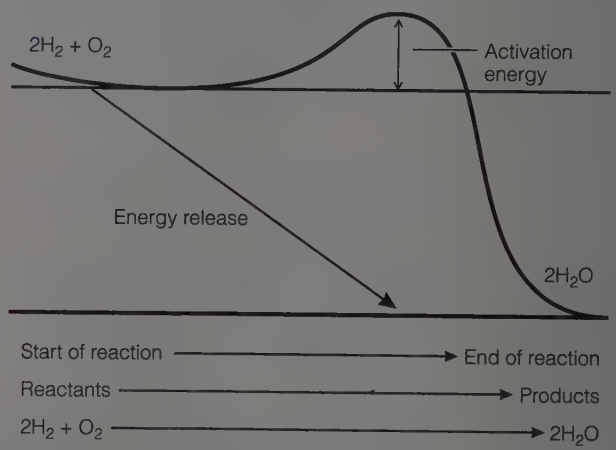


Formulas:

$2H_2 + O_2 \longrightarrow 2H_2O$

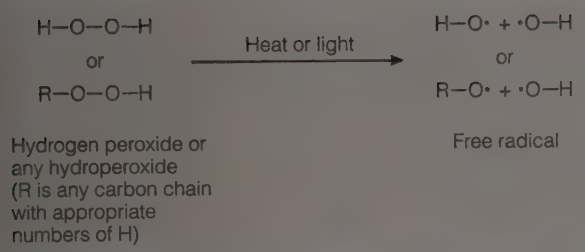
Hydrogen and oxygen react to form water.

Energy change as reaction occurs

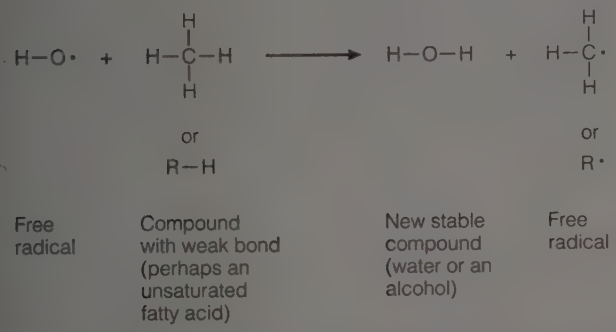


Formation of Free Radicals

Normally, when a chemical reaction takes place, bonds break and re-form with some redistribution of atoms and rearrangement of bonds to form new, stable compounds. Normally, bonds don't split in such a way as to leave a molecule with an odd, unpaired electron. When they do, free radicals are formed. Free radicals are highly unstable and quickly react with other compounds, forming more free radicals in a chain reaction. A cascade may ensue in which many highly reactive radicals are generated, resulting finally in the disruption of a living structure such as a cell membrane.



Free radicals are formed. The dots represent single electrons that are available for sharing (the atom needs another electron to fill its outer shell).



Free radicals destroy biological compounds. The free radical attacks a weak bond in a biological compound, disrupting it and forming a new stable molecule and another free radical. This free radical can attack another biological compound, and so on.

Oxidation of some compounds can be induced by air at room temperature in the presence of light. Such reactions are thought to take place through the formation of compounds called peroxides:

Peroxides:	
H—O—O—H	Hydrogen peroxide
R—O—O—H	Hydroperoxides (R is any carbon chain with appropriate numbers of H)
R—O—O—R	Peroxide

Some peroxides readily disintegrate into free radicals, initiating chain reactions like those just described.

Free radicals are of special interest in nutrition because the antioxidant properties of vitamins C and E as well as beta-carotene and the mineral selenium are thought to protect against the destructive effects of these free radicals (see Highlight 11). For example, vitamin E on the surface of the lungs reacts with, and is destroyed by, free radicals, thus preventing the radicals from reaching underlying cells and oxidizing the lipids in their membranes.

Appendix C Biochemical Structures and Pathways

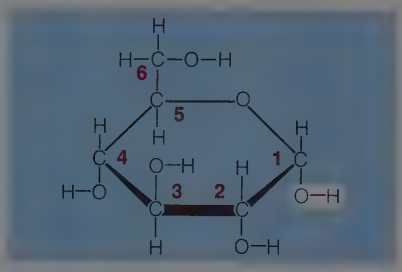
CONTENTS

Carbohydrates
Lipids
Protein: Amino Acids
Vitamins and Coenzymes
Glycolysis
Fatty Acid Oxidation
Amino Acid Degradation
The TCA Cycle
The Electron Transport Chain
Alcohol's Interference with Energy Metabolism
The Urea Cycle
Formation of Ketone Bodies

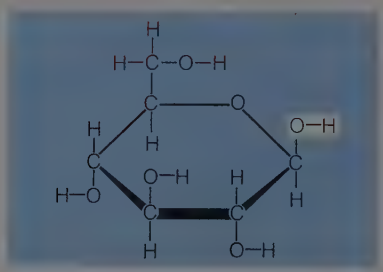
The diagrams of nutrients presented here are meant to enhance your understanding of the most important organic molecules in the human diet. Following the diagrams of nutrients are sections on the major metabolic pathways mentioned in Chapter 7—glycolysis, fatty acid oxidation, amino acid degradation, the TCA cycle, and the electron transport chain—and a description of how alcohol interferes with these pathways. Discussions of the urea cycle and the formation of ketone bodies complete the appendix.

Carbohydrates

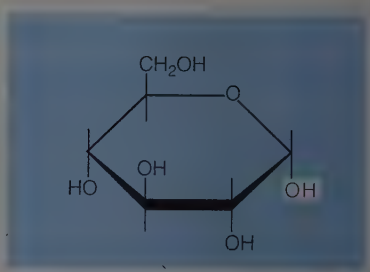
Monosaccharides



Glucose (alpha form). The ring would be at right angles to the plane of the paper. The bonds directed upward are above the plane; those directed downward are below the plane. This molecule is considered an alpha form because the OH on carbon 1 points downward.

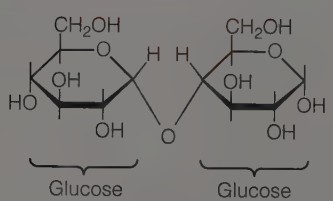


Glucose (beta form). The OH on carbon 1 points upward.
Fructose, galactose: see Chapter 4.

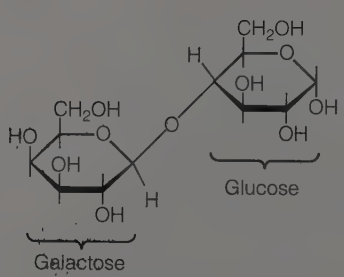


Glucose (alpha form) shorthand notation. This notation, in which the carbons in the ring and single hydrogens have been eliminated, will be used throughout this appendix.

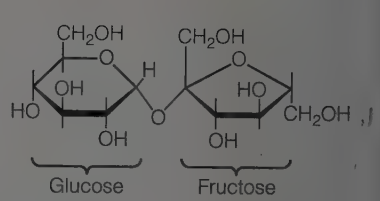
Disaccharides



Maltose.

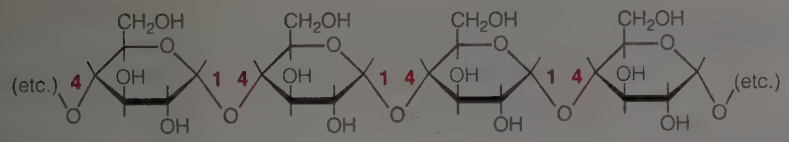


Lactose (alpha form).

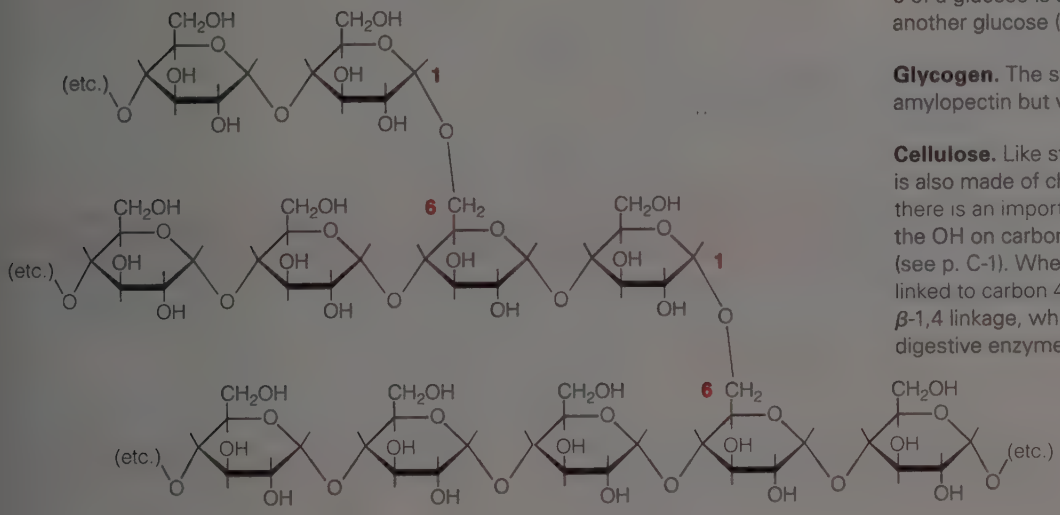


Sucrose.

Polysaccharides As described in Chapter 4, starch, glycogen, and cellulose are all long chains of glucose molecules covalently linked together.



Amylose (unbranched starch)



Amylopectin (branched starch)

Starch. Two kinds of covalent linkages occur between glucose molecules in starch, giving rise to two kinds of chains. Amylose is composed of straight chains, with carbon 1 of one glucose linked to carbon 4 of the next (α-1,4 linkage). Amylopectin is made up of straight chains like amylose but has occasional branches arising where the carbon 6 of a glucose is also linked to the carbon 1 of another glucose (α-1,6 linkage).

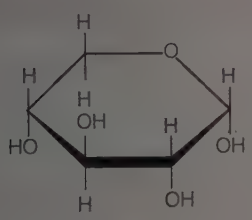
Glycogen. The structure of glycogen is like amylopectin but with many more branches.

Cellulose. Like starch and glycogen, cellulose is also made of chains of glucose units, but there is an important difference: in cellulose, the OH on carbon 1 is in the beta position (see p. C-1). When carbon 1 of one glucose is linked to carbon 4 of the next, it forms a β-1,4 linkage, which cannot be broken by digestive enzymes in the human GI tract.

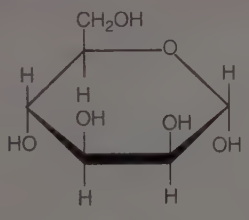
APPENDIX C

Fibers, such as hemicelluloses, consist of long chains of various monosaccharides.

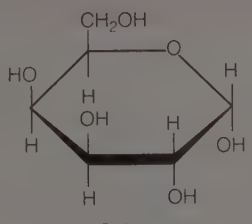
Monosaccharides common in the backbone chain of hemicelluloses:*



Xylose



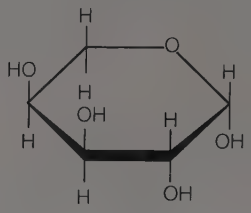
Mannose



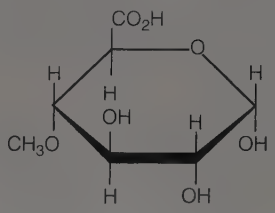
Galactose

*These structures are shown in the alpha form with the H on the carbon pointing upward and the OH pointing downward, but they may also appear in the beta form with the H pointing downward and the OH upward.

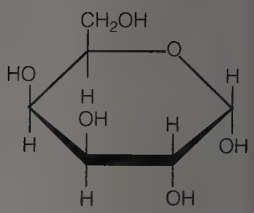
Monosaccharides common in the side chains of hemicelluloses:



Arabinose



Glucuronic acid



Galactose

Hemicelluloses. The most common hemicelluloses are composed of a backbone chain of xylose, mannose, and galactose, with branching side chains of arabinose, glucuronic acid, and galactose.

Lipids

TABLE C-1 Saturated Fatty Acids Found in Natural Fats

Saturated Fatty Acids	Chemical Formulas	Number of Carbons	Major Food Sources
Butyric	C_3H_7COOH	4	Butterfat
Caproic	$C_5H_{11}COOH$	6	Butterfat
Caprylic	$C_7H_{15}COOH$	8	Coconut oil
Capric	$C_9H_{19}COOH$	10	Palm oil
Laurie	$C_{11}H_{23}COOH$	12	Coconut oil, palm oil
Myristic[a]	$C_{13}H_{27}COOH$	14	Coconut oil, palm oil
Palmitic[a]	$C_{15}H_{31}COOH$	16	Palm oil
Stearic[c]	$C_{17}H_{35}COOH$	18	Most animal fats
Arachidic	$C_{19}H_{39}COOH$	20	Peanut oil
Behenic	$C_{21}H_{43}COOH$	22	Seeds
Lignoceric	$C_{23}H_{47}COOH$	24	Peanut oil

[a]Most common saturated fatty acids.

TABLE C-2 Unsaturated Fatty Acids Found in Natural Fats

Unsaturated Fatty Acids	Chemical Formulas	Number of Carbons	Number of Double Bonds	Standard Notation[a]	Omega Notation[b]	Major Food Sources
Palmitoleic	$C_{15}H_{29}COOH$	16	1	16:1;9	16:1ω7	Seafood, beef
Oleic	$C_{17}H_{33}COOH$	18	1	18:1;9	18:1ω9	Olive oil, canola oil
Linoleic	$C_{17}H_{31}COOH$	18	2	18:2;9,12	18:2ω6	Sunflower oil, safflower oil
Linolenic	$C_{17}H_{29}COOH$	18	3	18:3;9,12,15	18:3ω3	Soybean oil, canola oil
Arachidonic	$C_{19}H_{31}COOH$	20	4	20:4;5,8,11,14	20:4ω6	Eggs, most animal fats
Eicosapentaenoic	$C_{19}H_{29}COOH$	20	5	20:5;5,8,11,14,17	20:5ω3	Seafood
Docosahexaenoic	$C_{21}H_{31}COOH$	20	6	22:6;4,7,10,13,16,19	22:6ω3	Seafood

NOTE: A fatty acid has two ends; designated the methyl (CH_3) end and the carboxyl, or acid (COOH), end.

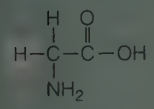
[a]Standard chemistry notation begins counting carbons at the acid end. The number of carbons the fatty acid contains comes first, followed by a colon and another number that indicates the number of double bonds; next comes a semicolon followed by a number or numbers indicating the positions of the double bonds. Thus the notation for linoleic acid, an 18-carbon fatty acid with two double bonds between carbons 9 and 10 and between carbons 12 and 13, is 18:2;9,12.

[b]Because fatty acid chains are lengthened by adding carbons at the acid end of the chain, chemists use the omega system of notation to ease the task of identifying them. The omega system begins counting carbons at the methyl end. The number of carbons the fatty acid contains comes first, followed by a colon and the number of double bonds; next come the omega symbol (ω) and a number indicating the position of the double bond nearest the methyl end. Thus linoleic acid with its first double bond at the sixth carbon from the methyl end would be noted 18:2ω6 in the omega system.

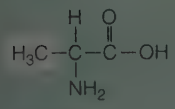
Protein: Amino Acids

The common amino acids may be classified into the seven groups listed below. Amino acids marked with an asterisk (*) are essential.

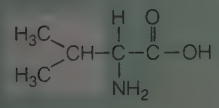
1. Amino acids with aliphatic side chains, which consist of hydrogen and carbon atoms (hydrocarbons):



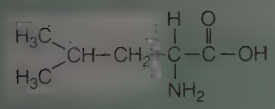
Glycine (Gly)



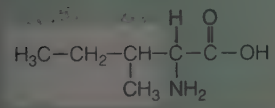
Alanine (Ala)



Valine* (Val)

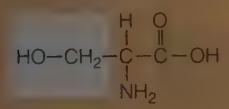


Leucine* (Leu)

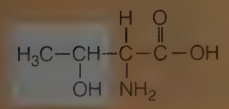


Isoleucine* (Ile)

2. Amino acids with hydroxyl (OH) side chains:

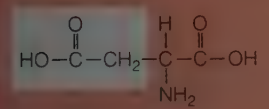


Serine (Ser)

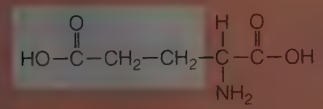


Threonine* (Thr)

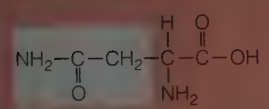
3. Amino acids with side chains containing acidic groups or their amides, which contain the group NH_2:



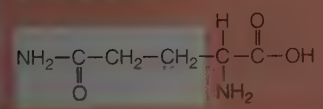
Aspartic acid (Asp)



Glutamic acid (Glu)

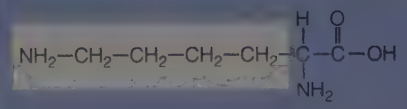


Asparagine (Asn)

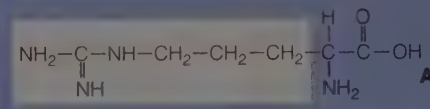


Glutamine (Gln)

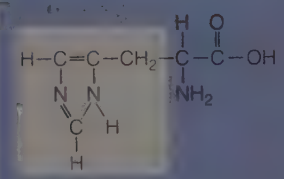
4. Amino acids with basic side chains:



Lysine* (Lys)

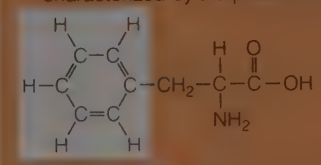


Arginine (Arg)

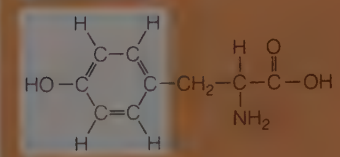


Histidine* (His)

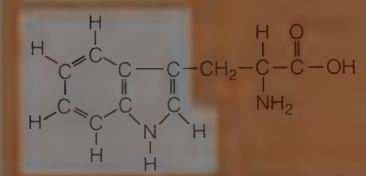
5. Amino acids with aromatic side chains, which are characterized by the presence of at least one ring structure:



Phenylalanine* (Phe)

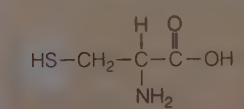


Tyrosine (Tyr)

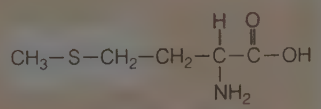


Tryptophan* (Trp)

6. Amino acids with side chains containing sulfur atoms:

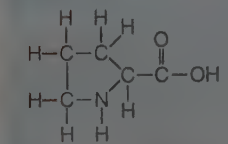


Cysteine (Cys)



Methionine* (Met)

7. Imino acid:

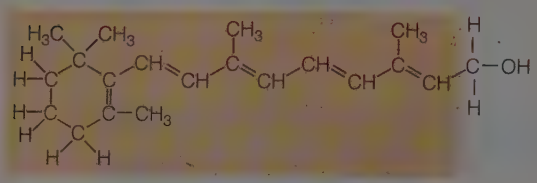


Proline (Pro)

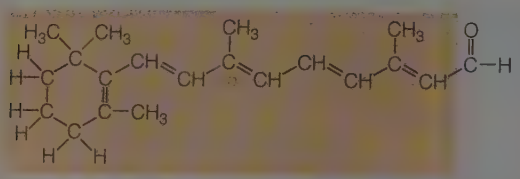
Proline has the same chemical structure as the other amino acids, but its amino group has given up a hydrogen to form a ring.

APPENDIX C

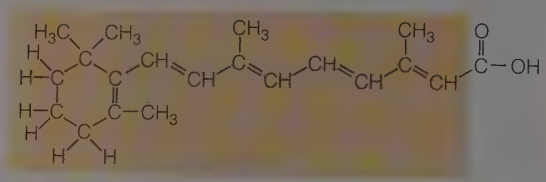
Vitamins and Coenzymes



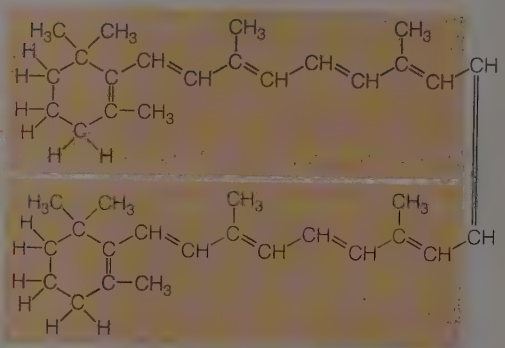
Vitamin A: retinol. This molecule is the alcohol form of vitamin A.



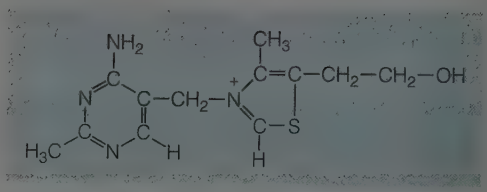
Vitamin A: retinal. This molecule is the aldehyde form of vitamin A.



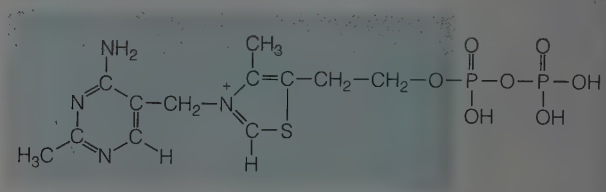
Vitamin A: retinoic acid. This molecule is the acid form of vitamin A.



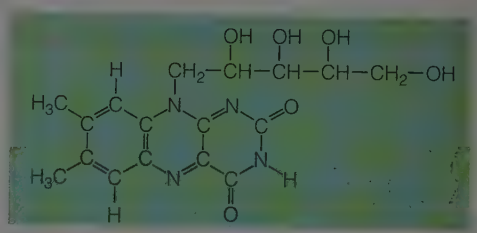
Vitamin A precursor: beta-carotene. This molecule is the carotenoid with the most vitamin A activity.



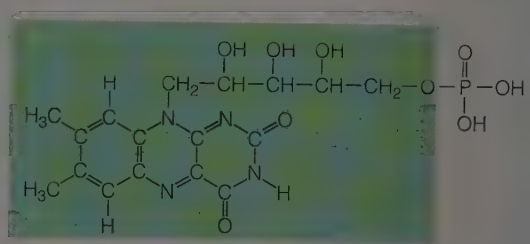
Thiamin. This molecule is part of the coenzyme thiamin pyrophosphate (TPP).



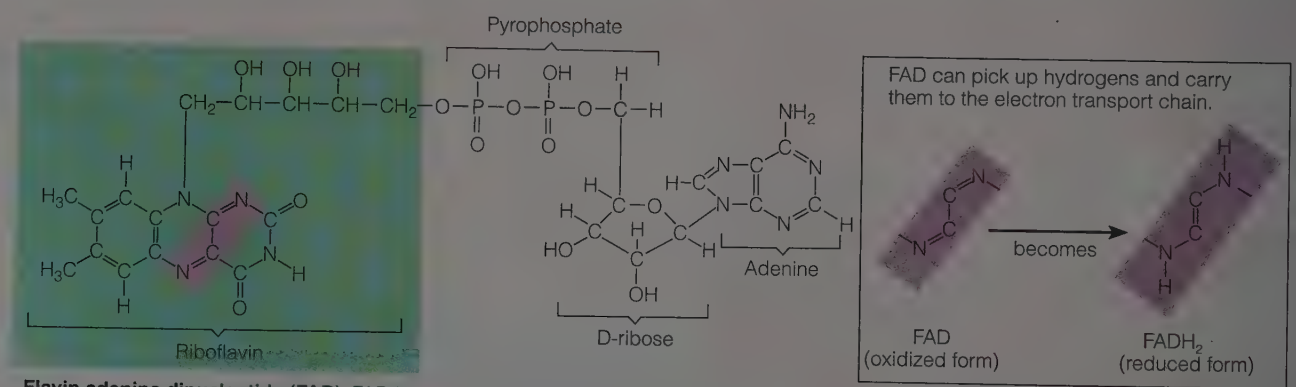
Thiamin pyrophosphate (TPP). TPP is a coenzyme that includes the thiamin molecule as part of its structure.



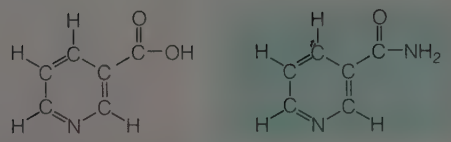
Riboflavin. This molecule is a part of two coenzymes—flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD).



Flavin mononucleotide (FMN). FMN is a coenzyme that includes the riboflavin molecule as part of its structure.

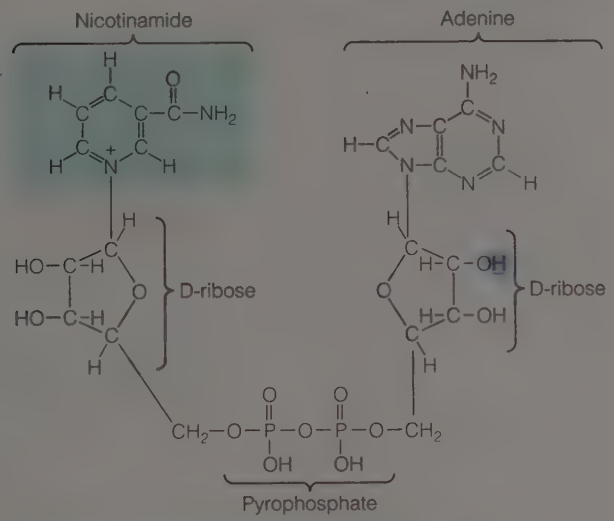


Flavin adenine dinucleotide (FAD). FAD is a coenzyme that includes the riboflavin molecule as part of its structure.

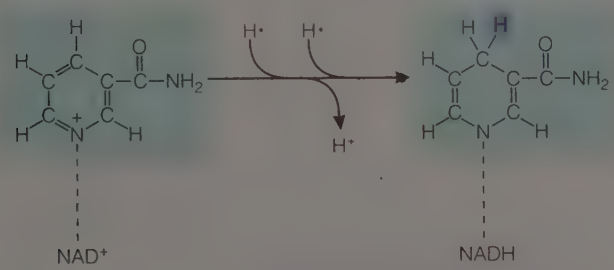


Nicotinic acid Nicotinamide

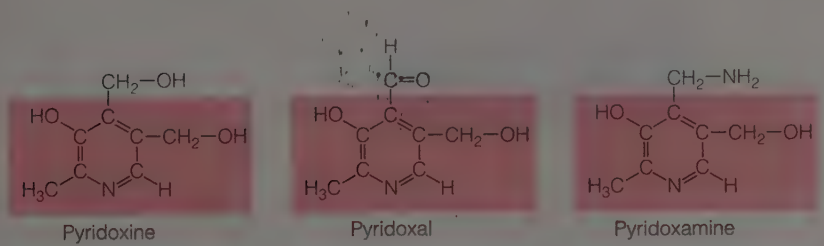
Niacin (nicotinic acid and nicotinamide). These molecules are a part of two coenzymes—nicotinamide adenine dinucleotide (NAD^+) and nicotinamide adenine dinucleotide phosphate ($NADP^+$).



Nicotinamide adenine dinucleotide (NAD^+) and nicotinamide adenine dinucleotide phosphate ($NADP^+$). NADP has the same structure as NAD but with a phosphate group attached to the O instead of the H.

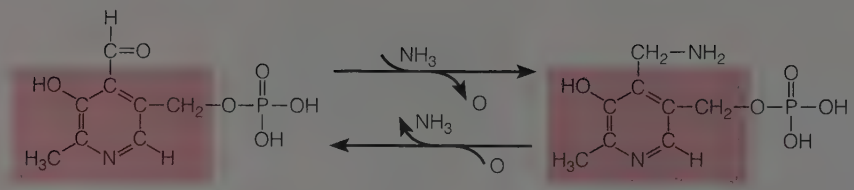


Reduced NAD^+ (NADH). When NAD^+ is reduced by the addition of H^+ and two electrons, it becomes the coenzyme NADH. (The dots on the H entering this reaction represent electrons—see Appendix B.)

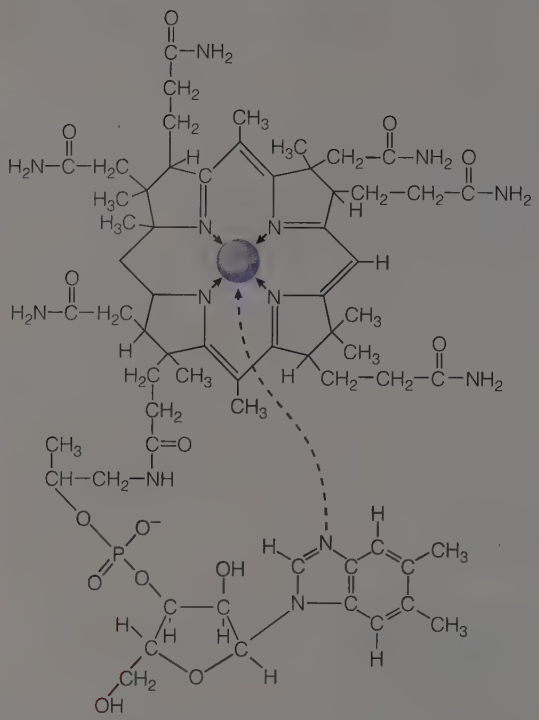


Pyridoxine Pyridoxal Pyridoxamine

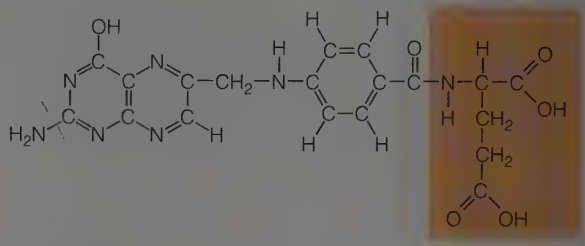
Vitamin B_6 (a general name for three compounds—pyridoxine, pyridoxal, and pyridoxamine). These molecules are a part of two coenzymes—pyridoxal phosphate and pyridoxamine phosphate.



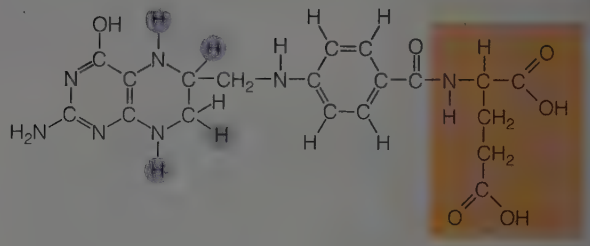
Pyridoxal phosphate (PLP) and pyridoxamine phosphate. These coenzymes include vitamin B_6 as part of their structures.



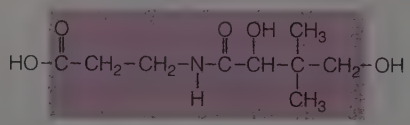
Vitamin B_{12} (cyanocobalamin). The arrows in this diagram indicate that the spare electron pairs on the nitrogens attract them to the cobalt.



Folate (folacin or folic acid). This molecule consists of a double ring combined with a single ring and at least one glutamate (a nonessential amino acid marked in the box). Folate's biologically active form is tetrahydrofolate.

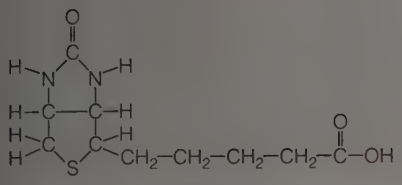


Tetrahydrofolate. This active coenzyme form of folate has four added hydrogens. An intermediate form, dihydrofolate, has two added hydrogens.

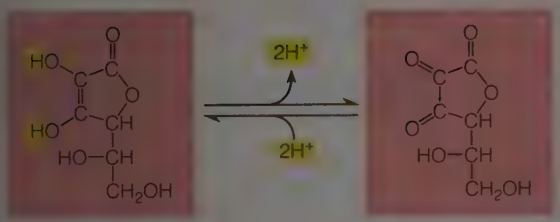


Pantothenic acid. This molecule is part of coenzyme A (CoA).

Coenzyme A (CoA). Coenzyme A is a coenzyme that includes pantothenic acid as part of its structure.



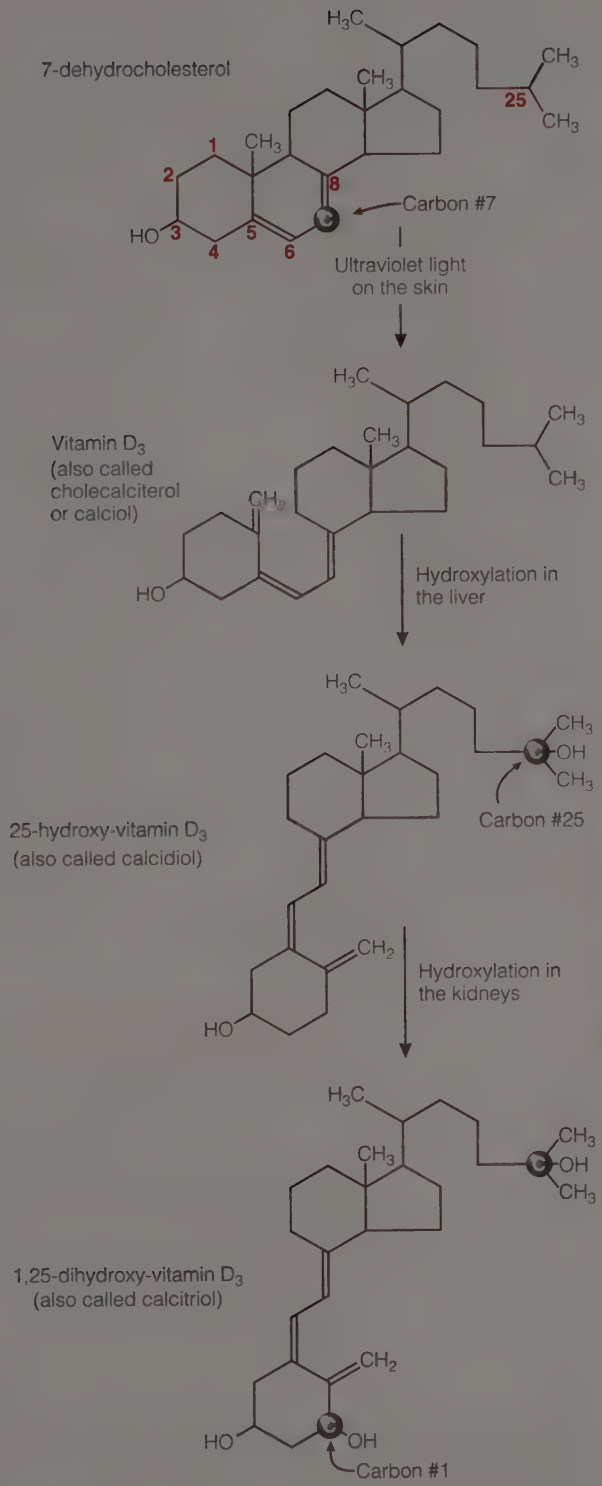
Biotin.



Ascorbic acid
(reduced form)

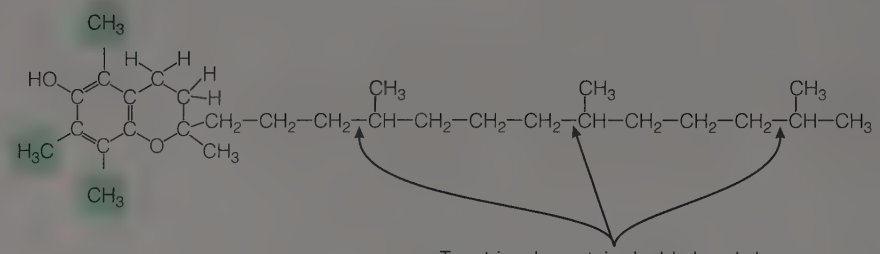
Dehydroascorbic acid
(oxidized form)

Vitamin C. Two hydrogen atoms with their electrons are lost when ascorbic acid is oxidized and gained when it is reduced again.

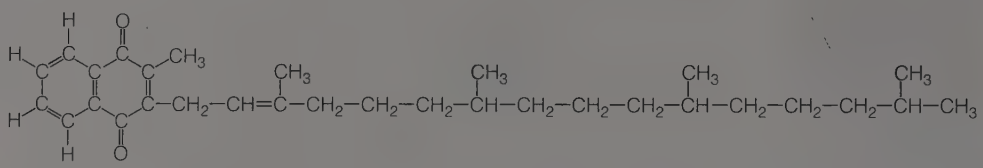


Vitamin D. The synthesis of active vitamin D begins with 7-dehydrocholesterol. (The carbon atoms at which changes occur are numbered.)

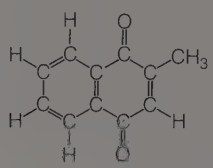
APPENDIX C



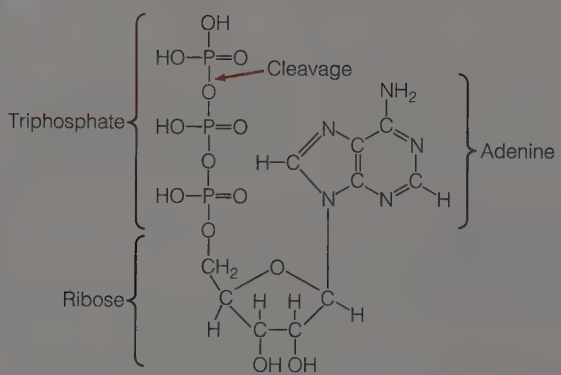
Vitamin E (alpha-tocopherol). The number and position of the methyl groups (CH_3) bonded to the ring structure differentiate among the tocopherols.



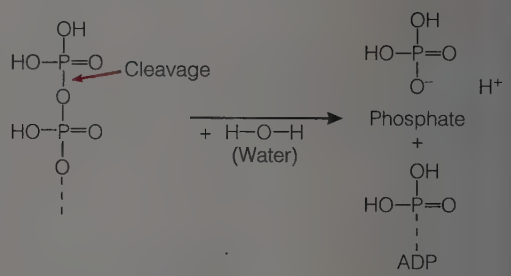
Vitamin K. Naturally occurring compounds with vitamin K activity include phylloquinones (from plants) and menaquinones (from bacteria).



Menadione. This synthetic compound has the same activity as natural vitamin K.



Adenosine triphosphate (ATP), the energy carrier. The cleavage point marks the bond that is broken when ATP splits to become ADP + P.

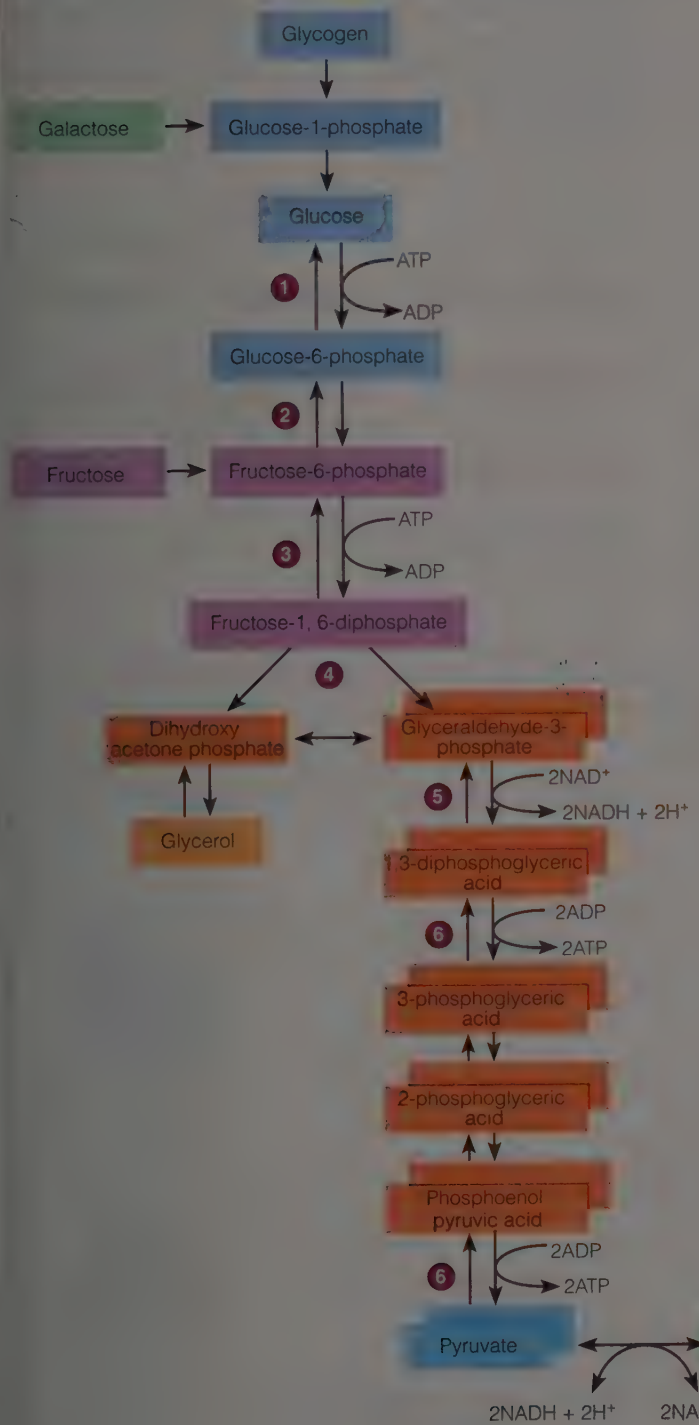


Adenosine diphosphate (ADP).

Glycolysis

Figure C-1 depicts glycolysis. The following text describes key steps as numbered on the figure.

FIGURE C-1 Glycolysis
Notice that galactose and fructose enter at different places but continue on the same pathway.



1. A phosphate is attached to glucose at the carbon that chemists call number 6 (review the first diagram of glucose on p. C-1 to see how chemists number the carbons in a glucose molecule). The product is called, logically enough, glucose-6-phosphate. One ATP molecule is used to accomplish this.
2. Glucose-6-phosphate is rearranged by an enzyme.
3. A phosphate is added in another reaction that uses another molecule of ATP. The product this time is fructose-1,6-diphosphate. At this point the 6-carbon sugar has a phosphate group on its first and sixth carbons and is ready to break apart.
4. When fructose-1,6-diphosphate breaks in half, the two 3-carbon compounds are not identical. Each has a phosphate group attached, but only glyceraldehyde-3-phosphate converts directly to pyruvate. The other compound, however, converts easily to glyceraldehyde-3-phosphate.
5. In the next step, enough energy is released to convert NAD^+ to NADH + H^+.
6. In two of the following steps ATP is regenerated.

Remember that in effect two molecules of glyceraldehyde-3-phosphate are produced from glucose; therefore, four ATP molecules are generated from each glucose molecule. Two ATP were needed to get the sequence started, so the net gain at this point is two ATP and two molecules of NADH + H^+. As you will see later, each NADH + H^+ moves to the electron transport chain to unload its hydrogens, producing more ATP.

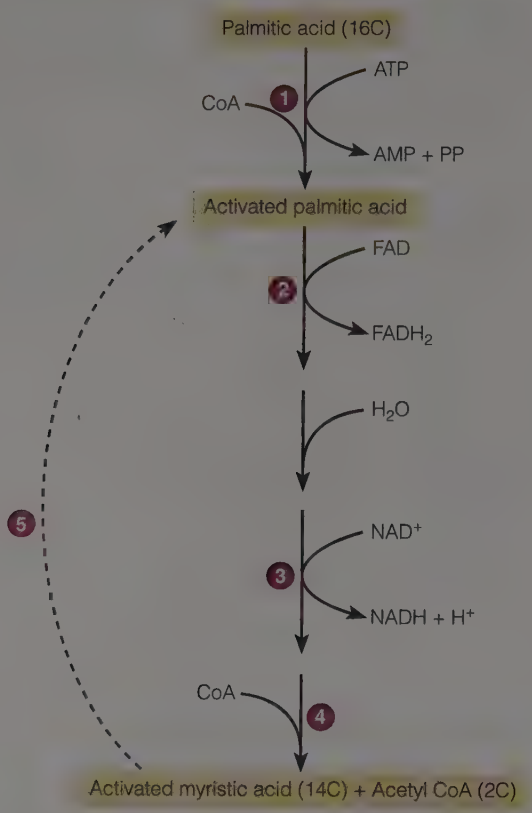
APPENDIX C

Fatty Acid Oxidation

Figure C-2 presents fatty acid oxidation. The sequence is as follows.

1. The fatty acid is activated by combining with coenzyme A (CoA). In this reaction, ATP loses two phosphorus atoms (PP, or pyrophosphate) and becomes AMP (adenosine monophosphate)—the equivalent of a loss of two ATP.
2. In the next reaction, two H with their electrons are removed and transferred to FAD, forming $FADH_2$.
3. In a later reaction, two H are removed and go to NAD^+ (forming NADH + H^+).
4. The fatty acid is cleaved at the "beta" carbon, the second carbon from the carboxyl (COOH) end. This break results in a fatty acid that is two carbons shorter than the previous one and a 2-carbon molecule of acetyl CoA.

> FIGURE C-2 **Fatty Acid Oxidation**



At the same time, another CoA is attached to the fatty acid, thus activating it for its turn through the series of reactions.

5. The sequence is repeated with each cycle producing an acetyl CoA and a shorter fatty acid until only a 2-carbon fatty acid remains—acetyl CoA.

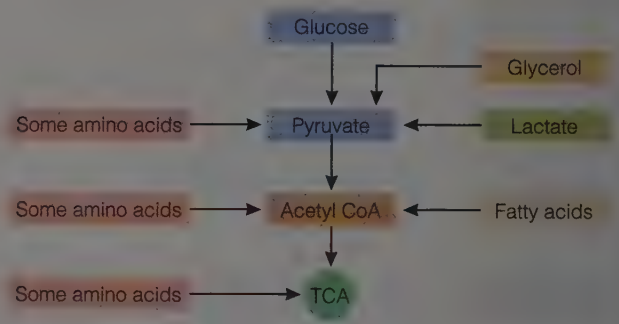
In the example shown in Figure C-2, palmitic acid (a 16-carbon fatty acid) will go through this series of reactions seven times, using the equivalent of two ATP for the initial activation and generating seven $FADH_2$, seven $NADH + H^+$, and eight acetyl CoA. As you will see later, each of the seven $FADH_2$ will enter the electron transport chain, yielding two ATP (for a total of 14). Similarly, each $NADH + H^+$ will enter the electron transport chain, yielding three ATP (for a total of 21). Thus the oxidation of a 16-carbon fatty acid uses 2 ATP and generates 35 ATP. When the eight acetyl CoA enter the TCA cycle, even more ATP will be generated, as a later section describes.

Amino Acid Degradation

The first step in amino acid degradation is the removal of the nitrogen-containing amino group through either deamination (Figure 6-11 on p. 179) or transamination (Figure 6-12 on p. 179) reactions. Then the remaining carbon skeletons may enter the metabolic pathways at different places, as shown in Figure C-3 (p. C-12).

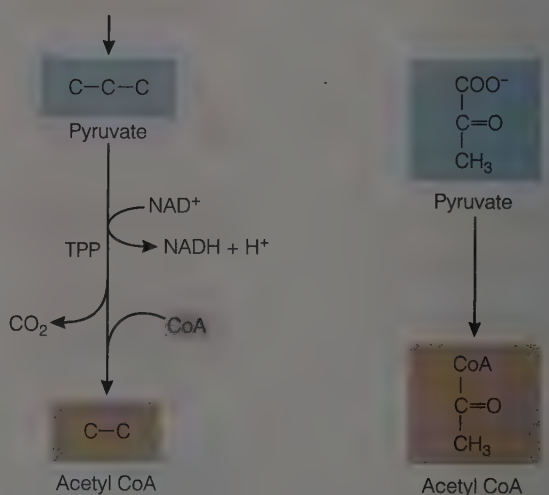
The TCA Cycle

The tricarboxylic acid, or TCA, cycle is the set of reactions that break down acetyl CoA to carbon dioxide and hydrogens. Pyruvate derived from glycolysis does not enter the TCA cycle directly; instead pyruvate enters the mitochondrion, loses a carbon group, and bonds with a molecule of CoA to become acetyl CoA. The TCA cycle uses any substance that can be converted to acetyl CoA directly or indirectly through pyruvate.



Any substance that can be converted to acetyl CoA directly, or indirectly through pyruvate, may enter the TCA cycle.

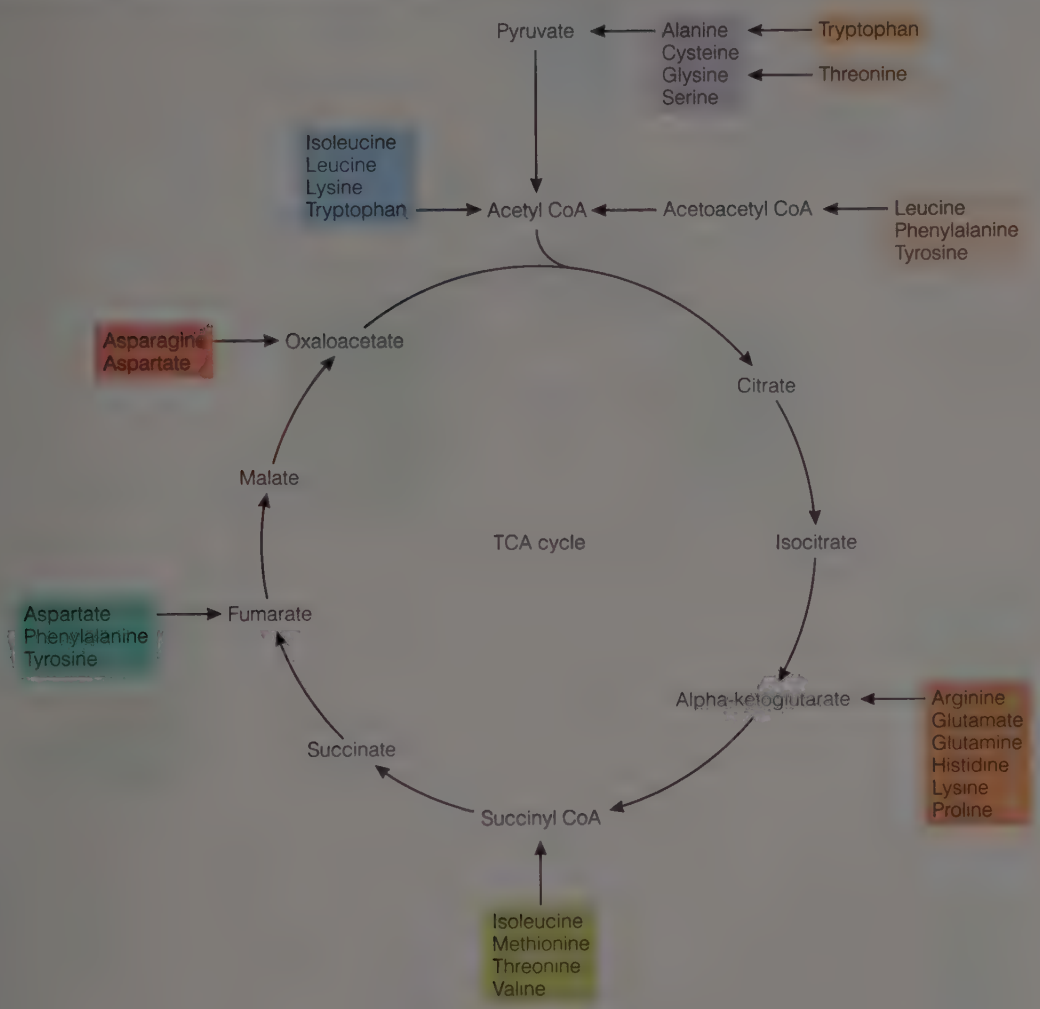
The step from pyruvate to acetyl CoA is complex. We have included only those substances that will help you understand the transfer of energy from the nutrients. Pyruvate loses a carbon to carbon dioxide and is attached to a molecule of CoA. In the process, NAD^+ picks up two hydrogens with their associated electrons, becoming $NADH + H^+$.



The step from pyruvate to acetyl CoA. (TPP and NAD are coenzymes containing the B vitamins thiamin and niacin, respectively.)

> FIGURE C-3 Amino Acids Enter the Metabolic Pathways

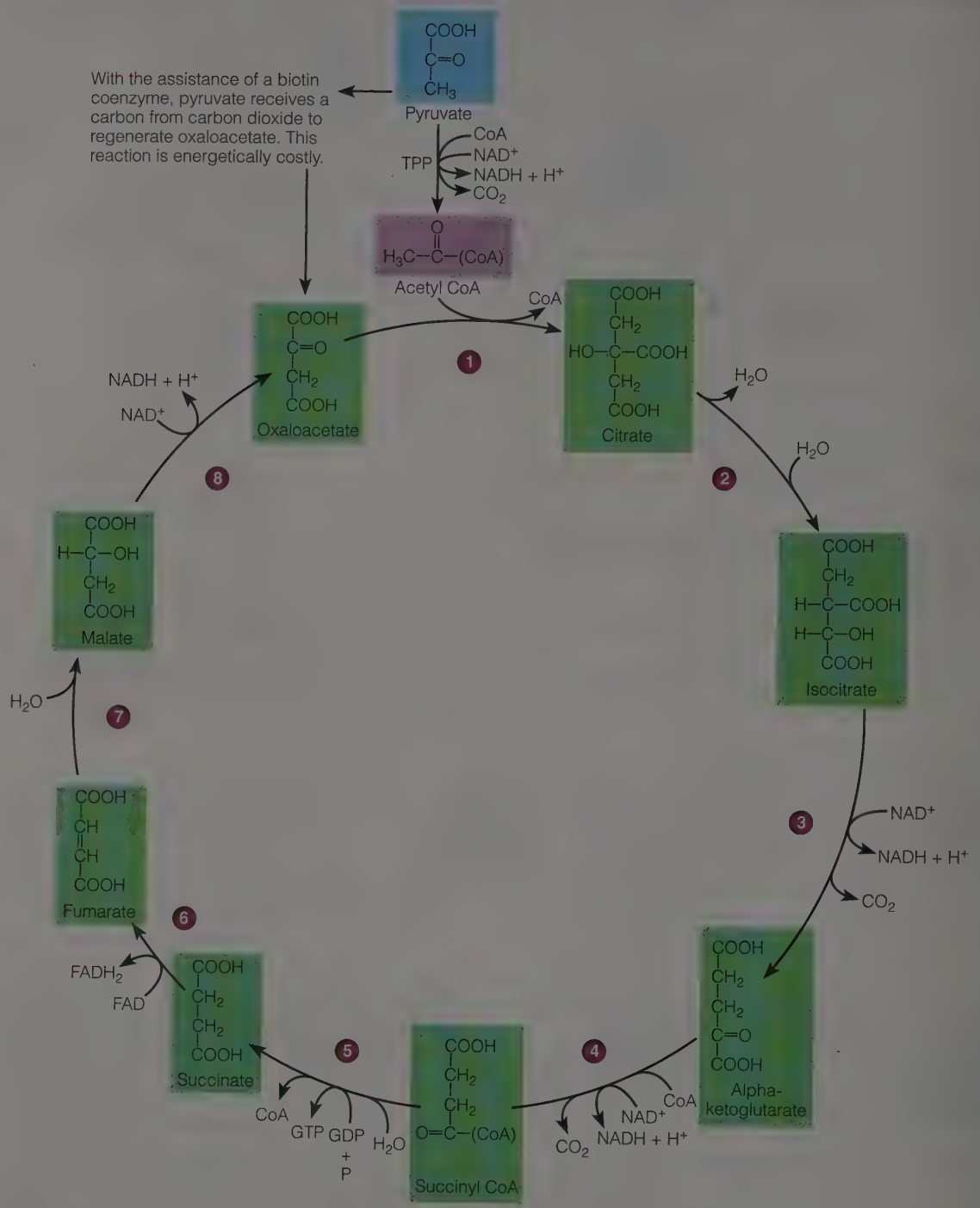
After losing their amino groups, carbon skeletons can be converted to one of seven molecules that can enter the TCA cycle (presented in Figure C-4).



Let's follow the steps of the TCA cycle (see the corresponding numbers in Figure C-4 on the next page).

1. The 2-carbon acetyl CoA combines with a 4-carbon compound, oxaloacetate. The CoA comes off, and the product is a 6-carbon compound, citrate.
2. The atoms of citrate are rearranged to form isocitrate.
3. Now two H (with their two electrons) are removed from the isocitrate. One H becomes attached to the NAD^+ with the two electrons; the other H is released as H^+. Thus NAD^+ becomes NADH + H^+. (Remember this NADH + H^+, but let's follow the carbons first.) A carbon is combined with two oxygens, forming carbon dioxide (which diffuses away into the blood and is exhaled). What is left is the 5-carbon compound alpha-ketoglutarate.
4. Now two compounds interact with alpha-ketoglutarate—a molecule of CoA and a molecule of NAD^+. In this complex reaction, a carbon and two oxygens are removed (forming carbon dioxide); two hydrogens are removed and go to NAD^+ (forming NADH + H^+); and the remaining 4-carbon compound is attached to the CoA, forming succinyl CoA. (Remember this NADH + H^+ also. You will see later what happens to it.)
5. Now two molecules react with succinyl CoA—a molecule called GDP and one of phosphate (P). The CoA comes off, the GDP and P combine to form the high-energy compound GTP (similar to ATP), and succinate remains. (Remember this GTP.)
6. In the next reaction, two H with their electrons are removed from succinate and are transferred to a molecule of FAD (a coenzyme like NAD^+) to form $FADH_2$. The product that remains is fumarate. (Remember this $FADH_2$.)
7. Next a molecule of water is added to fumarate, forming malate.

> FIGURE C-4 The TCA Cycle



8. A molecule of NAD^+ reacts with the malate; two H with their associated electrons are removed from the malate and form NADH + H^+. The product that remains is the 4-carbon compound oxaloacetate. (Remember this NADH + H^+.)

We are back where we started. The oxaloacetate formed in this process can combine with another molecule of acetyl CoA (step 1), and the cycle can begin again, as shown in Figure C-4.

So far, we have seen two carbons brought in with acetyl CoA and two carbons ending up in carbon dioxide. But where are the energy and the ATP that were promised?

A review of the eight steps of the TCA cycle shows that the compounds NADH + H^+ (three molecules), $FADH_2$, and GTP

capture energy originally found in acetyl CoA. To see how this energy ends up in ATP, we must follow the electrons further—into the electron transport chain.

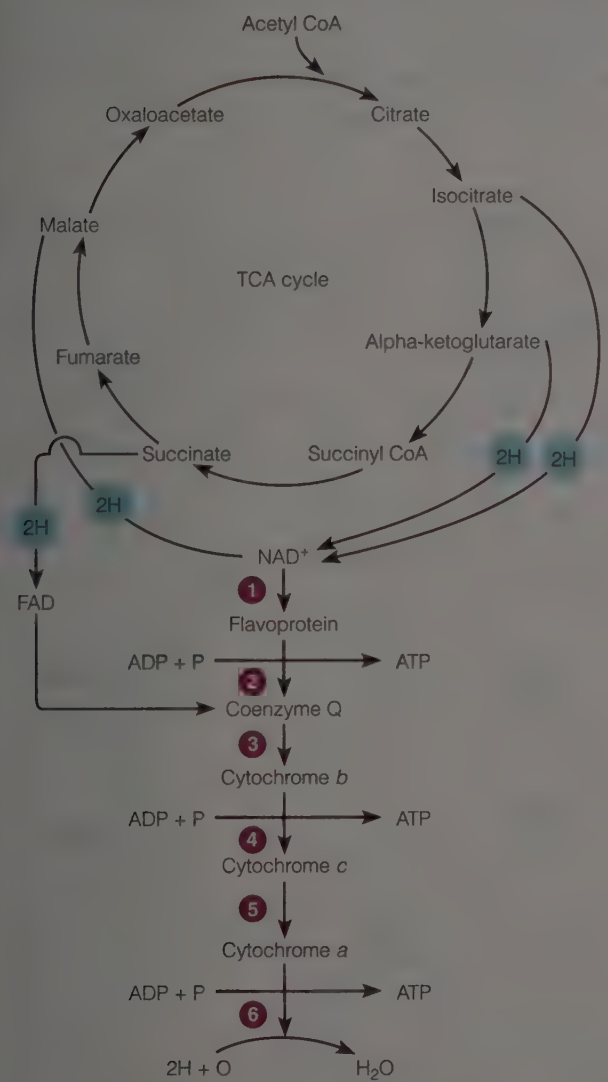
The Electron Transport Chain

The six reactions described here are those of the electron transport chain, which is shown below the TCA cycle in Figure C-5. Since oxygen is required for these reactions, and ADP and P are combined to form ATP in several of them (ADP is phosphorylated), the reactions of the electron transport chain are also called *oxidative phosphorylation*.

An important concept to remember at this point is that an electron is not a fixed amount of energy. The electrons that bond the H to NAD^+ in NADH have a relatively large amount of energy. In the series of reactions that follow, they release this energy in small amounts, until at the end they are attached (with H) to oxygen (O) to make water (H_2O). In some of the steps, the energy they release is captured into ATP in coupled reactions.

1. In the first step of the electron transport chain, NADH reacts with a molecule called a flavoprotein, losing its electrons (and their H). The products are NAD^+ and reduced flavoprotein. A little energy is released as heat in this reaction.
2. The flavoprotein passes on the electrons to a molecule called coenzyme Q. Again they release some energy as heat, but ADP and P bond together and form ATP, storing much of the energy. This is a coupled reaction: ADP + P → ATP.
3. Coenzyme Q passes the electrons to cytochrome *b*. Again the electrons release energy.
4. Cytochrome *b* passes the electrons to cytochrome *c* in a coupled reaction in which ATP is formed: ADP + P → ATP.
5. Cytochrome *c* passes the electrons to cytochrome *a*.
6. Cytochrome *a* passes them (with their H) to an atom of oxygen (O), forming water (H_2O). This is a coupled reaction in which ATP is formed: ADP + P → ATP.

> **FIGURE C-5** The Electron Transport Chain



As Figure C-5 shows, each time NADH is oxidized (loses its electrons) by this means, the energy it releases is captured into three ATP molecules. When the electrons are passed on to water at the end, they are much lower in energy than they were originally. This completes the story of the electrons from NADH.

As for $FADH_2$, its electrons enter the electron transport chain at coenzyme Q. From coenzyme Q to water, ATP is generated in only two steps. Therefore, $FADH_2$ coming out of the TCA cycle yields just two ATP molecules.

One energy-receiving compound of the TCA cycle (GTP) does not enter the electron transport chain but gives its energy directly to ADP in a simple phosphorylation reaction. This reaction yields one ATP.

It is now possible to draw up a balance sheet of glucose metabolism (see Table C-3). Glycolysis has yielded 4 NADH + H^+ and 4 ATP molecules and has spent 2 ATP. The 2 acetyl CoA going through the TCA cycle have yielded 6 NADH + H^+, 2 $FADH_2$, and 2 GTP molecules. After the NADH + H^+ and $FADH_2$ have gone through the electron transport chain, there are 28 ATP. Added to these are the 4 ATP from glycolysis and the 2 ATP from GTP, making the total 34 ATP generated from one molecule of glucose. After the expense of 2 ATP is subtracted, there is a net gain of 32 ATP.*

*The total may sometimes be 30 ATP. The NADH + H^+ generated in the cytoplasm during glycolysis pass their electrons on to shuttle molecules, which move them into the mitochondria. One shuttle, malate, contributes its electrons to the electron transport chain before the first site of ATP synthesis, yielding 5 ATP. Another, glycerol phosphate, adds its electrons into the chain beyond that first site, yielding 3 ATP. Thus sometimes 5, and sometimes 3, ATP result from the NADH + H^+ that arise from glycolysis. The amount depends on the cell.

TABLE C-3 Balance Sheet for Glucose Metabolism

		ATP
Glycolysis:	4 ATP − 2 ATP	2
1 glucose to 2 pyruvate	2 NADH + H^+	3–5[a]
2 pyruvate to 2 acetyl CoA	2 NADH + H^+	5
TCA cycle and electron transport chain:		
2 isocitrate	2 NADH + H^+	5
2 alpha-ketoglutarate	2 NADH + H^+	5
2 succinyl CoA	2 GTP	2
2 succinate	2 $FADH_2$	3
2 malate	2 NADH + H^+	5
Total ATP collected from one molecule glucose:		30–32

[a]Each NADH + H^+ from glycolysis can yield 1.5 or 2.5 ATP. See the accompanying text.

A similar balance sheet from the complete breakdown of one 16-carbon fatty acid would show a net gain of 129 ATP. As mentioned earlier, 35 ATP were generated from the 7 $FADH_2$ and 7 NADH + H^+ produced during fatty acid oxidation. The 8 acetyl CoA produced will each generate 12 ATP as they go through the TCA cycle and the electron transport chain, for a total of 96 more ATP. After subtracting the 2 ATP needed to activate the fatty acid initially, the net yield from one 16-carbon fatty acid: 35 + 96 − 2 = 129 ATP.

These calculations help explain why fat yields more energy (measured as kcalories) per gram than carbohydrate or protein. The more hydrogen atoms a fuel contains, the more ATP will be generated during oxidation. The 16-carbon fatty acid molecule, with its 32 hydrogen atoms, generates 129 ATP, whereas glucose, with its 12 hydrogen atoms, yields only 32 ATP.

The TCA cycle and the electron transport chain are the body's major means of capturing the energy from nutrients in ATP molecules. Other means, such as anaerobic glycolysis, contribute energy quickly, but the aerobic processes are the most efficient.

Alcohol's Interference with Energy Metabolism

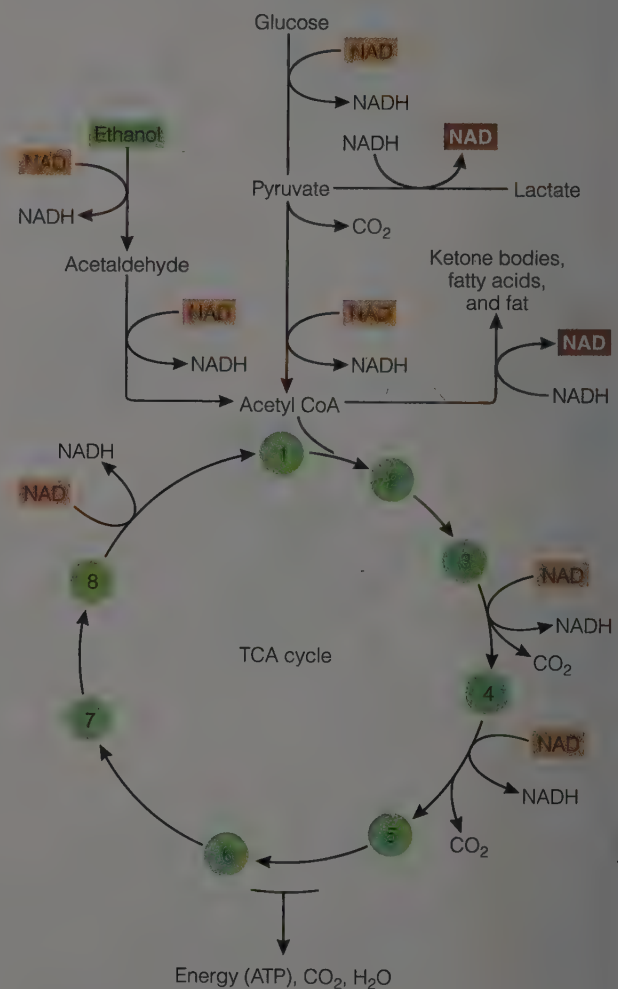
Highlight 7 provides an overview of how alcohol interferes with energy metabolism. With an understanding of the TCA cycle, a few more details may be appreciated. During alcohol metabolism, the enzyme alcohol dehydrogenase oxidizes alcohol to acetaldehyde while it simultaneously reduces a molecule of NAD^+ to NADH + H^+. The related enzyme acetaldehyde dehydrogenase reduces another NAD^+ to NADH + H^+ while it oxidizes acetaldehyde to acetyl CoA, the compound that enters the TCA cycle to generate energy. Thus, whenever alcohol is being metabolized in the body, NAD^+ diminishes, and NADH + H^+ accumulates, thus altering the body's "redox state." NAD^+ can oxidize, and NADH + H^+ can reduce, many other compounds as well. During alcohol metabolism, however, NAD^+ becomes unavailable for the multitude of reactions for which it is required.

As the previous sections just explained, for glucose to be completely metabolized, the TCA cycle must be operating, and NAD^+ must be present. If these conditions are not met (and when alcohol is present, they may not be), the pathway will be blocked, and traffic will back up—or an alternate route will be taken. Think about this as you follow the pathway shown in Figure C-6.

In each step of alcohol metabolism in which NAD^+ is converted to NADH + H^+, hydrogen ions accumulate, resulting in a dangerous shift of the acid-base balance toward acid (Chapter 12 explains acid-base balance). The accumulation of NADH + H^+ slows TCA cycle activity, so pyruvate and acetyl CoA build up. This condition favors the conversion of

> FIGURE C-6 Ethanol Enters the Metabolic Pathways

This is a simplified version of the glucose-to-energy pathway showing the entry of ethanol. The coenzyme NAD (which is the active form of the B vitamin niacin) is the only one shown here; however, many others are involved.



pyruvate to lactate, which serves as a temporary storage place for hydrogens from NADH + H^+. The conversion of pyruvate to lactate restores some NAD^+, but a lactate buildup has serious consequences of its own. It adds to the body's acid burden and interferes with the excretion of uric acid, causing goutlike symptoms. Molecules of acetyl CoA become building blocks for fatty acids or ketone bodies. The making of ketone bodies consumes acetyl CoA and generates NAD^+; but some ketone bodies are acids, so they push the acid-base balance further toward acid.

Thus alcohol cascades through the metabolic pathways, wreaking havoc along the way. These consequences have physical effects, as Highlight 7 describes.

The Urea Cycle

Chapter 6 sums up the process by which waste nitrogen is eliminated from the body by stating that ammonia molecules combine with carbon dioxide to produce urea. This is true, but it is not the whole story. Urea is produced in a multistep process within the cells of the liver.

Ammonia, freed from an amino acid or other compound during metabolism anywhere in the body, arrives at the liver by way of the bloodstream and is taken into a liver cell. There, it is first combined with carbon dioxide and a phosphate group from ATP to form carbamyl phosphate:

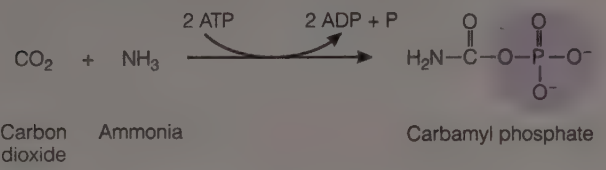
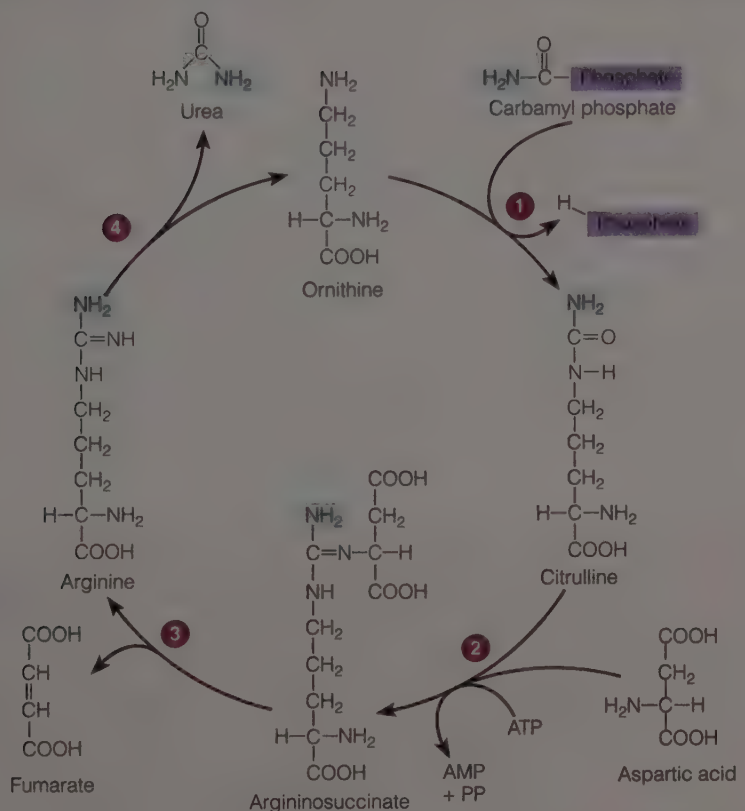


Figure C-7 shows the cycle of four reactions that follow.

1. Carbamyl phosphate combines with the amino acid ornithine, losing its phosphate group. The compound formed is citrulline.
2. Citrulline combines with the amino acid aspartic acid, to form argininosuccinate. The reaction requires energy from ATP. (ATP was shown earlier losing one phosphorus atom in a phosphate group, P, to become ADP. In this reaction, it loses two phosphorus atoms joined together, PP, and becomes adenosine monophosphate, AMP.)
3. Argininosuccinate is split, forming another acid, fumarate, and the amino acid arginine.
4. Arginine loses its terminal carbon with two attached amino groups and picks up an oxygen from water. The

> FIGURE C-7 The Urea Cycle



APPENDIX C

end product is urea, which the kidneys excrete in the urine. The compound that remains is ornithine, identical to the ornithine with which this series of reactions began, and ready to react with another molecule of carbamyl phosphate and turn the cycle again.

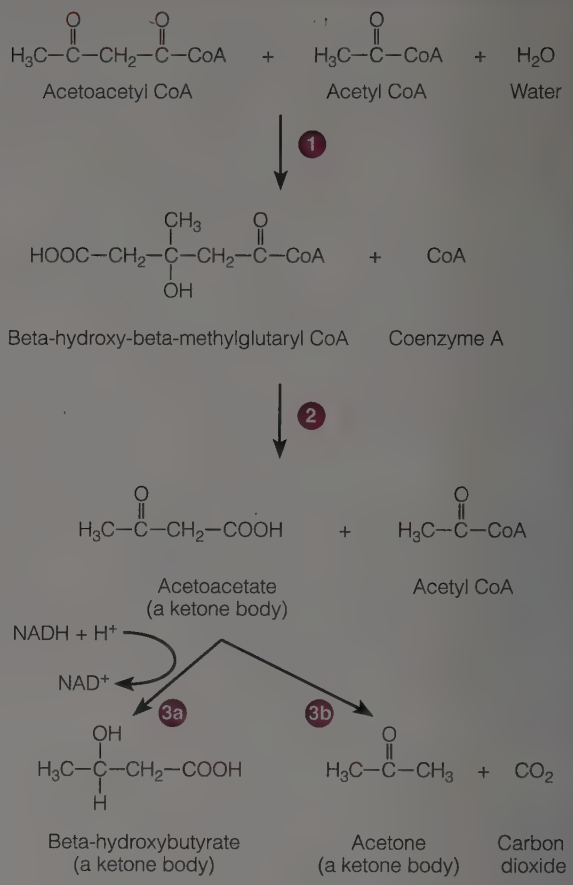
Formation of Ketone Bodies

Normally, fatty acid oxidation proceeds all the way to carbon dioxide and water. However, in ketosis (discussed in Chapter 7), an intermediate is formed from the condensation of two molecules of acetyl CoA: acetoacetyl CoA. Figure C-8 shows the formation of ketone bodies from that intermediate.

1. Acetoacetyl CoA condenses with acetyl CoA to form a 6-carbon intermediate, beta-hydroxy-beta-methylglutaryl CoA.
2. This intermediate is cleaved to acetyl CoA and acetoacetate.
3. Acetoactate can be metabolized either to beta-hydroxybutyrate acid (step 3a) or to acetone (3b).

Acetoacetate, beta-hydroxybutyrate, and acetone are the ketone bodies of ketosis. Two are real ketones (they have a C=O group between two carbons); the other is an alcohol that has been produced during ketone formation—hence the term *ketone bodies,* rather than ketones, to describe the three of them. There are many other ketones in nature; these three are characteristic of ketosis in the body.

> **FIGURE C-8 The Formation of Ketone Bodies**



Appendix D Measures of Protein Quality

In a world where food is scarce and many people's diets contain marginal or inadequate amounts of protein, it is important to know which foods contain the highest-quality protein. Chapter 6 describes protein quality, and this appendix presents different measures researchers use to assess the quality of a food protein. The accompanying glossary defines related terms.

CONTENTS

Amino Acid Scoring
PDCAAS
Biological Value
Net Protein Utilizatin
Protein Efficiency Ratio

Amino Acid Scoring

Amino acid scoring evaluates a protein's quality by determining its amino acid composition and comparing it with that of a reference protein. The advantages of amino acid scoring are that it is simple and inexpensive, it easily identifies the limiting amino acid, and it can be used to score mixtures of different proportions of two or more proteins mathematically without having to make up a mixture and test it. Its chief weaknesses are that it fails to estimate the digestibility of a protein, which may strongly affect the protein's quality; it relies on a chemical procedure in which certain amino acids may be destroyed, making the pattern that is analyzed inaccurate; and it is blind to other features of the protein (such as the presence of substances that may inhibit the digestion or utilization of the protein) that would only be revealed by a test in living animals.

Table D-1 shows the reference pattern for the nine essential amino acids. To interpret the table, read, "For every 3210 units of essential amino acids, 145 must be histidine, 340 must be isoleucine, 540 must be leucine," and so on. To compare a test protein with the reference protein, the experimenter first obtains a chemical analysis of the test protein's amino acids. Then, taking 3210 units of the amino acids, the experimenter compares the amount of each amino acid to the amount found in 3210 units of essential amino acids in egg protein. For example, suppose the test protein contained (per 3210 units) 360 units of isoleucine; 500 units of leucine; 350 of lysine; and for each of the other amino acids, more units than egg protein contains. The two amino acids that are low are leucine (500 as compared with 540 in egg) and lysine (350 versus 440 in egg). The ratio—amino acid in the test protein divided by amino acid in egg—is 500/540 (or about 0.93) for leucine and 350/440 (or about 0.80) for lysine. Lysine is the

TABLE D-1 Reference Pattern for Amino Acid Scoring of Proteins

Essential Amino Acids	Reference Protein—Whole Egg (mg amino acid/g nitrogen)
Histidine	145
Isoleucine	340
Leucine	540
Lysine	440
Methionine + cystine[a]	355
Phenylalanine + tyrosine[b]	580
Threonine	294
Tryptophan	106
Valine	410
Total	3210

[a]Methionine is essential and is also used to make cystine. Thus the methionine requirement is lower if cystine is supplied.
[b]Phenylalanine is essential and is also used to make tyrosine if not enough of the latter is available. Thus the phenylalanine requirement is lower if tyrosine is also supplied

APPENDIX D

GLOSSARY

amino acid scoring: a measure of protein quality assessed by comparing a protein's amino acid pattern with that of a reference protein; sometimes called *chemical scoring.*

biological value (BV): a measure of protein quality assessed by measuring the amount of protein nitrogen that is retained from a given amount of protein nitrogen absorbed.

net protein utilization (NPU): a measure of protein quality assessed by measuring the amount of protein nitrogen that is retained from a given amount of protein nitrogen eaten.

PDCAAS (protein digestibility-corrected amino acid score): a measure of protein quality assessed by comparing the amino acid score of a food protein with the amino acid requirements of preschool-age children and then correcting for the true digestibility of the protein; recommended by the FAO/WHO and used to establish protein quality of foods for Daily Value percentages on food labels.

protein efficiency ratio (PER): a measure of protein quality assessed by determining how well a given protein supports weight gain in growing rats; used to establish the protein quality for infant formulas and baby foods.

TABLE D-2 PDCAAS Values of Selected Foods

Casein (milk protein)	1.00
Egg white	1.00
Soybean (isolate)	.99
Beef	.92
Pea flour	.69
Kidney beans (canned)	.68
Chickpeas (canned)	.66
Pinto beans (canned)	.66
Rolled oats	.57
Lentils (canned)	.52
Peanut meal	.52
Whole wheat	.40

NOTE: 1.0 is the maximum PDCAAS a food protein can receive.

limiting amino acid (the one that falls shortest compared with egg). If the protein's limiting amino acid is 80 percent of the amount found in the reference protein, it receives a score of 80.

PDCAAS

The **protein digestibility-corrected amino acid score,** or **PDCAAS,** compares the amino acid composition of a protein with human amino acid requirements and corrects for digestibility. First the protein's amino acid composition is determined, and then it is compared against the amino acid requirements of preschool-aged children. This comparison reveals the most limiting amino acid—the one that falls shortest compared with the reference. If a food protein's limiting amino acid is 70 percent of the amount found in the reference protein, it receives a score of 70. The amino acid score is multiplied by the food's protein digestibility percentage to determine the PDCAAS. The accompanying "How To" provides an example of how to calculate the PDCAAS, and Table D-2 lists the PDCAAS values of selected foods.

>How To

Measure Protein Quality Using PDCAAS

To calculate the PDCAAS (protein digestibility-corrected amino acid score), researchers first determine the amino acid profile of the test protein (in this example, pinto beans). The second column of the table below presents the essential amino acid profile for pinto beans. The third column presents the amino acid reference pattern.

To determine how well the food protein meets human needs, researchers calculate the ratio by dividing the second column by the third column (for example, 30 ÷ 18 = 1.67). The amino acid with the lowest ratio is the most limiting amino acid—in this case, methionine. Its ratio is the amino acid score for the protein—in this case, 0.84.

The amino acid score alone, however, does not account for digestibility. Protein digestibility, as determined by rat studies, yields a value of 79 percent for pinto beans. Together, the amino acid score and the digestibility value determine the PDCAAS:

$$\text{PDCAAS} = \text{protein digestibility} \times \text{amino acid score}$$

$$\text{PDCAAS for pinto beans} = 0.79 \times 0.84 = 0.66$$

Thus the PDCAAS for pinto beans is 0.66 as Table D-2 confirms.

The PDCAAS is used to determine the % Daily Value on food labels. To calculate the % Daily Value for protein for canned pinto beans, multiply the number of grams of protein in a standard serving (in the case of pinto beans, 7 grams per ½ cup) by the PDCAAS:

$$7\text{ g} \times 0.66 = 4.62$$

This value is then divided by the recommended standard for protein (for children over age four and adults, 50 grams):

$$4.62 \div 50 = 0.09 \text{ (or 9\%)}$$

The food label for this can of pinto beans would declare that one serving provides 7 grams protein, and if the label included a % Daily Value for protein (which is optional), the value would be 9 percent.

Essential Amino Acids	Amino Acid Profile of Pinto Beans (mg/g protein)	Amino Acid Reference Pattern (mg/g protein)	Amino Acid Score
Histidine	30.0	18	1.67
Isoleucine	42.5	25	1.70
Leucine	80.4	55	1.46
Lysine	69.0	51	1.35
Methionine (+ cystine)	21.1	25	0.84
Phenylalanine (+ tyrosine)	90.5	47	1.93
Threonine	43.7	27	1.62
Tryptophan	8.8	7	1.26
Valine	50.1	32	1.57

Biological Value

The **biological value (BV)** of a protein measures its efficiency in supporting the body's needs. In a test of biological value, two nitrogen balance studies are done. In the first, no protein is fed, and nitrogen (N) excretions in the urine and feces are measured. It is assumed that under these conditions, N lost in the urine is the amount the body always necessarily loses by filtration into the urine each day, regardless of what protein is fed (endogenous N). The N lost in the feces (called metabolic N) is the amount the body invariably loses into the intestine each day, whether or not food protein is fed. (To help you remember the terms: endogenous N is "urinary N on a zero-protein diet"; metabolic N is "fecal N on a zero-protein diet.")

In the second study, an amount of protein slightly below the requirement is fed. Intake and losses are measured; then the BV is derived using this formula:

$$\text{BV} = \frac{\text{N retained}}{\text{N absorbed}} \times 100$$

The denominator of this equation expresses the amount of nitrogen *absorbed:* food N minus fecal N (excluding the metabolic N the body would lose in the feces anyway, even without food). The numerator expresses the amount of N *retained* from the N absorbed: absorbed N (as in the denominator) minus the N excreted in the urine (excluding the endogenous N the body would lose in the urine anyway even without food). The more nitrogen retained, the higher the protein quality. (Recall that when an essential amino acid is missing, protein synthesis stops, and the remaining amino acids are deaminated and the nitrogen excreted.)

Egg protein has a BV of 100, indicating that 100 percent of the nitrogen absorbed is retained. Supplied in adequate quantity, a protein with a BV of 70 or greater can support human growth as long as energy intake is adequate. Table D-3 presents the BV for selected foods.

TABLE D-3 Biological Values (BV) of Selected Foods

Egg	100
Milk	93
Beef	75
Fish	75
Corn	72

NOTE: 100 is the maximum BV a food protein can receive.

This method has the advantages of being based on experiments with human beings (it can be done with animals, too, of course) and of measuring actual nitrogen retention. But it is also cumbersome, expensive, and often impractical, and it is based on several assumptions that may not be valid. For example, the physiology normal environment, or typical food intake of the subjects used for testing may not be similar to those for whom the test protein may ultimately be used. For another example, the retention of protein in the body does not necessarily mean that it is being well utilized. Considerable exchange of protein among tissues (protein turnover) occurs, but is hidden from view when only N intake and output are measured. The test of biological value wouldn't detect if one tissue were shorted.

Net Protein Utilization

Like BV, **net protein utilization (NPU)** measures how efficiently a protein is used by the body and involves two balance studies. The difference is that NPU measures retention of food nitrogen rather than food nitrogen absorbed (as in BV). The formula for NPU is:

$$\text{NPU} = \frac{\text{N retained}}{\text{N intake}} \times 100$$

The numerator is the same as for BV, but the denominator represents food N intake only—not N absorbed.

This method offers advantages similar to those of BV determinations and is used more frequently, with animals as the test subjects. A drawback is that if a low NPU is obtained, the test results offer no help in distinguishing between two possible causes: a poor amino acid composition of the test protein or poor digestibility. There is also a limit to the extent to which animal test results can be assumed to be applicable to human beings.

TABLE D-4 Protein Efficiency Ratio (PER) Values of Selected Proteins

Casein (milk)	2.8
Soy	2.4
Glutein (wheat)	0.4

Protein Efficiency Ratio

The **protein efficiency ratio (PER)** measures the weight gain of a growing animal and compares it to the animal's protein intake. Until recently, the PER was generally accepted in the United States and Canada as the official method for assessing protein quality and it is still used to evaluate proteins for infants.

Young rats are fed a measured amount of protein and weighed periodically as they grow. The PER is expressed as:

$$\text{PER} = \frac{\text{weight gain (g)}}{\text{protein intake (g)}}$$

This method has the virtues of economy and simplicity but it also has many drawbacks. The experiments are time-consuming; the amino acid needs of rats are not the same as those of human beings; and the amino acid needs for growth are not the same as for the maintenance of adult animals (growing animals need more lysine, for example). Table D-4 presents PER values for selected foods.

Appendix E Nutrition Assessment

Nutrition assessment evaluates a person's health from a nutrition perspective. Many factors influence or reflect nutrition status. Consequently, the assessor, usually a registered dietitian assisted by other qualified health-care professionals, gathers information from many sources, including:

- Historical information.
- Anthropometric measurements.
- Physical examinations.
- Biochemical analyses (laboratory tests).

Each of these methods involves collecting data in a variety of ways and interpreting each finding in relation to the others to create a total picture.

The accurate gathering of this information and its careful interpretation are the basis for a meaningful evaluation. The more information gathered about a person, the more accurate the assessment will be. Gathering information is a time-consuming process, however, and time is often a rare commodity in the health care setting. Nutrition care is only one part of total care. It may not be practical or essential to collect detailed information on each person.

A strategic compromise is to screen clients by collecting preliminary data. Data such as height-weight and hematocrit are easy to obtain and can alert health-care workers to potential problems. **Nutrition screening** identifies clients who will require additional nutrition assessment. This appendix provides a sample of the procedures, standards, and charts commonly used in nutrition assessment.

CONTENTS

Historical Information
Anthropometric Measurements
Physical Examinations
Biochemical Analyses
Cautions about Nutrition Assessment

Historical Information

Clues about present nutrition status become evident with a careful review of a person's historical data (see Table E-1). Even when the data are subjective, they reveal important facts about a person. A thorough history identifies risk factors associated with poor nutrition status (see Table E-2) and provides a sense of the whole person. As you can see, many aspects of a person's life influence nutrition status and provide clues to possible problems.

TABLE E-1 Historical Data Used in Nutrition Assessments

Type of History	What It Identifies
Health history	Current and previous health problems and family health history that affect nutrient needs, nutrition status, or the need for intervention to prevent or alleviate health problems
Socioeconomic history	Personal, cultural, financial, and environmental influences on food intake, nutrient needs, and diet therapy options
Drug history	Medications (prescription and over-the-counter), illicit drugs, dietary supplements, and alternative therapies that affect nutrition status
Diet history	Nutrient intake excesses or deficiencies and reasons for imbalances

nutrition screening: the use of preliminary nutrition assessment techniques to identify people who are malnourished or are at risk for malnutrition.

TABLE E-2 Risk Factors for Poor Nutrition Status

Health History

- Acquired immune deficiency syndrome (AIDS)
- Alcoholism
- Anorexia (lack of appetite)
- Anorexia nervosa
- Bulimia nervosa
- Burns
- Cancer
- Chewing or swallowing difficulties (including poorly fitted dentures, dental caries, missing teeth, and mouth ulcers)
- Chronic obstructive pulmonary disease
- Circulatory problems
- Constipation
- Crohn's disease
- Cystic fibrosis
- Decubitus ulcers (pressure sores)
- Dementia
- Depleted blood proteins
- Depression
- Diabetes mellitus
- Diarrhea, prolonged or severe
- Drug addiction
- Dysphagia
- Failure to thrive
- Feeding disabilities
- Fever
- GI tract disorders or surgery
- Heart disease
- HIV infection
- Hormonal imbalance
- Hyperlipidemia
- Hypertension
- Infections
- Kidney disease
- Liver disease
- Lung disease
- Malabsorption
- Mental illness
- Mental retardation
- Multiple pregnancies
- Nausea
- Neurologic disorders
- Organ failure
- Overweight
- Pancreatic insufficiency
- Paralysis
- Physical disability
- Pneumonia
- Pregnancy
- Radiation therapy
- Recent major illness
- Recent major surgery
- Recent weight loss or gain
- Tobacco use
- Trauma
- Ulcerative colitis
- Ulcers
- Underweight
- Vomiting, prolonged or severe

Socioeconomic History

- Access to groceries
- Activities
- Age
- Education
- Ethnic identity
- Income
- Kitchen facilities
- Number of people in household
- Occupation
- Religious affiliation

Drug History

- Amphetamines
- Analgesics
- Antacids
- Antibiotics
- Anticonvulsant agents
- Antidepressant agents
- Antidiabetic agents
- Antidiarrheals
- Antifungal agents
- Antihyperlipemics
- Antihypertensives
- Antineoplastics
- Antiulcer agents
- Antiviral agents
- Catabolic steroids
- Diuretics
- Hormonal agents
- Immunosuppressive agents
- Laxatives
- Oral contraceptives
- Vitamin and other dietary supplements

Diet History

- Deficient or excessive food intakes
- Frequently eating out
- Intravenous fluids (other than total parenteral nutrition) for 7 or more days
- Monotonous diet (lacking variety)
- No intake for 7 or more days
- Poor appetite
- Restricted or fad diets
- Unbalanced diet (omitting any food group)
- Recent weight gains or losses

An adept history taker uses the interview both to gather facts and to establish a rapport with the client. This section briefly reviews the major areas of nutrition concern in a person's history: health, socioeconomic factors, drugs, and diet.

Health History The assessor can obtain a **health history** from records completed by the attending physician, nurse, or other health-care professional. In addition, conversations with the client can uncover valuable information previously overlooked because no one thought to ask or because the client was not thinking clearly when asked.

An accurate, complete health history can reveal conditions that increase a client's risk for malnutrition (review Table E-2). Diseases and their therapies can have either immediate or long-term effects on nutrition status by interfering with ingestion, digestion, absorption, metabolism, or excretion of nutrients.

Socioeconomic History A **socioeconomic history** reveals factors that profoundly affect nutrition status. The ethnic background and educational level of

health history: an account of a client's current and past health status and disease risks.

socioeconomic history: a record of a person's social and economic background, including such factors as education, income, and ethnic identity.

both the client and the other members of the household influence food availability and food choices. An understanding of the community environment is also important in assessing nutrition status. For example, the interviewer should be familiar with the food habits of the major ethnic groups within the locale, regional food preferences, and nutrition resources and programs available in the community. Local health departments and social agencies often can provide such information.

Level of income also influences the diet. In general, the quality of the diet declines as income falls. At some point, the ability to purchase the foods required to meet nutrient needs is lost; an inadequate income puts an adequate diet out of reach. Agencies use poverty indexes to identify people at risk for poor nutrition and to qualify people for government food assistance programs.

Low income affects not only the power to purchase foods but also the ability to shop for, store, and cook them. A skilled assessor will note whether a person has transportation to a grocery store that sells a sufficient variety of low-cost foods, and whether the person has access to a refrigerator and stove.

Drug History The many interactions of foods and drugs require that health-care professionals take a **drug history** and pay special attention to any client who takes drugs routinely. If a person is taking any drug, the assessor records the name of the drug; the dose, frequency, and duration of intake; the reason for taking the drug; and signs of any adverse effects.

The interactions of drugs and nutrients may take many forms:

- Drugs can alter food intake and the absorption, metabolism, and excretion of nutrients.
- Foods and nutrients can alter the absorption, metabolism, and excretion of drugs.

Highlight 17 discusses nutrient-drug interactions in more detail, and Table H17-1 (p. 576) summarizes the mechanisms by which these interactions occur and provides specific examples.

Diet History A **diet history** provides a record of a person's eating habits and food intake and can help identify possible nutrient imbalances. Food choices are an important part of lifestyle and often reflect a person's philosophy. The assessor who asks nonjudgmental questions about eating habits and food intake encourages trust and enhances the likelihood of obtaining accurate information.

Assessors evaluate food intake using various tools such as the 24-hour recall, the usual intake record, the food record, and the food frequency questionnaire. Food models or photos and measuring devices can help clients identify the types of foods and quantities consumed. The assessor also needs to know how the foods are prepared and when they are eaten. In addition to asking about foods, assessors will ask about beverage consumption, including beverages containing alcohol or caffeine.

Besides identifying possible nutrient imbalances, diet histories provide valuable clues about how a person will accept diet changes should they be necessary. Information about what and how a person eats provides the background for realistic and attainable nutrition goals.

24-Hour Recall The **24-hour recall** provides data for one day only and is commonly used in nutrition surveys to obtain estimates of the typical food intakes for a population. The assessor asks the client to recount everything eaten or drunk in the past 24 hours or for the previous day.

An advantage of the 24-hour recall is that it is easy to obtain. It is also more likely to provide accurate data, at least about the past 24 hours, than estimates of average intakes over long periods. It does not, however, provide enough information to allow accurate generalizations about an individual's usual food intake. The previous day's intake may not be typical, for example, or the person may be unable to report portion sizes accurately or may conceal or forget information

drug history: a record of all the drugs, over-the-counter and prescribed, that a person takes routinely.

diet history: a record of eating behaviors and the foods a person eats.

24-hour recall: a record of foods eaten by a person for one 24-hour period.

about foods eaten. This limitation is partially overcome when 24-hour recalls are collected on several nonconsecutive days.

Usual Intake To obtain data about a person's usual intake, an inquiry might begin with "What is the first thing you usually eat or drink during the day?" Similar questions follow until a typical daily intake pattern emerges. This method can be useful, especially in verifying food intake when the past 24 hours have been atypical. It also helps the assessor verify food habits. For example, one person may always eat an afternoon snack; another may never eat breakfast. A person whose intake varies widely from day to day, however, may find it difficult to answer such general questions, and in that case, another food intake tool should be used to estimate nutrient intake.

Food Record Another tool for history taking is the **food record,** in which the person records food eaten, including the quantity and method of preparation. Chapter 9 (p. 284) provides an example. A food record can help both the assessor and the client to determine factors associated with eating that may affect dietary balance and adequacy.

Food records work especially well with cooperative people but require considerable time and effort on their part. A prime advantage is that the record keeper assumes an active role and may for the first time become aware of personal food habits and assume responsibility for them. It also provides the assessor with an accurate picture of the person's lifestyle and factors that affect food intake. For these reasons, a food record can be particularly useful in outpatient counseling for such nutrition problems as overweight, underweight, or food allergy. The major disadvantages stem from poor compliance in recording the data and conscious or unconscious changes in eating habits that may occur while the person is keeping the record.

Food Frequency Questionnaire An assessor uses a **food frequency questionnaire** to compare a client's food intake with the Daily Food Patterns. Clients may be asked how many servings of each of the following they eat in a typical day: grains; vegetables; fruits; protein foods; and solid fats and added sugars. This information helps pinpoint food groups, and therefore nutrients, that may be excessive or deficient in the diet. That a person ate no vegetables yesterday may not seem particularly significant, but never eating vegetables is a warning of possible nutrient deficiencies. When used with the usual intake or 24-hour recall approach, the food frequency questionnaire enables the assessor to double-check the accuracy of the information obtained.

Analysis of Food Intake Data After collecting food intake data, the assessor estimates nutrient intakes, either informally by using food guides or formally by using diet analysis programs. The assessor compares intakes with standards, usually nutrient recommendations or dietary guidelines, to determine how closely the person's diet meets the standards. Are the types and amounts of proteins, carbohydrates (including fiber), and fats (including cholesterol) appropriate? Are all food groups included in appropriate amounts? Is caffeine or alcohol consumption excessive? Are intakes of any vitamins or minerals (including sodium and iron) excessive or deficient? An informal evaluation is possible only if the assessor has enough prior experience with formal calculations to "see" nutrient amounts in reported food intakes without calculations. Even then, such an informal analysis is best followed by a spot check for key nutrients by actual calculation.

Formal calculations can be performed either manually (by looking up each food in a table of food composition, recording its nutrients, and adding them up) or by using a diet analysis program. The assessor then compares the intakes with standards such as the RDA.

Limitations of Food Intake Analysis Diet histories can be superbly informative, but the skillful assessor also keeps their limitations in mind. For example, a diet analysis program tends to imply greater accuracy than is possible to obtain from

food record: an extensive, accurate log of all foods eaten over a period of several days or weeks. A food record that includes associated information such as when, where, and with whom each food is eaten is sometimes called a *food diary.*

food frequency questionnaire: a checklist of foods on which a person can record the frequency with which he or she eats each food.

data as uncertain as the starting information. Nutrient contents of foods listed in tables of food composition or stored in computer databases are averages and, for some nutrients, incomplete. In addition, the available data on nutrient contents of foods do not reflect the amounts of nutrients a person actually absorbs. Iron is a case in point: its availability from a given meal may vary depending on the person's iron status; the relative amounts of heme iron, nonheme iron, vitamin C, meat, fish, and poultry eaten at the meal; and the presence of inhibitors of iron absorption such as tea, coffee, and nuts. (Chapter 13 describes the many factors that influence iron absorption from a meal.)

Furthermore, reported portion sizes may not be correct. The person who reports eating "a serving" of greens may not distinguish between ¼ cup and 2 whole cups; only individuals who have practice measuring food quantities can accurately report serving sizes. Children tend to remember the serving sizes of foods they like as being larger than serving sizes of foods they dislike.

An estimate of nutrient intakes from a diet history, combined with other sources of information, allows the assessor to confirm or eliminate the possibility of suspected nutrition problems. The assessor must constantly remember that nutrient intakes in adequate amounts do not guarantee adequate nutrient status for an individual. Likewise, insufficient intakes do not always indicate deficiencies, but instead alert the assessor to possible problems. Each person digests, absorbs, metabolizes, and excretes nutrients in a unique way; individual needs vary. Intakes of nutrients identified by diet histories are only pieces of a puzzle that must be put together with other indicators of nutrition status in order to extract meaning.

Anthropometric Measurements

Anthropometrics are physical measurements that reflect body composition and development (see Table E-3). They serve three main purposes: first, to evaluate the progress of growth in pregnant women, infants, children, and adolescents; second, to detect undernutrition and overnutrition in all age groups; and third, to measure changes in body composition over time.

Health-care professionals compare anthropometric measurements taken on an individual with population standards specific for gender and age or with previous measures of the individual. Measurements taken periodically and compared with previous measurements reveal changes in an individual's status.

Mastering the techniques for taking anthropometric measurements requires proper instruction and practice to ensure reliability. Once the correct techniques are learned, taking measurements is easy and requires minimal equipment.

Height and weight are well-recognized anthropometrics; other anthropometrics include skinfold measurements and various measures of lean tissue. Other measures are useful in specific situations. For example, a head circumference measurement may help to assess brain development in an infant, and an abdominal girth measurement supplies information about abdominal fluid retention in individuals with liver disease.

Measures of Growth and Development

Height and weight are among the most common and useful anthropometric measurements. Length measurements for infants and children up to age 3 and height measurements for children

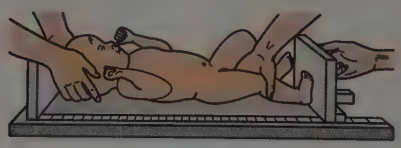
TABLE E-3 Anthropometric Measurements Used in Nutrition Assessments

Type of Measurement	What It Reflects
Abdominal girth measurement	Abdominal fluid retention and abdominal organ size
Height-weight	Overnutrition and undernutrition; growth in children
Head circumference	Brain growth and development in infants and children under age 2
Skinfold	Subcutaneous and total body fat
Waist circumference	Body fat distribution

anthropometrics: measurements of the physical characteristics of the body, such as height and weight.
- **anthropos** = human
- **metric** = measuring

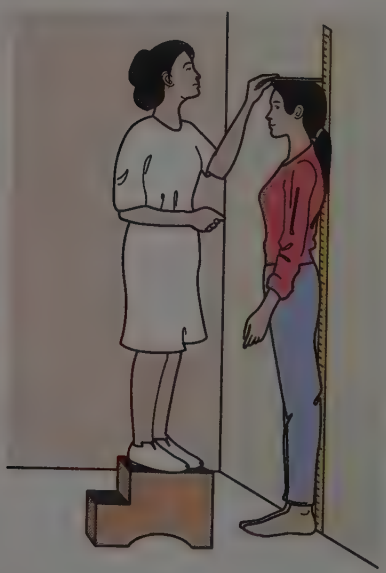
> FIGURE E-1 Length Measurement of an Infant

An infant is measured lying down on a measuring board with a fixed headboard and a movable footboard. Note that two people are needed to measure the infant's length.



> FIGURE E-2 Height Measurement of an Older Child or Adult

Height is measured most accurately when the person stands against a flat wall to which a measuring tape has been affixed.



over 3 are particularly valuable in assessing growth and therefore nutrition status. For adults, height measurements alone are not critical, but help to estimate healthy weight and to interpret other assessment data. Once adult height has been reached, changes in body weight provide useful information in assessing overnutrition and undernutrition.

Height For infants and children younger than 3, health-care professionals may use special equipment to measure length. The assessor lays the barefoot infant on a measuring board that has a fixed headboard and movable footboard attached at right angles to the surface (see Figure E-1). Often two people are needed to obtain an accurate measurement: one to hold the infant's head against the headboard, and the other to keep the legs straight and do the measuring. This method provides the most accurate measure possible, but many health-care professionals use a less exacting method. They may simply hold the infant straight with its head against the headboard or other vertical support, mark the blanket with a chalk or pen at the infant's heel, and then measure the distance from the headboard to the mark. Even more informally and less accurately, they may lay the infant on a flat surface and extend a nonstretchable measuring tape along the side of the infant from the top of the head to the heel of the foot.

The procedure for measuring a child who can stand erect and cooperate is the same as for an adult. The best way to measure standing height is with the person's back against a flat wall to which a nonstretchable measuring tape or stick has been fixed (see Figure E-2). The person stands erect, without shoes, with heels together. The person's line of sight should be horizontal, with the heels, buttocks, shoulders, and head touching the wall. The assessor places a ruler, book, or other inflexible object on top of the head at a right angle to the wall; carefully checks the height measurement; and records it immediately in either inches or centimeters so that the correct measurement will not be forgotten.

The measuring rod of a scale is commonly used, but is less accurate because it bends easily. The assessor follows the same general procedure, asking the person to face away from the scale and to take extra care to stand erect.

Unfortunately, many health-care professionals merely ask clients how tall they are rather than measuring their height. Self-reported height is often inaccurate and should be used only as a last resort when measurement is impractical (in the case of an uncooperative client, an emergency admission, or the like).

Weight Valid weight measurements require scales that have been carefully maintained, calibrated, and checked for accuracy at regular intervals. Beam balance and electronic scales are the most accurate types of scales. To measure infants' weight, assessors use special scales that allow infants to lie or sit (see Figure E-3). Weighing infants naked, without diapers, is standard procedure. Children who can stand are weighed in the same way as adults (see Figure E-4). To make repeated measures useful, standardized conditions are necessary. Each weighing should take place at the same time of day (preferably before breakfast), in the same amount of clothing (without shoes), after the person has voided, and on the same scale. Special scales and hospital beds with built-in scales are available for weighing people who are bedridden. Bathroom scales are inaccurate and inappropriate in a professional setting. As with all measurements, the assessor records the observed weight immediately in either pounds or kilograms.

Head Circumference Assessors may also measure head circumference to confirm that infant growth is proceeding normally or to help detect protein malnutrition and evaluate the extent of its impact on brain size. To measure head circumference, the assessor places a nonstretchable tape so that it encircles the largest part of the infant's or child's head: just above the eyebrow ridges, just above the point where the ears attach, and around the occipital prominence at the back of the head. To ensure accurate recording, the assessor immediately notes the measure in either inches or centimeters.

Analysis of Measures in Infants and Children Growth retardation is a sign of poor nutrition status. Obesity is also a sign that dietary intervention may be needed.

Health professionals generally evaluate physical development by monitoring the growth rate of a child and comparing this rate with standard charts. Standard charts compare weight to age, height to age, and weight to height; ideally, height and weight are in roughly the same percentile. Although individual growth patterns may vary, a child's growth curve will generally stay at about the same percentile throughout childhood. In children whose growth has been retarded, nutrition rehabilitation will ideally induce height and weight to increase to higher percentiles. In overweight children, the goal is for weight to remain stable as height increases, until weight becomes appropriate for height.

To evaluate growth in infants, an assessor uses charts such as those in Figures E-5 (A and B) through E-10 (A and B). The assessor follows these steps to plot a weight measurement on a percentile graph:

- Select the appropriate chart based on age and gender.
- Locate the child's age along the horizontal axis on the bottom of the chart.
- Locate the child's weight in pounds or kilograms along the vertical axis.
- Mark the chart where the age and weight lines intersect, and read off the percentile.

To assess length, height, or head circumference, the assessor follows the same procedure, using the appropriate chart. (When length is measured, use the chart for birth to 36 months; when height is measured, use the chart for 2 to 20 years.) Head circumference percentile should be similar to the child's height and weight percentiles. With height, weight, and head circumference measures plotted on growth percentile charts, a skilled clinician can begin to interpret the data.

Percentile charts divide the measures of a population into 100 equal divisions. Thus half of the population falls above the 50th percentile, and half falls below. The use of percentile measures allows for comparisons among people of the same age and gender. For example, a 6-month-old female infant whose weight is at the 75 percentile weighs more than 75 percent of the female infants her age.

Head circumference is generally measured in children under 2 years of age. Because the brain grows rapidly before birth and during early infancy, extreme and chronic malnutrition during these times can impair brain development, curtailing the number of brain cells and the size of head circumference. Nonnutritional factors, such as certain disorders and genetic variation, can also influence head circumference.

Analysis of Measures in Adults For adults, health-care professionals typically compare weights with weight-for-height standards. One such standard is the body mass index (BMI), ♦ described in Chapter 8, which is useful for estimating the risk to health associated with overnutrition. The inside back cover shows BMI for various heights and weights.

Measures of Body Fat and Lean Tissue

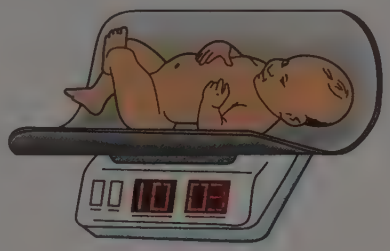
Significant weight changes in both children and adults can reflect overnutrition and undernutrition with respect to energy and protein. To estimate the degree to which fat stores or lean tissues are affected by overnutrition or malnutrition, several anthropometric measurements are useful (review Table E-3 on p. E-5).

Skinfold Measures Skinfold measures provide a good estimate of total body fat and a fair assessment of the fat's location. Approximately half the fat in the body lies directly beneath the skin, and the thickness of this subcutaneous fat reflects total body fat. In some parts of the body, such as the back and the back of the arm over the triceps muscle, this fat is loosely attached; ♦ a person can pull it up between the thumb and forefinger to obtain a measure of skinfold thickness. To measure skinfold, a skilled assessor follows a standard procedure using reliable calipers (illustrated in Figure E-11, p. E-14) and then compares the measurement with standards. Triceps skinfold measures greater than 15 millimeters in men or 25 millimeters in women suggest excessive body fat.

Skinfold measurements correlate directly with the risk of heart disease. They assess central obesity and its associated risks better than do weight measures

> FIGURE E-3 Weight Measurement of an Infant

Infants sit or lie down on scales that are designed to hold them while they are being weighed.



♦ The *body mass index (BMI)* is an index of a person's weight in relation to height, determined by dividing the weight in kilograms by the square of the height in meters:

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$$

♦ Common sites for skinfold measures:

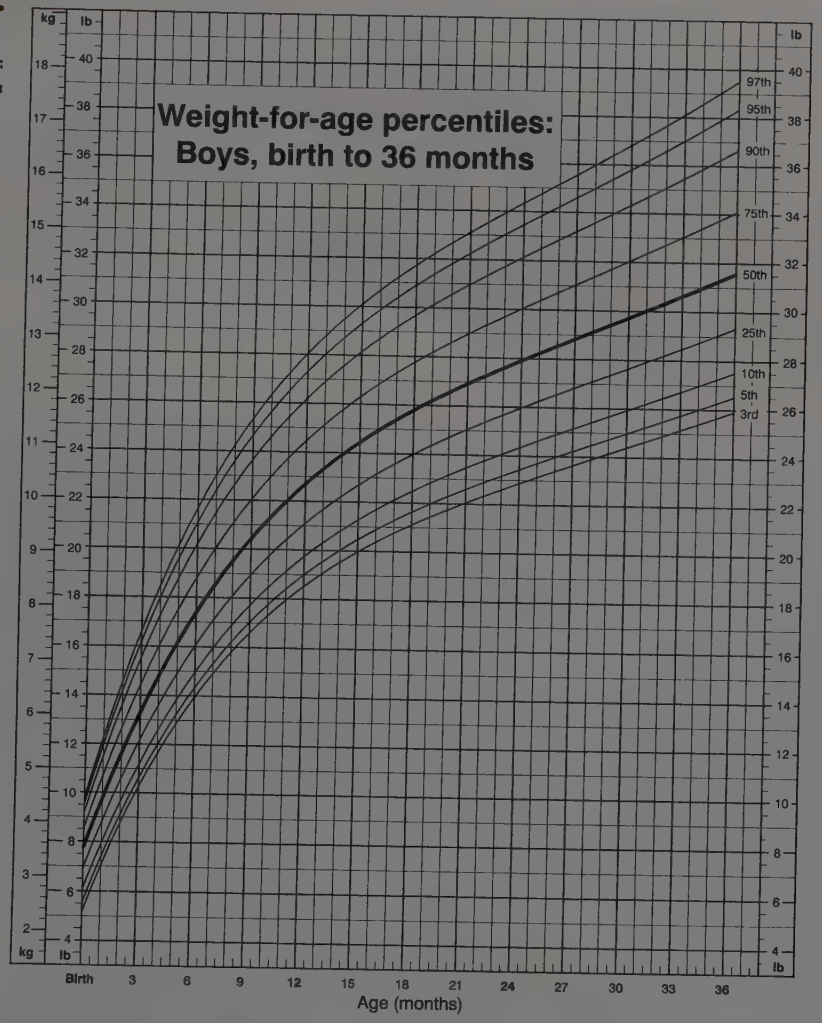
- Triceps
- Biceps
- Subscapular (below shoulder blade)
- Suprailiac (above hip bone)
- Abdomen
- Upper thigh

> FIGURE E-4 Weight Measurement of an Older Child or Adult

Whenever possible, children and adults are measured on beam balance or electronic scales to ensure accuracy.



FIGURE E-5A Weight-for-Age Percentiles: Boys, Birth to 36 Months

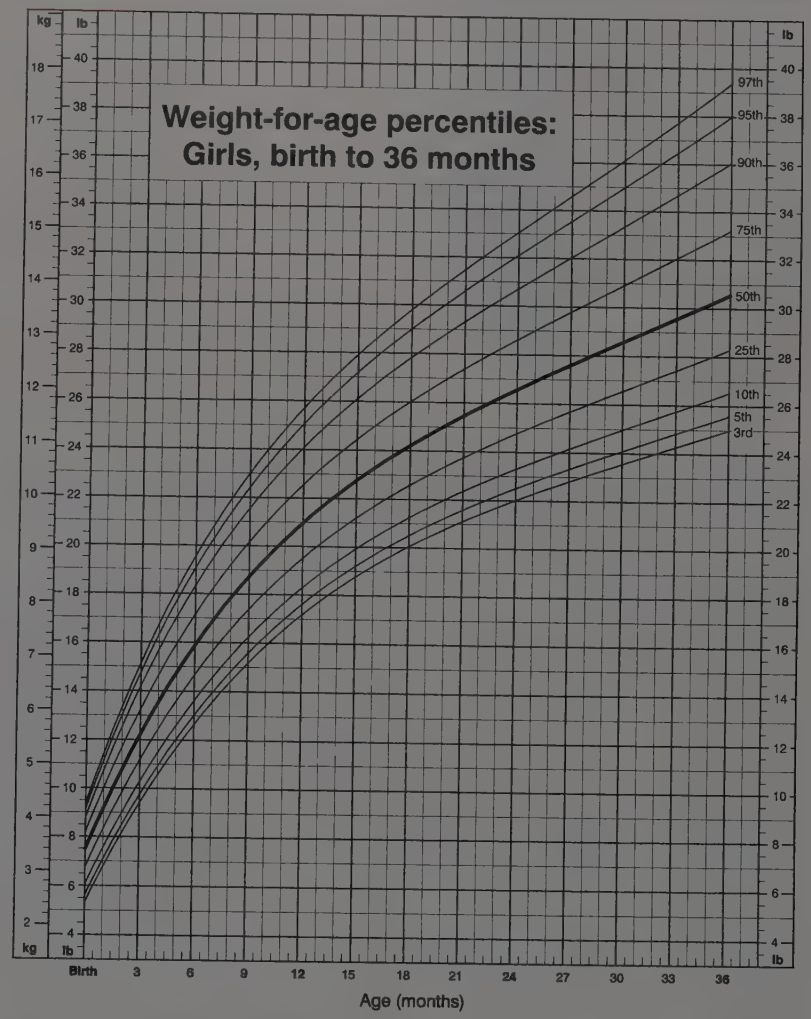


SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

CDC

Figure 1. Weight-for-age percentiles, boys, birth to 36 months, CDC growth charts: United States

FIGURE E-5B Weight-for-Age Percentiles: Girls, Birth to 36 Months

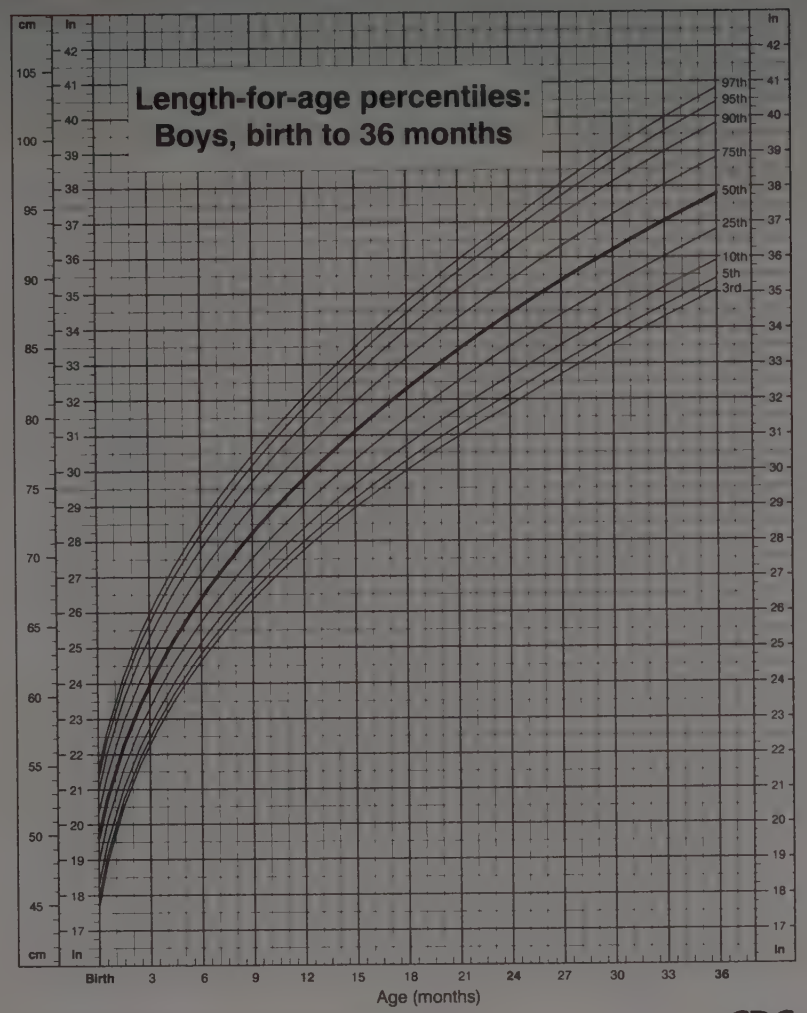


SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

CDC

Figure 2. Weight-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States

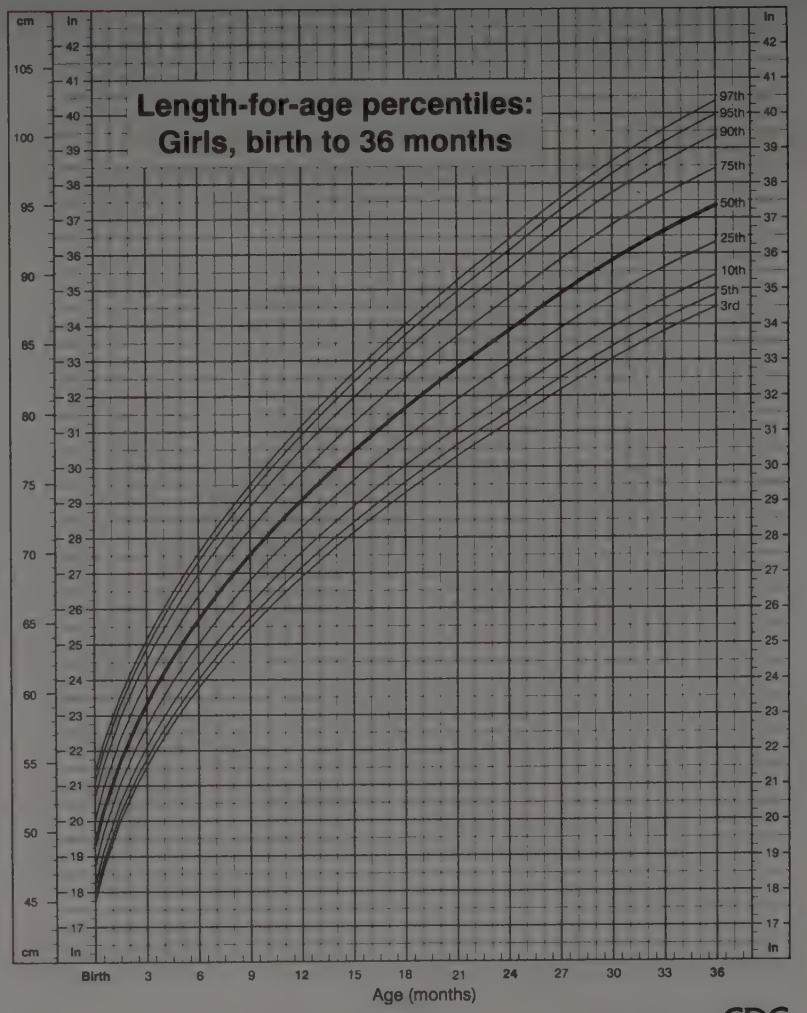
> FIGURE E-6A Length-for-Age Percentiles: Boys, Birth to 36 Months



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 3. Length-for-age percentiles, boys, birth to 36 months, CDC growth charts: United States

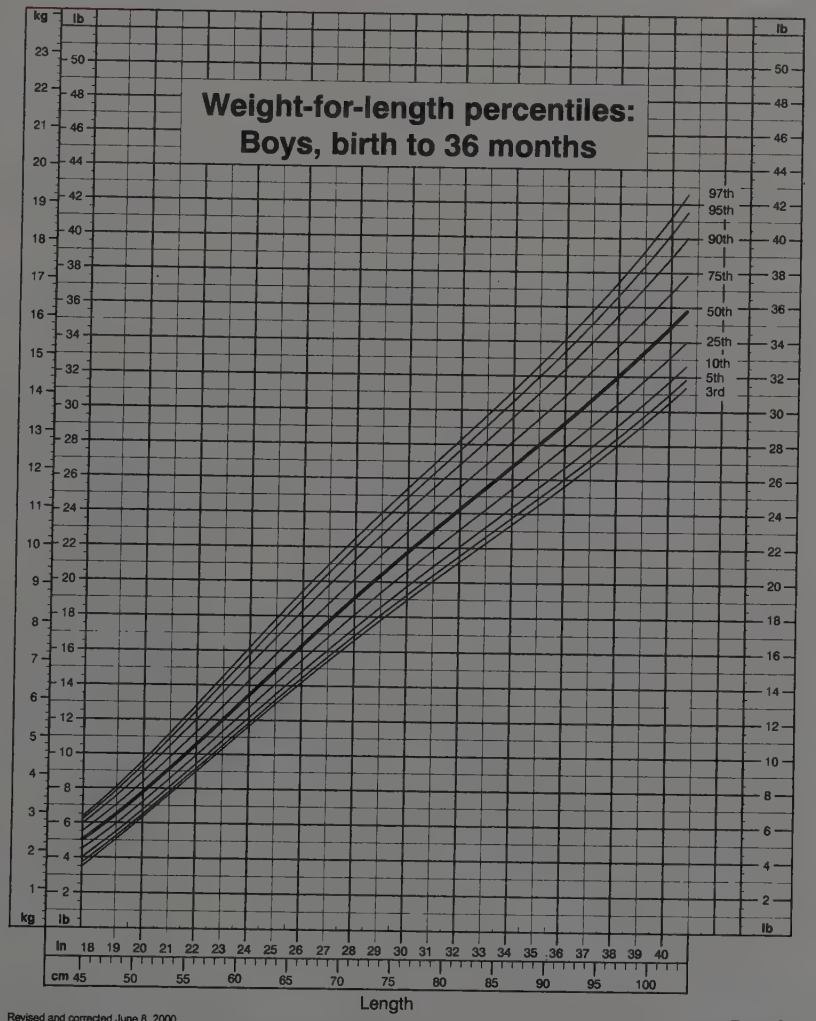
> FIGURE E-6B Length-for-Age Percentiles: Girls, Birth to 36 Months



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 4. Length-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States

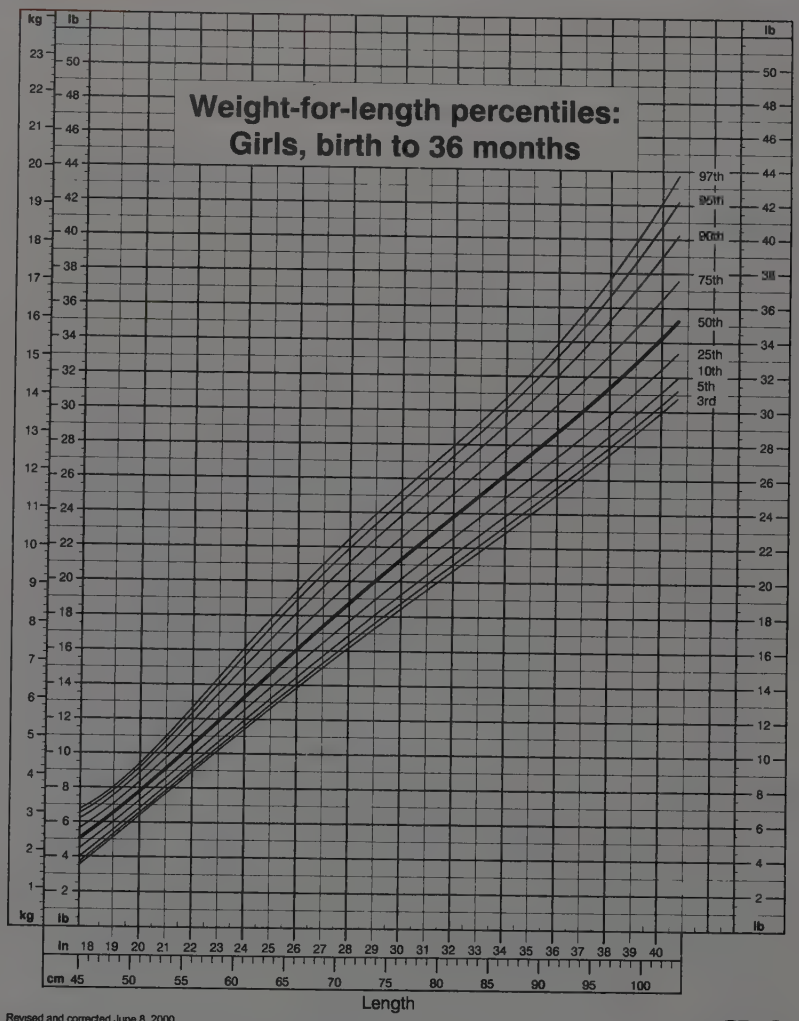
> FIGURE E-7A Weight-for-Length Percentiles: Boys, Birth to 36 Months



Revised and corrected June 8, 2000.
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 5. Weight-for-length percentiles, boys, birth to 36 months, CDC growth charts: United States

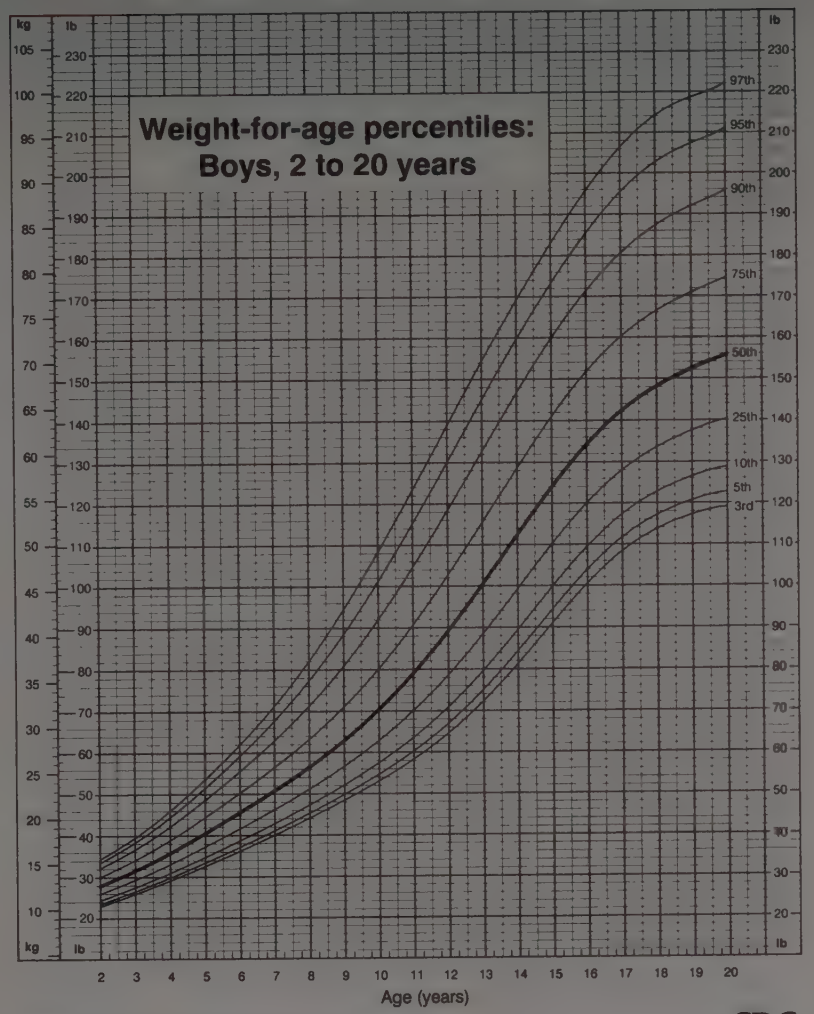
> FIGURE E-7B Weight-for-Length Percentiles: Girls, Birth to 36 Months



Revised and corrected June 8, 2000.
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 6. Weight-for-length percentiles, girls, birth to 36 months, CDC growth charts: United States

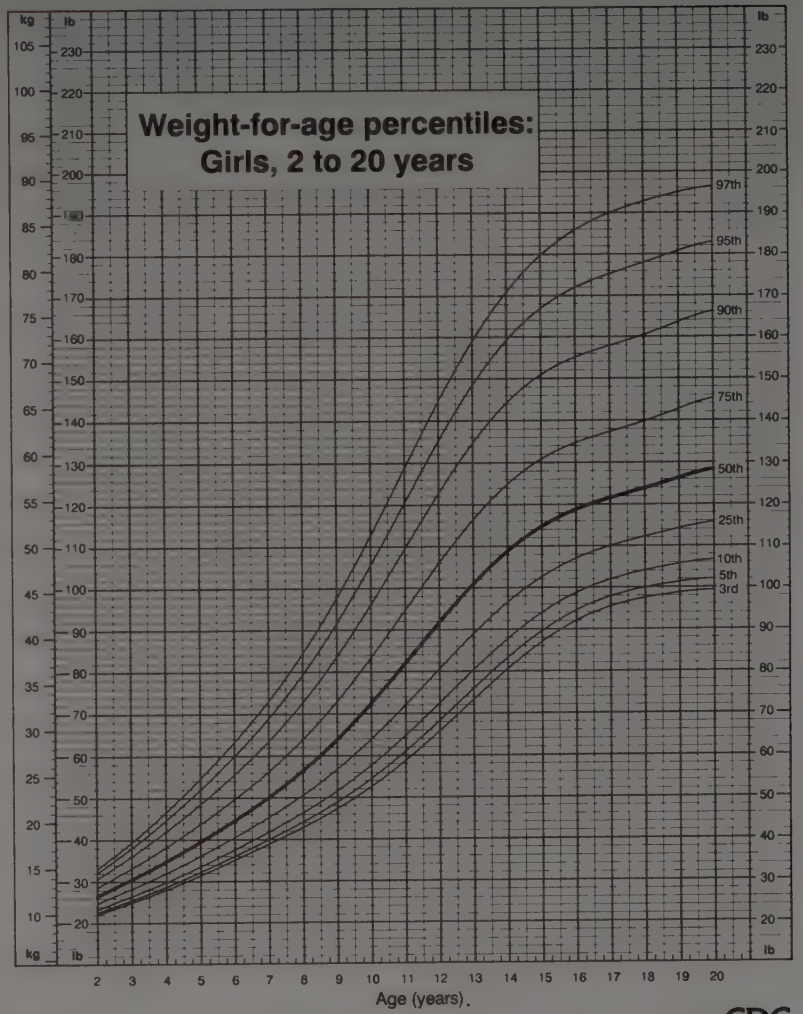
> FIGURE E-8A Weight-for-Age Percentiles: Boys, 2 to 20 Years



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 9. Weight-for-age percentiles, boys, 2 to 20 years, CDC growth charts: United States

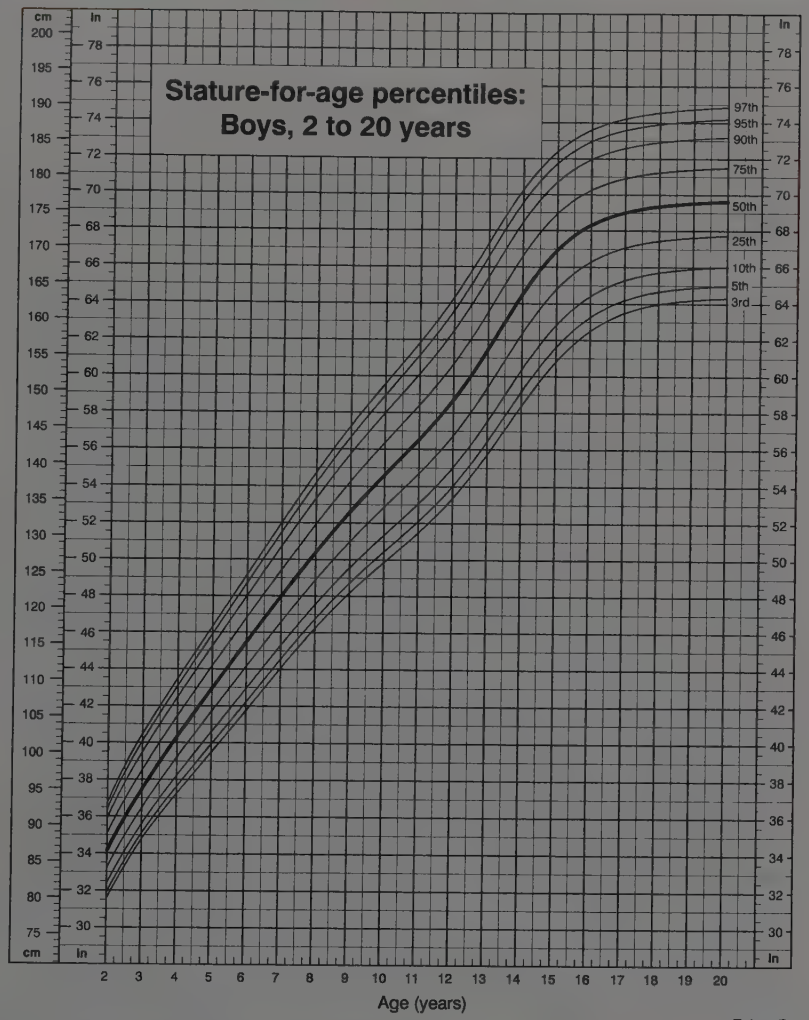
> FIGURE E-8B Weight-for-Age Percentiles: Girls, 2 to 20 Years



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 10. Weight-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States

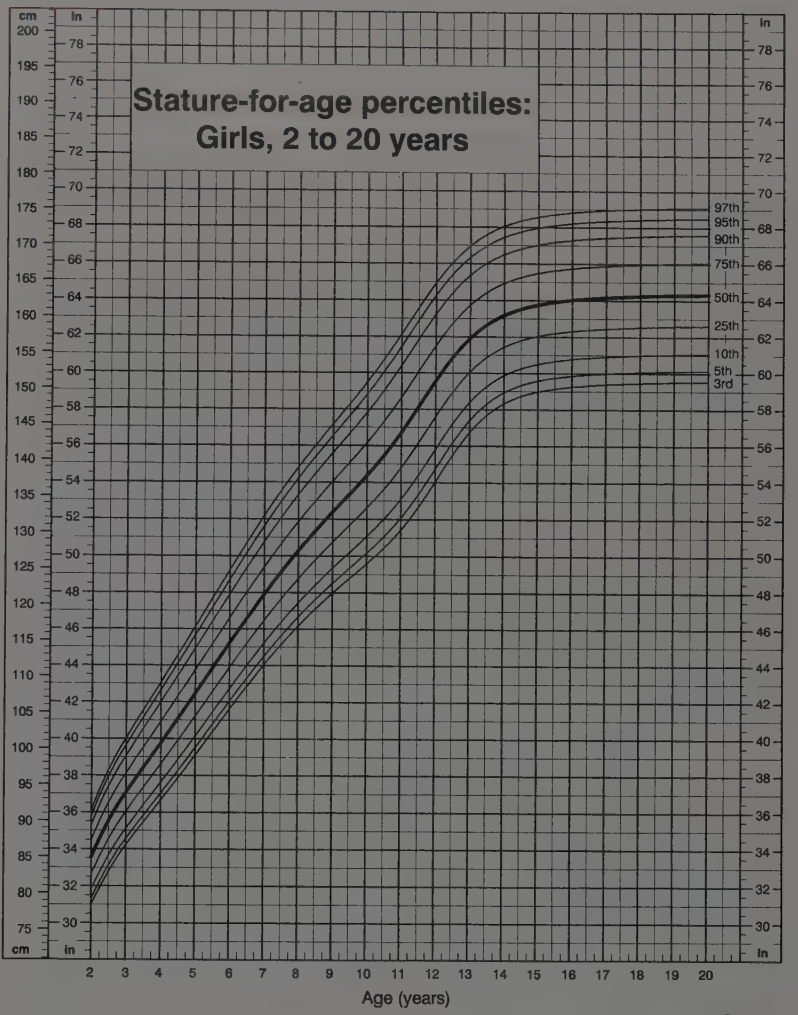
FIGURE E-9A Stature-for-Age Percentiles: Boys, 2 to 20 Years



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 11. Stature-for-age percentiles, boys, 2 to 20 years, CDC growth charts: United States

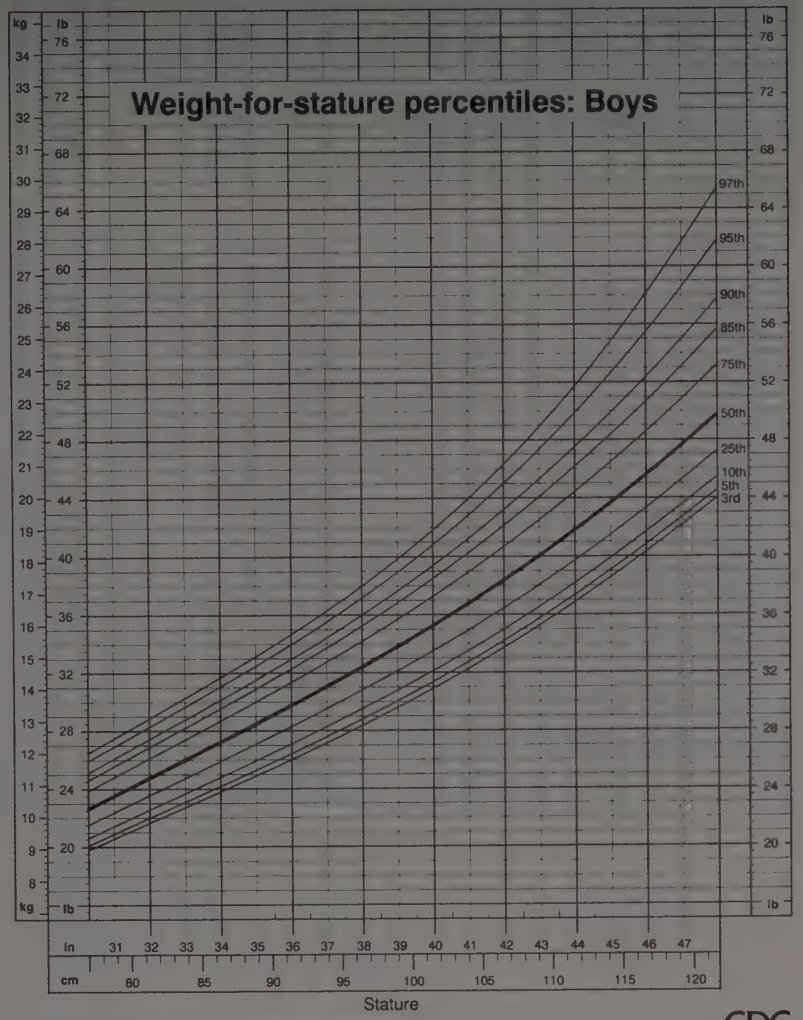
FIGURE E-9B Stature-for-Age Percentiles: Girls, 2 to 20 Years



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 12. Stature-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States

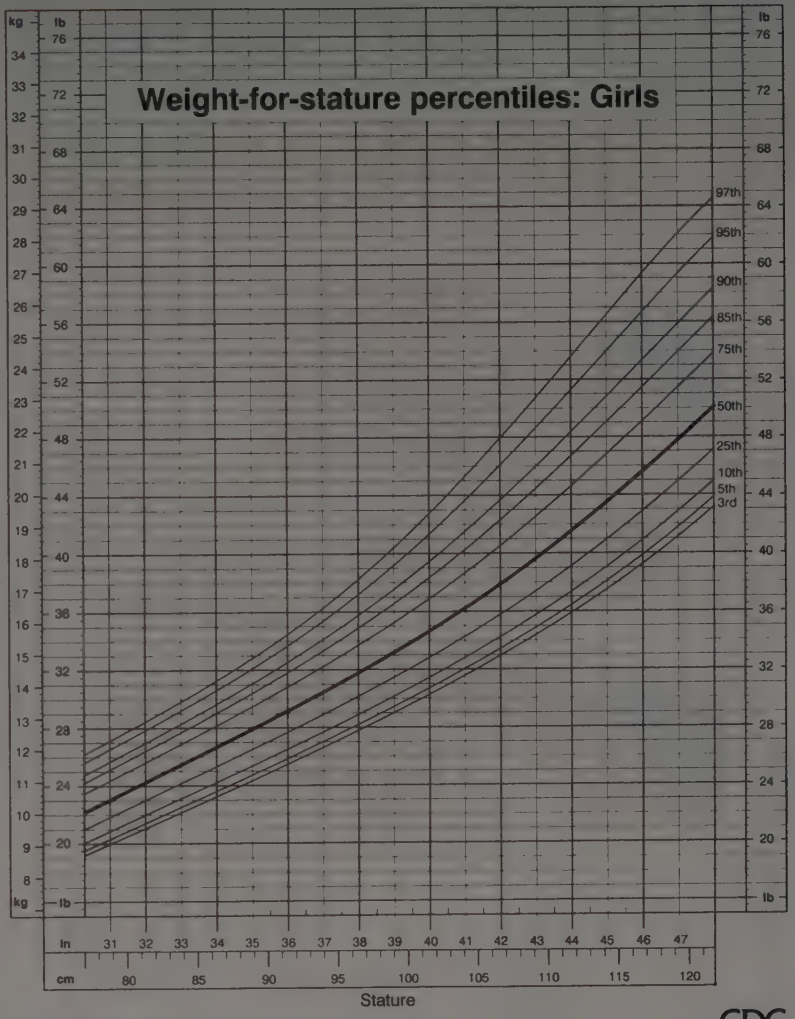
FIGURE E-10A Weight-for-Stature Percentiles: Boys, 2 to 20 Years



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000)

Figure 13. Weight-for-stature percentiles, boys, CDC growth charts: United States

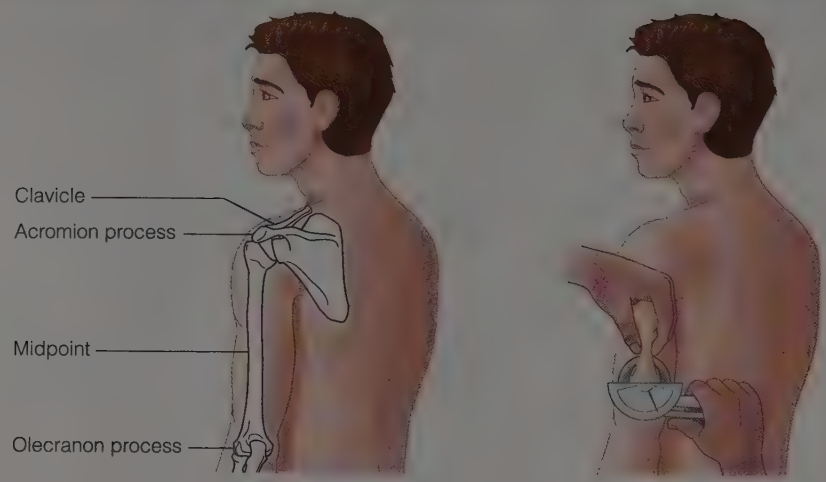
FIGURE E-10B Weight-for-Stature Percentiles: Girls, 2 to 20 Years



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 14. Weight-for-stature percentiles, girls, CDC growth charts: United States

> **FIGURE E-11 How to Measure the Triceps Skinfold**



A. Find the midpoint of the arm:
1. Ask the subject to bend his or her arm at the elbow and lay the hand across the stomach. (If he or she is right-handed, measure the left arm, and vice versa.)
2. Feel the shoulder to locate the acromion process. It helps to slide your fingers along the clavicle to find the acromion process. The olecranon process is the tip of the elbow.
3. Place a measuring tape from the acromion process to the tip of the elbow. Divide this measurement by 2, and mark the midpoint of the arm with a pen.

B. Measure the skinfold:
1. Ask the subject to let his or her arm hang loosely to the side.
2. Grasp a fold of skin and subcutaneous fat between the thumb and forefinger slightly above the midpoint mark. Gently pull the skin away from the underlying muscle. (This step takes a lot of practice. To be sure you don't have muscle as well as fat, ask the subject to contract and relax the muscle. You should be able to feel if you are pinching muscle.)
3. Place the calipers over the skinfold at the midpoint mark, and read the measurement to the nearest 1.0 millimeter in two to three seconds. (If using plastic calipers, align pressure lines, and read the measurement to the nearest 1.0 millimeter in two to three seconds.)
4. Repeat steps 2 and 3 twice more. Add the three readings, and then divide by 3 to find the average.

alone. If a person gains body fat, the skinfold increases proportionately; if the person loses fat, it decreases. Measurements taken from central-body sites (around the abdomen) better reflect changes in fatness than those taken from upper sites (arm and back). A major limitation of the skinfold test is that fat may be thicker under the skin in one area than in another. A pinch at the side of the waistline may not yield the same measurement as a pinch on the back of the arm. This limitation can be overcome by taking skinfold measurements at several (often three) different places on the body (including upper-, central-, and lower-body sites) and comparing each measurement with standards for that site. Multiple measures are not always practical in clinical settings, however, and most often, the triceps skinfold measurement alone is used because it is easily accessible. Skinfold measures are not useful in assessing changes in body fat over time.

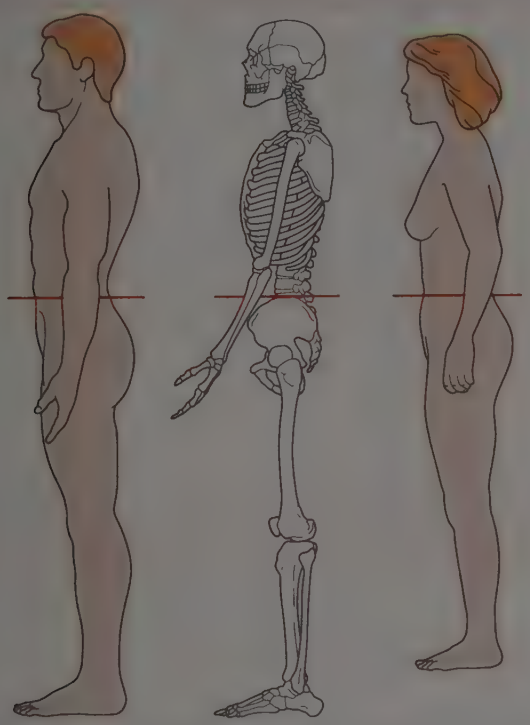
Waist Circumference Chapter 8 describes how fat distribution correlates with health risks and mentioned that the waist circumference is a valuable indicator of fat distribution. To measure waist circumference, the assessor places a nonstretchable tape around the person's body, crossing just above the upper hip bones and making sure that the tape remains on a level horizontal plane on all sides (see Figure E-12). The tape is tightened slightly, but without compressing the skin.

Waist-to-Hip Ratio Alternatively, some clinicians measure both the waist and the hips. The waist-to-hip ratio ♦ also assesses abdominal obesity, but provides no more information than using the waist circumference alone. In general, women with a waist-to-hip ratio of 0.80 or greater and men with a waist-to-hip ratio of 0.90 or greater have a high risk of health problems.

♦ To calculate the waist-to-hip ratio, divide the waistline measurement by the hip measurement. For example, a woman with a 28-inch waist and 38-inch hips would have a ratio of 28 ÷ 38 = 0.74.

> **FIGURE E-12 How to Measure Waist Circumference**

Place the measuring tape around the waist just above the bony crest of the hip. The tape runs parallel to the floor and is snug (but does not compress the skin). The measurement is taken at the end of normal expiration.



SOURCE: National Institutes of Health Obesity Education Initiative, *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults* (Washington, D.C.: U.S. Department of Health and Human Services, 1998), p. 59.

Hydrodensitometry To estimate body density using hydrodensitometry, the person is weighed twice—first on land and then again when submerged under water. Underwater weighing usually generates a good estimate of body fat and is useful in research, although the technique has drawbacks: it requires bulky, expensive, and nonportable equipment. Furthermore, submerging some people (especially those who are very young, very old, ill, or fearful) under water is not always practical.

Bioelectric Impedance To measure body fat using the bioelectric impedance technique, a very-low-intensity electrical current is briefly sent through the body by way of electrodes placed on the wrist and ankle. As is true of other anthropometric techniques, bioelectrical impedance requires standardized procedures and calibrated instruments to provide reliable results. Recent food intake and hydration status, for example, influence results. Bioelectrical impedance is most accurate for people within a normal fat range; it tends to overestimate fat in lean people and underestimate fat in obese people.

Chapter 8 (p. 246) illustrates several anthropometric measures of body fat and lean tissue. Clinicians use other methods to estimate body fat and its distribution as well. Each has its advantages and disadvantages as Table E-4 (p. E-16) summarizes.

Physical Examinations

An assessor can use a physical examination to search for signs of nutrient deficiency or toxicity. Like the other assessment methods, such an examination requires knowledge and skill. Many physical signs are nonspecific; they can reflect any of several nutrient deficiencies as well as conditions not related to nutrition

TABLE E-4 Methods of Estimating Body Fat and Its Distribution

Method	Cost	Ease of Use	Accuracy	Measures Fat Distribution
Height and weight	Low	Easy	High	No
Skinfolds	Low	Easy	Low	Yes
Circumferences	Low	Easy	Moderate	Yes
Ultrasound	Moderate	Moderate	Moderate	Yes
Hydrodensitometry	Low	Moderate	High	No
Heavy water tritiated	Moderate	Moderate	High	No
Deuterium oxide, or heavy oxygen	High	Moderate	High	No
Potassium isotope (^{40}K)	Very high	Difficult	High	No
Total body electrical conductivity (TOBEC)	High	Moderate	High	No
Bioelectric impedance (BIA)	Moderate	Easy	High	No
Dual-energy X-ray absorptiometry (DEXA)	High	Easy	High	No
Computed tomography (CT)	Very high	Difficult	High	Yes
Magnetic resonance imaging (MRI)	Very high	Difficult	High	Yes

SOURCE: Adapted with permisssion from G. A. Bray, a handout presented at the North American Association for the Study of Obesity and Emory University School of Medicine Conference on Obesity. Update: Pathophysiology, Clinical Consequences, and Therapeutic Options, Atlanta, Georgia, August 31–September 2, 1992.

(see Table E-5). For example, cracked lips may be caused by sunburn, windburn, dehydration, or any of several B vitamin deficiencies, to name just a few possible causes. For this reason, physical findings are most valuable in revealing problems for other assessment techniques to confirm or for confirming other assessment measures.

With this limitation understood, physical symptoms can be most informative and communicate much information about nutrition health. Many tissues and organs can reflect signs of malnutrition. The signs appear most rapidly in parts of the body where cell replacement occurs at a high rate, such as in the hair, skin, and digestive tract (including the mouth and tongue). The summary tables in Chapters 10, 11, 12, and 13 list additional physical signs of vitamin and mineral malnutrition.

TABLE E-5 Physical Findings Used in Nutrition Assessments

Body System	Healthy Findings	Malnutrition Findings	What the Findings Reflect
Hair	Shiny, firm in the scalp	Dull, brittle, dry, loose; falls out	Protein malnutrition
Eyes	Bright, clear pink membranes; adjust easily to light	Pale membranes; spots; redness; adjust slowly to darkness	Vitamin A, B vitamin, zinc, and iron status
Teeth and gums	No pain or caries, gums firm, teeth bright	Missing, discolored, decayed teeth; gums bleed easily and are swollen and spongy	Mineral and vitamin C status
Glands	No lumps	Swollen at front of neck	Protein malnutrition and iodine status
Tongue	Red, bumpy, rough	Sore, smooth, purplish, swollen	B vitamin status
Skin	Smooth, firm, good color	Off-color, scaly, flaky, cracked, dry, rough, spotty; "sandpaper" feel or sores; lack of fat under skin	Protein malnutrition, essential fatty acid, vitamin A, B vitamin, and vitamin C status
Nails	Firm, pink	Spoon-shaped, brittle, ridged, pale	Iron status
Internal systems	Regular heart rhythm, heart rate, and blood pressure; no impairment of digestive function, reflexes, or mental status	Abnormal heart rate, heart rhythm, or blood pressure; enlarged liver, spleen; abnormal digestion; burning, tingling of hands, feet; loss of balance, coordination; mental confusion, irritability, fatigue	Protein malnutrition and mineral status
Muscles and bones	Muscle tone; posture, long bone development appropriate for age	"Wasted" appearance of muscles; swollen bumps on skull or ends of bones; small bumps on ribs; bowed legs or knock-knees	Protein malnutrition, mineral, and vitamin D status

Biochemical Analyses

All of the approaches to nutrition assessment discussed so far are external approaches. Biochemical analyses or laboratory tests help to determine what is happening to the body internally. Common tests are based on analysis of blood and urine samples, which contain nutrients, enzymes, and metabolites that reflect nutrition status. Other tests, such as blood glucose, help pinpoint disease-related problems with nutrition implications. Tests that define fluid and electrolyte balance, acid-base balance, and organ function also have nutrition implications. Table E-6 lists biochemical tests most useful for assessing vitamin and mineral status.

The interpretation of biochemical data requires skill. Long metabolic sequences lead to the production of the end-products and metabolites seen in blood and urine. No single test can reveal nutrition status because many factors influence test results. The low blood concentration of a nutrient may reflect a primary deficiency of that nutrient, but it may also be secondary to the deficiency of one or several other nutrients or to a disease. Taken together with other assessment data,

TABLE E-6 Biochemical Tests Useful for Assessing Vitamin and Mineral Status

Nutrient	Assessment Tests
Vitamins	
Vitamin A	Serum retinol, retinol-binding protein
Thiamin[a]	Erythrocyte (red blood cell) transketolase activity, erythrocyte thiamin pyrophosphate
Riboflavin[a]	Erythrocyte glutathione reductase activity
Vitamin B_6[a]	Urinary xanthurenic acid excretion after tryptophan load test, erythrocyte transaminase activity, plasma pyridoxal 5'-phosphate (PLP)
Niacin	Plasma or urinary metabolites NMN (N-methyl nicotinamide) or 2-pyridone, or preferably both expressed as a ratio
Folate[b]	Serum folate, erythrocyte folate (reflects liver stores)
Vitamin B_{12}[b]	Serum vitamin B_{12}, serum and urinary methylmalonic acid, Schilling test
Biotin	Urinary biotin, urinary 3-hydroxyisovaleric acid
Vitamin C	Plasma vitamin C[c], leukocyte vitamin C
Vitamin D	Serum vitamin D
Vitamin E	Serum α-tocopherol, erythrocyte hemolysis
Vitamin K	Serum vitamin K, plasma prothrombin; blood-clotting time (prothrombin time) is not an adequate indicator
Minerals	
Phosphorus	Serum phosphate
Sodium	Serum sodium
Chloride	Serum chloride
Potassium	Serum potassium
Magnesium	Serum magnesium, urinary magnesium
Iron	Hemoglobin, hematocrit, serum ferritin, total iron-binding capacity (TIBC), erythrocyte protoporphyrin, serum iron, transferrin saturation
Iodine	Serum thyroxine or thyroid-stimulating hormone (TSH), urinary iodine
Zinc	Plasma zinc, hair zinc
Copper	Erythrocyte superoxide dismutase, serum copper, serum ceruloplasmin
Selenium	Erythrocyte selenium, glutathione peroxidase activity

[a]Urinary measurements for these vitamins are common, but may be of limited use. Urinary measurements reflect recent dietary intakes and may not provide reliable information concerning the severity of a deficiency.
[b]Folate assessments should always be conducted in conjunction with vitamin B_{12} assessments (and vice versa) to help distinguish the cause of common deficiency symptoms.
[c]Vitamin C shifts between the plasma and the white blood cells known as leukocytes; thus a plasma determination may not accurately reflect the body's pool. A measurement of leukocyte vitamin C can provide information about the body's stores of vitamin C. A combination of both tests may be more reliable than either one alone.
SOURCE: Adapted from H. E. Sauberlich, *Laboratory Tests for the Assessment of Nutritional Status* (Boca Raton, FIA.: CRC Press, 1999).

TABLE E-7 Normal Values for Serum Proteins

Indicator	Normal
Albumin (g/dL)	3.5–5.0
Transferrin (mg/dL)	200–400
Transthyretin (mg/dL)	16–40
Retinol-binding protein (mg/dL)	3–7
IGF-1 (μg/L)	300

NOTE: Levels less than normal suggest compromised protein status.

♦ A *subclinical deficiency* is a nutrient deficiency in the early stages before the outward signs have appeared.

♦ Transthyretin is also known as *prealbumin* or *thyroxine-binding prealbumin.*

however, laboratory test results help to create a picture that becomes clear with careful interpretation. They are especially useful in helping to detect subclinical malnutrition by uncovering early signs of malnutrition before the clinical signs of a classic deficiency disease appear.

Laboratory tests used to assess vitamin and mineral status (review Table E-6) are particularly useful when combined with diet histories and physical findings. Vitamin and mineral levels present in the blood and urine sometimes reflect recent rather than long-term intakes. This makes detecting subclinical deficiencies ♦ difficult. Furthermore, many nutrients interact; therefore, the amounts of other nutrients in the body can affect a lab value for a particular nutrient. It is also important to remember that nonnutrient conditions such as diseases influence biochemical measures.

It is beyond the scope of this text to describe all lab tests and their relations to nutrition status. Instead, the emphasis is on lab tests used to detect protein malnutrition and nutritional anemias.

Protein Malnutrition

No single biochemical analysis can adequately evaluate protein malnutrition. This discussion focuses on the measures commonly used today—transthyretin, retinol-binding protein, serum transferrin, and IGF-1 (insulin-like growth factor 1). Table E-7 provides standards for these indicators. Although serum albumin is easily and routinely measured, it lacks the sensitivity to assess protein malnutrition because of its long turnover rate.*

Transthyretin and Retinol-Binding Protein

Transthyretin ♦ and retinol-binding protein occur as a complex in the plasma. They have a rapid turnover and thus respond quickly to dietary protein inadequacy and therapy.** Conditions other than malnutrition that lower transthyretin include metabolic stress, hemodialysis, and hypothyroidism; those that raise transthyretin include kidney disease and corticosteroid use. Conditions other than protein malnutrition that lower retinol-binding protein include vitamin A deficiency, metabolic stress, hyperthyroidism, liver disease, and cystic fibrosis; kidney disease raises retinol-binding protein levels.

Serum Transferrin

Serum transferrin transports iron; consequently, its concentrations reflect both protein and iron status. Using transferrin as an indicator of protein status is complicated when an iron deficiency is present. Transferrin rises as iron deficiency grows worse and falls as iron status improves. Markedly reduced transferrin levels indicate severe protein malnutrition; in mild-to-moderate protein malnutrition, transferrin levels may vary, limiting their usefulness. Conditions other than protein malnutrition that lower transferrin include liver disease, kidney disease, and metabolic stress; those that raise transferrin include pregnancy, iron deficiency, hepatitis, blood loss, and oral contraceptive use. Although transferrin breaks down in the body more quickly than albumin, it is still relatively slow to respond to changes in protein intake and is not a sensitive indicator of the response to therapy.***

IGF-1 (Insulin-like Growth Factor 1)

IGF-1 (insulin-like growth factor 1) declines in protein malnutrition. IGF-1 has a relatively short half-life and responds specifically to dietary protein rather than energy.**** For these reasons, it is a sensitive indicator of protein status and response to therapy. Conditions that decrease IGF-1 include anorexia nervosa, inflammatory bowel disease, celiac disease, HIV infection, and fasting.

Nutritional Anemias

Anemia, a symptom of a wide variety of nutrition- and nonnutrition-related disorders, is characterized by a reduced number of red blood cells. Iron, folate, and vitamin B_{12} deficiencies caused by inadequate intake, poor absorption, or abnormal metabolism of these nutrients are the most

*The half-life of albumin is 14 to 20 days, an indication of a slow degradation rate.
**The half-lives of transthyretin and retinol-binding protein are 2 days and 12 hours, respectively.
***The half-life of transferrin is 8 to 10 days.
****The half-life of IGF-1 is 12 to 15 hours.

common nutritional anemias. Some nonnutrition-related causes of anemia include massive blood loss, infections, hereditary blood disorders such as sickle-cell anemia, and chronic liver or kidney disease.

Assessment of Iron-Deficiency Anemia Iron deficiency, a common mineral deficiency, develops in stages. ♦ Chapter 13 describes iron deficiency in detail. This section describes tests used to uncover iron deficiency as it progresses. Table E-8 shows which laboratory tests detect various nutrition-related anemias, and Table E-9 (p. E-20) provides values used for assessing iron status. Although other tests are more specific in detecting early deficiencies, hemoglobin and hematocrit are the most commonly available tests.

♦ Stages of iron deficiency:
1. Iron stores diminish.
2. Transport iron decreases.
3. Hemoglobin production falls.

Hemoglobin Iron forms an integral part of the hemoglobin molecule that transports oxygen to the cells. In iron deficiency, the body cannot synthesize hemoglobin. Low hemoglobin values signal depleted iron stores. Table E-9 provides hemoglobin values used in nutrition assessment. Hemoglobin's usefulness in evaluating iron status is limited, however, because hemoglobin concentrations drop fairly late in the development of iron deficiency, and other nutrient deficiencies and medical conditions can also alter hemoglobin concentrations.

Hematocrit Hematocrit is commonly used to diagnose iron deficiency, even though it is an inconclusive measure of iron status. To measure the hematocrit, a clinician spins a volume of blood in a centrifuge to separate the red blood cells from the plasma. The hematocrit is the percentage of red blood cells in the total blood volume. Table E-9 includes values used to assess hematocrit status. Low values indicate incomplete hemoglobin formation, which is manifested by microcytic (abnormally small-celled), hypochromic (abnormally lacking in color) red blood cells.

TABLE E-8 Laboratory Tests Useful in Evaluating Nutrition-Related Anemias

Test or Test Result	What It Reflects
For Anemia (general)	
Hemoglobin (Hg)	Total amount of hemoglobin in the red blood cells (RBC)
Hematocrit (Hct)	Percentage of RBC in the total blood volume
Red blood cell (RBC) count	Number of RBC
Mean corpuscular volume (MCV)	RBC size; helps to determine if anemia is microcytic (iron deficiency) or macrocytic (folate or vitamin B_{12} deficiency)
Mean corpuscular hemoglobin concentration (MCHC)	Hemoglobin concentration within the average RBC; helps to determine if anemia is hypochromic (iron deficiency) or normochromic (folate or vitamin B_{12} deficiency)
Bone marrow aspiration	The manufacture of blood cells in different developmental states
For Iron-Deficiency Anemia	
↓ Serum ferritin	Early deficiency state with depleted iron stores
↓ Transferrin saturation	Progressing deficiency state with diminished transport iron
↑ Erythrocyte protoporphyrin	Later deficiency state with limited hemoglobin production
For Folate-Deficiency Anemia	
↓ Serum folate	Progressing deficiency state
↓ RBC folate	Later deficiency state
For Vitamin B_{12}–Deficiency Anemia	
↓ Serum vitamin B_{12}	Progressing deficiency state
Schilling test	Absorption of vitamin B_{12}

TABLE E-9 Criteria for Assessing Iron Status

Test	Age (yr)	Gender	Deficiency Value
Hemoglobin (g/dL)	0.5–10	M–F	<11
	11–15	M	<12
		F	<11.5
	>15	M	<13
		F	<12
	Pregnancy		<11
Hematocrit (%)	0.5–4	M–F	<32
	5–10	M–F	<33
	11–15	M	<35
		F	<34
	>15	M	<40
		F	<36
Serum ferritin (μg/L)	0.5–15	M–F	<10
	>15	M–F	<12
Total iron-binding capacity (μg/dL)	>15	M–F	>400
Serum iron (μg/dL)	>15	M–F	<60
Transferrin saturation (%)	0.5–4	M–F	<12
	5–10	M–F	<14
	>10	M–F	<16
Erythrocyte protoporphyrin (μg/dL RBC)	0.5–4	M–F	>80
	>4	M–F	>70

Low hemoglobin and hematocrit values alert the assessor to the possibility of iron deficiency. However, many nutrients and other conditions can affect hemoglobin and hematocrit. The other tests of iron status help pinpoint true iron deficiency.

Serum Ferritin In the first stage of iron deficiency, iron stores diminish. Measures of serum ferritin provide an estimate of iron stores. Such information is most valuable to iron assessment. Table E-9 shows serum ferritin cutoff values that indicate iron store depletion in children and adults. Serum ferritin is not reliable for diagnosing iron deficiency in infants, since normal serum ferritin values are often present in conjunction with iron-responsive anemia.

A decrease in transport iron characterizes the second stage of iron deficiency. This is revealed by an increase in the iron-binding capacity of the protein transferrin and a decrease in serum iron. These changes are reflected by the transferrin saturation, which is calculated from the ratio of the other two values as described in the following paragraphs.

Total Iron-Binding Capacity (TIBC) Iron travels through the blood bound to the protein transferrin. TIBC is a measure of the total amount of iron that transferrin can carry. Lab technicians measure iron-binding capacity directly. Table E-9 includes the cutoff for TIBC.

Serum Iron Lab technicians can also measure serum iron directly. Elevated values indicate iron overload; reduced values indicate iron deficiency. Table E-9 shows the deficient value for serum iron.

Transferrin Saturation The percentage of transferrin that is saturated with iron is an indirect measure that is derived from the serum iron and total iron-binding capacity measures as follows:

$$\% \text{ Transferrin} = \frac{\text{serum iron}}{\text{total iron-binding capacity}} \times 100$$

Table E-9 shows deficient transferrin saturation values for various age groups.

The third stage of iron deficiency occurs when the supply of transport iron diminishes to the point that it limits hemoglobin production. It is characterized by increases in erythrocyte protoporphyrin, a decrease in mean corpuscular volume, and decreased hemoglobin and hematocrit.

Erythrocyte Protoporphyrin The iron-containing portion of the hemoglobin molecule is heme. Heme is a combination of iron and protoporphyrin. Protoporphyrin accumulates in the blood when iron supplies are inadequate for the formation of heme. Lab technicians can measure erythrocyte protoporphyrin directly in a blood sample. The cutoffs for abnormal values of erythrocyte protoporphyrin are shown in Table E-9.

Mean Corpuscular Volume (MCV) A direct or calculated measure of the mean corpuscular volume (MCV) determines the average size of a red blood cell. Such a measure helps to classify the type of nutrient anemia. In iron deficiency, the red blood cells are smaller than average.

Assessment of Folate and Vitamin B_{12} Anemias Folate deficiency and vitamin B_{12} deficiency present a similar clinical picture—an anemia characterized by abnormally large red blood cell precursors (megaloblasts) in the bone marrow and abnormally large, mature red blood cells (macrocytic cells) in the blood. Distinguishing between these two deficiencies is particularly important because their treatments differ. Giving folate to a person with vitamin B_{12} deficiency improves many of the lab test results indicative of vitamin B_{12} deficiency, but this is a dangerous error because vitamin B_{12} deficiency causes nerve damage that folate cannot correct. Thus inappropriate folate administration masks vitamin B_{12}–deficiency anemia, and nerve damage worsens. For this reason, it is critical to determine whether the anemia results from a folate deficiency or from a vitamin B_{12} deficiency. The following biochemical assessment techniques help to make this distinction.

Mean Corpuscular Volume (MCV) As previously mentioned, the MCV is a measure of red blood cell size. In folate and vitamin B_{12} deficiencies, the red blood cells are larger than average (macrocytic). Additional tests must be performed to differentiate folate deficiency from vitamin B_{12} deficiency.

Folate Levels Serum folate levels fluctuate with changes in folate intake and metabolism. Thus serum folate concentrations reflect current status, but provide little information about folate stores. As folate deficiency progresses and low serum levels persist, folate stores decline, resulting in folate depletion. Folate depletion is characterized by a fall in the folate concentrations of red blood cells (erythrocytes). As erythrocyte folate levels diminish, folate-deficiency anemia develops. Because low erythrocyte folate concentrations also occur with vitamin B_{12} deficiency, serum vitamin B_{12} concentrations must also be measured. Table E-10 shows standards for folate assessment.

Vitamin B_{12} Levels Serum and urinary methylmalonic acid are elevated in vitamin B_{12} deficiency, but not in folate deficiency. Thus this measure is useful in distinguishing between the two. Vitamin B_{12} deficiency usually arises from malabsorption. To determine whether malabsorption is the cause, a small oral dose of

TABLE E-10 Criteria for Assessing Folate and Vitamin B_{12}

	Deficient	Borderline	Acceptable
Serum folate (ng/mL)[a]	<3.0	3.0–5.9	>6.0
Erythrocyte folate (ng/mL)[a]	<140	140–159	>160
Serum vitamin B_{12} (pg/mL)	<150	150–200	≥201
Serum methylmalonic acid (nmol/L)	<376	—	—

NOTE: A nanogram (ng) is one-billionth of a gram; a picogram (pg) is one-trillionth of a gram.
[a]To convert folate values (ng/mL) to international standard units (nmol/L), multiply by 2.266.

vitamin B_{12} is given, and urinary excretion is measured. This procedure measures vitamin B_{12} absorption and is called a Schilling test.

Early stages of vitamin B_{12} deficiency can be detected by a low percentage saturation of its transport protein, a measure similar to iron's transferrin saturation. As the deficiency progresses, serum vitamin B_{12} concentrations fall. Table E-10 shows standards for vitamin B_{12} assessment.

Cautions about Nutrition Assessment

To give all the details of nutrition assessment procedures would entail writing another textbook. Nevertheless, any student of nutrition should know the basics of a proper nutrition assessment procedure for two reasons.

First, competent medical care includes attention to nutrition. Physicians should either employ a person skilled in nutrition assessment techniques or refer all clients to such a person to ensure the sound nutrition health of their clients. Health care facilities should make nutrition assessment a routine part of the initial workup on every client so that poor nutrition will not hinder the response to medical treatment and the recovery from illness.

Second, because nutrition is such a popular subject today, fraudulent practices are even more abundant than they have been in the past (and they have always been rampant). The knowledgeable consumer needs to know what procedures to expect in a nutrition assessment and what kinds of information they yield. This appendix has presented the basics of nutrition assessment for these reasons.

This caution is added: the tests outlined here yield information that becomes meaningful only when integrated into a whole picture by a skilled, experienced, and educated interpreter. Potential sources of error are many, from the taking of the initial data to their reporting and analysis. Each assessment method and measure is useful only as a part of the whole to confirm or eliminate the possibility of suspected nutrition problems. For example, the assessor must constantly remember that a sufficient intake of a nutrient does not guarantee adequate nutrient status for an individual. Conversely, the apparent inadequate intake of a nutrient does not, by itself, establish that a deficiency exists.

Similarly, many uncertainties, such as the calibration of the equipment, the skills of the measurer, and the perspective of the interpreter, limit the accuracy and value of anthropometric measures. This is also true of the results of a physical examination. Physical signs suggestive of malnutrition are nonspecific: they can reflect nutrient deficiencies or may be totally unrelated to nutrition. Assessors must interpret physical findings in light of other assessment findings. Finally, the usefulness of biochemical tests is also limited; the assessor must use caution in interpreting results. Vitamin and mineral blood concentrations may reflect disease processes, abnormal hormone levels, or aberrations other than dietary intake. Even if concentrations do reflect dietary intake, they may reflect what the person has been eating recently and not give a true picture of the person's nutrient status. Such complications sometimes make it difficult to detect a subclinical deficiency. Furthermore, many nutrients interact. The assessor has to keep in mind that an abnormal lab value for one nutrient may reflect abnormal status of other nutrients. The final diagnosis is therefore appropriately tentative, and its confirmation comes only after careful remedial steps successfully alleviate the observed problems.

Appendix F Physical Activity and Energy Requirements

Chapter 8 describes how to calculate estimated energy requirements (EER) for adults by using an equation that accounts for gender, age, weight, height, and physical activity level. Table F-1 presents additional equations to determine the EER for infants, children, adolescents, and pregnant and lactating women.

This appendix helps you determine the correct physical activity (PA) factor to use in the equations, either by calculating the physical activity level or by estimating it. For those who prefer to bypass these steps, the appendix presents tables that provide a shortcut to estimating total energy expenditure.*

CONTENTS

Calculating Physical Activity Level
Estimating Physical Activity Level
Using a Shortcut to Estimate Total Energy Expenditure

Calculating Physical Activity Level

To calculate your physical activity level, record all of your activities for a typical 24-hour day, noting the type of activity, the level of intensity, and the duration. Then, using a copy of Table F-2 (p. F-2), find your activity in the first column (or an activity that is reasonably similar) and multiply the number of minutes spent on that activity by the factor in the third column. Put your answer in the last column and total the accumulated values for the day. Now

TABLE F-1 Equations to Determine Estimated Energy Requirement (EER)

Infants	
0–3 months	EER = (89 × weight − 100) + 175
4–6 months	EER = (89 × weight − 100) + 56
7–12 months	EER = (89 × weight − 100) + 22
13–15 months	EER = (89 × weight − 100) + 20
Children and Adolescents	
Boys	
3–8 years	EER = 88.5 − (61.9 × age) + PA × [(26.7 × weight) + (903 × height)] + 20
9–18 years	EER = 88.5 − (61.9 × age) + PA × [(26.7 × weight) + (903 × height)] + 25
Girls	
3–8 years	EER = 135.3 − (30.8 × age) + PA × [(10.0 × weight) + (934 × height)] + 20
9–18 years	EER = 135.3 − (30.8 × age) + PA × [(10.0 × weight) + (934 × height)] + 25
Adults	
Men	EER = 662 − (9.53 × age) + PA × [(15.91 × weight) + (539.6 × height)]
Women	EER = 354 − (6.91 × age) + PA × [(9.36 × weight) + (726 × height)]
Pregnancy	
1st trimester	EER = nonpregnant EER + 0
2nd trimester	EER = nonpregnant EER + 340
3rd trimester	EER = nonpregnant EER + 452
Lactation	
0–6 months postpartum	EER = nonpregnant EER + 500 − 170
7–12 months postpartum	EER = nonpregnant EER + 400 − 0

NOTE: Select the appropriate equation for gender and age and insert weight in kilograms, height in meters, and age in years. See the text and Table F-3 to determine PA.

*This appendix, including the tables, is adapted from Committee on Dietary Reference Intakes, *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids* (Washington, D.C.: National Academies Press, 2005).

add the subtotal of the last column to 1.1 (to account for basal energy and the thermic effect of food) as shown. This score indicates your physical activity level. Using Table F-3 (p. F-3), find the PA factor for your age and gender that correlates with your physical activity level and use it in the energy equations presented in Table F-1.

Estimating Physical Activity Level

As an alternative to recording your activities for a day, you can use the third column of Table F-3 to decide if your daily activity is sedentary, low active, active, or very active. Find the PA factor for your age and gender that correlates with your typical physical activity level and use it in the energy equations presented in Table F-1.

Using a Shortcut to Estimate Total Energy Expenditure

The DRI Committee has developed estimates of total energy expenditure based on the equations for adults presented in Table F-1. These estimates are presented in Table F-4 (p. F-4) for women and Table F-5 (p. F-5) for men. You can use these tables to estimate your energy requirement—that is, the number of kcalories needed to maintain your current body weight. On the table appropriate for your gender, find your height in meters (or inches) in the left-hand column. Then follow the row across to find your weight in kilograms (or pounds). (If you can't find your exact height and weight, choose a value between the two closest ones.) Look down the column to find the number of kcalories that corresponds to your activity level.

Importantly the values given in the tables are for 30-year-old people. Women 19 to 29 should add 7 kcalories per day for each year younger than age 30; older women should subtract 7 kcalories per day for each year older than age 30. Similarly men 19 to 29 should add 10 kcalories per day for each year younger than age 30; older men should subtract 10 kcalories per day for each year older than age 30.

TABLE F-2 Physical Activities and Their Scores

If your activity was equivalent to this	Then list the number of minutes here and	Multiply by this factor	Add this column to get your physical activity level score
Activities of Daily Living			
Gardening (no lifting)		0.0032	
Household tasks (moderate effort)		0.0024	
Lifting items continuously		0.0029	
Loading/unloading car		0.0019	
Lying quietly		0.0000	
Mopping		0.0024	
Mowing lawn (power mower)		0.0033	
Raking lawn		0.0029	
Riding in a vehicle		0.0000	
Sitting (idle)		0.0000	
Sitting (doing light activity)		0.0005	
Taking out trash		0.0019	
Vacuuming		0.0024	
Walking the dog		0.0019	
Walking from house to car or bus		0.0014	
Watering plants		0.0014	

TABLE F-2 Physical Activities and Their Scores (*continued*)

If your activity was equivalent to this	Then list the number of minutes here and	Multiply by this factor	Add this column to get your physical activity level score:
Additional Activities			
Billiards		0.0013	
Calisthenics (no weight)		0.0029	
Canoeing (leisurely)		0.0014	
Chopping wood		0.0037	
Climbing hills (carrying 11 lb load)		0.0061	
Climbing hills (no load)		0.0056	
Cycling (leisurely)		0.0024	
Cycling (moderately)		0.0045	
Dancing (aerobic or ballet)		0.0048	
Dancing (ballroom, leisurely)		0.0018	
Dancing (fast ballroom or square)		0.0043	
Golf (with cart)		0.0014	
Golf (without cart)		0.0032	
Horseback riding (walking)		0.0012	
Horseback riding (trotting)		0.0053	
Jogging (6 mph)		0.0088	
Music (playing accordion)		0.0008	
Music (playing cello)		0.0012	
Music (playing flute)		0.0010	
Music (playing piano)		0.0012	
Music (playing violin)		0.0014	
Rope skipping		0.0105	
Skating (ice)		0.0043	
Skating (roller)		0.0052	
Skiing (water or downhill)		0.0055	
Squash		0.0106	
Surfing		0.0048	
Swimming (slow)		0.0033	
Swimming (fast)		0.0057	
Tennis (doubles)		0.0038	
Tennis (singles)		0.0057	
Volleyball (noncompetitive)		0.0018	
Walking (2 mph)		0.0014	
Walking (3 mph)		0.0022	
Walking (4 mph)		0.0033	
Walking (5 mph)		0.0067	
Subtotal			
Factor for basal energy and the thermic effect of food			**1.1**
Your physical activity level score			

TABLE F-3 Physical Activity Equivalents and Their PA Factors

Physical Activity Level	Description	Physical Activity Equivalents	Men, 19+ yr PA Factor	Women, 19+ yr PA Factor	Boys, 3–18 yr PA Factor	Girls, 3–18 yr PA Factor
1.0 to 1.39	Sedentary	Only those physical activities required for typical daily living	1.0	1.0	1.0	1.0
1.4 to 1.59	Low active	Daily living + 30–60 min moderate activity[a]	1.11	1.12	1.13	1.16
1.6 to 1.89	Active	Daily living + ⩾ 60 min moderate activity	1.25	1.27	1.26	1.31
1.9 and above	Very active	Daily living + ⩾ 60 min moderate activity *and* ⩾ 60 min vigorous activity *or* ⩾ 120 min moderate activity	1.48	1.45	1.42	1.56

[a]Moderate activity is equivalent to walking at a pace of 3 to 4½ miles per hour.

TABLE F-4 Total Energy Expenditure (TEE in kCalories per Day) for Women 30 Years of Age[a] at Various Levels of Activity and Various Heights and Weights

Height m (in)	Physical Activity Level	Weight[b] kg (lb)					
1.45 (57)		38.9 (86)	45.2 (100)	52.6 (116)	63.1 (139)	73.6 (162)	84.1 (185)
		kCalories					
	Sedentary	1564	1623	1698	1813	1927	2042
	Low active	1734	1800	1912	2043	2174	2304
	Active	1946	2021	2112	2257	2403	2548
	Very active	2201	2287	2387	2553	2719	2886
1.50 (59)		41.6 (92)	48.4 (107)	56.3 (124)	67.5 (149)	78.8 (174)	90.0 (198)
		kCalories					
	Sedentary	1625	1689	1771	1894	2017	2139
	Low active	1803	1874	1996	2136	2276	2415
	Active	2025	2105	2205	2360	2516	2672
	Very active	2291	2382	2493	2671	2849	3027
1.55 (61)		44.4 (98)	51.7 (114)	60.1 (132)	72.1 (159)	84.1 (185)	96.1 (212)
		kCalories					
	Sedentary	1688	1756	1846	1977	2108	2239
	Low active	1873	1949	2081	2230	2380	2529
	Active	2104	2190	2299	2466	2632	2798
	Very active	2382	2480	2601	2791	2981	3171
1.60 (63)		47.4 (104)	55.0 (121)	64.0 (141)	76.8 (169)	89.6 (197)	102.4 (226)
		kCalories					
	Sedentary	1752	1824	1922	2061	2201	2340
	Low active	1944	2025	2168	2327	2486	2645
	Active	2185	2276	2396	2573	2750	2927
	Very active	2474	2578	2712	2914	3116	3318
1.65 (65)		50.4 (111)	58.5 (129)	68.1 (150)	81.7 (180)	95.3 (210)	108.9 (240)
		kCalories					
	Sedentary	1816	1893	1999	2148	2296	2444
	Low active	2016	2102	2556	2425	2594	2763
	Active	2267	2364	2494	2682	2871	3059
	Very active	2567	2678	2824	3039	3254	3469
1.70 (67)		53.5 (118)	62.1 (137)	72.3 (159)	86.7 (191)	101.2 (223)	115.6 (255)
		kCalories					
	Sedentary	1881	1963	2078	2235	2393	2550
	Low active	2090	2180	2345	2525	2705	2884
	Active	2350	2453	2594	2794	2994	3194
	Very active	2662	2780	2938	3166	3395	3623
1.75 (69)		56.7 (125)	65.8 (145)	76.6 (169)	91.9 (202)	107.2 (236)	122.5 (270)
		kCalories					
	Sedentary	1948	2034	2158	2325	2492	2659
	Low active	2164	2260	2437	2627	2817	3007
	Active	2434	2543	2695	2907	3119	3331
	Very active	2758	2883	3054	3296	3538	3780
1.80 (71)		59.9 (132)	69.7 (154)	81.0 (178)	97.2 (214)	113.4 (250)	129.6 (285)
		kCalories					
	Sedentary	2015	2106	2239	2416	2593	2769
	Low active	2239	2341	2529	2731	2932	3133
	Active	2519	2634	2799	3023	3247	3472
	Very active	2855	2987	3172	3428	3684	3940

[a]For each year younger than 30, add 10 kcalories/day to TEE. For each year older than 30, subtract 10 kcalories/day from TEE.
[b]These columns represent a BMI of 18.5, 22.5, 25, 30, 35, and 40, respectively.

TABLE F-4 Total Energy Expenditure (TEE in kCalories per Day) for Women 30 Years of Age[a] at Various Levels of Activity and Various Heights and Weights (*continued*)

Heights m (in)	Physical Activity Level	Weight[b] kg (lb)					
1.85 (73)		63.3 (139)	73.6 (162)	85.6 (189)	102.7 (226)	119.8 (264)	136.9 (302)
		kCalories					
	Sedentary	2083	2179	2322	2509	2695	2882
	Low active	2315	2422	2624	2836	3049	3262
	Active	2605	2727	2904	3141	3378	3615
	Very active	2954	3093	3292	3562	3833	4103
1.90 (75)		66.8 (147)	77.6 (171)	90.3 (199)	108.3 (239)	126.4 (278)	144.4 (318)
		kCalories					
	Sedentary	2151	2253	2406	2603	2800	2996
	Low active	2392	2505	2720	2944	3168	3393
	Active	2693	2821	3011	3261	3511	3760
	Very active	3053	3200	3414	3699	3984	4270
1.95 (77)		70.3 (155)	81.8 (180)	95.1 (209)	114.1 (251)	133.1 (293)	152.1 (335)
		kCalories					
	Sedentary	2221	2328	2492	2699	2906	3113
	Low active	2470	2589	2817	3053	3290	3526
	Active	2781	2917	3119	3383	3646	3909
	Very active	3154	3309	3538	3838	4139	4439

[a]For each year younger than 30, add 7 kcalories/day to TEE. For each year older than 30, subtract 7 kcalories/day from TEE.
[b]These columns represent a BMI of 18.5, 22.5, 25, 30, 35, and 40, respectively.

TABLE F-5 Total Energy Expenditure (TEE in kCalories per Day) for Men 30 Years of Age[a] at Various Levels of Activity and Various Heights and Weights

Heights m (in)	Physical Activity Level	Weight[b] kg (lb)					
1.45 (57)		38.9 (86)	47.3 (100)	52.6 (116)	63.1 (139)	73.6 (163)	84.1 (185)
		kCalories					
	Sedentary	1777	1911	2048	2198	2347	2496
	Low active	1931	2080	2225	2393	2560	2727
	Active	2127	2295	2447	2636	2826	3015
	Very active	2450	2648	2845	3075	3305	3535
1.50 (59)		41.6 (92)	50.6 (107)	56.3 (124)	67.5 (149)	78.8 (174)	90.0 (198)
		kCalories					
	Sedentary	1848	1991	2126	2286	2445	2605
	Low active	2009	2168	2312	2491	2670	2849
	Active	2215	2394	2545	2748	2951	3154
	Very active	2554	2766	2965	3211	3457	3703
1.55 (61)		44.4 (98)	54.1 (114)	60.1 (132)	72.1 (159)	84.1 (185)	96.1 (212)
		kCalories					
	Sedentary	1919	2072	2205	2376	2546	2717
	Low active	2089	2259	2401	2592	2783	2974
	Active	2305	2496	2646	2862	3079	3296
	Very active	2660	2887	3087	3349	3612	3875

[a]For each year younger than 30, add 10 kcalories/day to TEE. For each year older than 30, subtract 10 kcalories/day from TEE.
[b]These columns represent a BMI of 18.5, 22.5, 25, 30, 35, and 40, respectively.

(continued)

TABLE F-5 Total Energy Expenditure (TEE in kCalories per Day) for Men 30 Years of Age[a] at Various Levels of Activity and Various Heights and Weights (*continued*)

Height m (in)	Physical Activity Level	Weight[b] kg (lb)					
1.60 (63)		47.4 (104)	57.6 (121)	64.0 (141)	76.8 (169)	89.6 (197)	102.4 (226)
		kCalories					
	Sedentary	1993	2156	2286	2468	2650	2831
	Low active	2171	2351	2492	2695	2899	3102
	Active	2397	2601	2749	2980	3210	3441
	Very active	2769	3010	3211	3491	3771	4051
1.65 (65)		50.4 (111)	61.3 (129)	68.1 (150)	81.7 (180)	95.3 (210)	108.9 (240)
		kCalories					
	Sedentary	2068	2241	2369	2562	2756	2949
	Low active	2254	2446	2585	2801	3017	3234
	Active	2490	2707	2854	3099	3345	3590
	Very active	2880	3136	3339	3637	3934	4232
1.70 (67)		53.5 (118)	65.0 (137)	72.3 (159)	86.7 (191)	101.2 (223)	115.6 (255)
		kCalories					
	Sedentary	2144	2328	2454	2659	2864	3069
	Low active	2338	2542	2679	2909	3139	3369
	Active	2586	2816	2961	3222	3483	3743
	Very active	2992	3265	3469	3785	4101	4417
1.75 (69)		56.7 (125)	68.9 (145)	76.6 (169)	91.9 (202)	107.2 (236)	122.5 (270)
		kCalories					
	Sedentary	2222	2416	2540	2757	2975	3192
	Low active	2425	2641	2776	3020	3263	3507
	Active	2683	2927	3071	3347	3623	3900
	Very active	3108	3396	3602	3937	4272	4607
1.80 (71)		59.9 (132)	72.9 (154)	81.0 (178)	97.2 (214)	113.4 (250)	129.6 (285)
		kCalories					
	Sedentary	2301	2507	2628	2858	3088	3318
	Low active	2513	2741	2875	3132	3390	3648
	Active	2782	3040	3183	3475	3767	4060
	Very active	3225	3530	3738	4092	4447	4801
1.85 (73)		63.3 (139)	77.0 (162)	85.6 (189)	102.7 (226)	119.8 (264)	136.9 (302)
		kCalories					
	Sedentary	2382	2599	2718	2961	3204	3447
	Low active	2602	2844	2976	3248	3520	3792
	Active	2883	3155	3297	3606	3915	4223
	Very active	3344	3667	3877	4251	4625	4999
1.90 (75)		66.8 (147)	81.2 (171)	90.3 (199)	108.3 (239)	126.4 (278)	144.4 (318)
		kCalories					
	Sedentary	2464	2693	2810	3066	3322	3579
	Low active	2693	2948	3078	3365	3652	3939
	Active	2986	3273	3414	3739	4065	4390
	Very active	3466	3806	4018	4413	4807	5202
1.95 (77)		70.3 (155)	85.6 (180)	95.1 (209)	114.1 (251)	133.1 (293)	152.1 (335)
		kCalories					
	Sedentary	2547	2789	2903	3173	3443	3713
	Low active	2786	3055	3183	3485	3788	4090
	Active	3090	3393	3533	3875	4218	4561
	Very active	3590	3948	4162	4578	4993	5409

[a]For each year younger than 30, add 10 kcalories/day to TEE. For each year older than 30, subtract 10 kcalories/day from TEE.
[b]These columns represent a BMI of 18.5, 22.5, 25, 30, 35, and 40, respectively.

Appendix G Exchange Lists for Diabetes

Chapter 2 introduces the exchange system, and this appendix provides details from the *2008 Choose Your Foods: Exchange Lists for Diabetes.* Exchange lists can help people with diabetes to manage their blood glucose levels by controlling the amount and kinds of carbohydrates they consume. These lists can also help in planning diets for weight management by controlling kcalorie and fat intake.*

CONTENTS

The Exchange System
Serving Sizes
The Foods on the Lists
Controlling Energy, Fat, and Sodium
Planning a Healthy Diet

The Exchange System

The exchange system sorts foods into groups by their proportions of carbohydrate, fat, and protein (Table G-1). These groups may be organized into several exchange lists of foods (Tables G-2 through G-12 on pp. G-3–G-16). For example, the carbohydrate group includes these exchange lists:

- Starch
- Fruits
- Milk (fat-free, reduced-fat, and whole)
- Sweets, Desserts, and Other Carbohydrates
- Nonstarchy Vegetables

TABLE G-1 The Food Lists

Lists	Typical Item/Portion Size	Carbohydrate (g)	Protein (g)	Fat (g)	Energy[a] (kcal)
Carbohydrates					
Starch[b]	1 slice bread	15	0–3	0–1	80
Fruits	1 small apple	15	—	—	60
Milk					
Fat-free, low-fat, 1%	1 c fat-free milk	12	8	0-3	100
Reduced-fat, 2%	1 c reduced-fat milk	12	8	5	120
Whole	1 c whole milk	12	8	8	160
Sweets, desserts, and other carbohydrates[c]	2 small cookies	15	varies	varies	varies
Nonstarchy vegetables	½ c cooked carrots	5	2	—	25
Meat and Meat Substitutes					
Lean	1 oz chicken (no skin)	—	7	0–3	45
Medium-fat	1 oz ground beef	—	7	4–7	75
High-fat	1 oz pork sausage	—	7	8+	100
Plant-based proteins	½ c tofu	varies	7	varies	varies
Fats	1 tsp butter	—	—	5	45
Alcohol	12 oz beer	varies	—	—	100

[a]The energy value for each exchange list represents an approximate average for the group and does not reflect the precise number of grams of carbohydrate, protein, and fat. For example, a slice of bread contains 15 grams of carbohydrate (60 kcalories), 3 grams protein (12 kcalories), and a little fat—rounded to 80 kcalories for ease in calculating. A ½ cup of vegetables (not including starchy vegetables) contains 5 grams carbohydrate (20 kcalories) and 2 grams protein (8 more), which has been rounded down to 25 kcalories.
[b]The Starch list includes cereals, grains, breads, crackers, snacks, starchy vegetables (such as corn, peas, and potatoes), and legumes (dried beans, peas, and lentils)
[c]The Sweets, Desserts, and Other Carbohydrates list includes foods that contain added sugars and fats such as sodas, candy, cakes, cookies, doughnuts, ice cream, pudding, syrup, and frozen yogurt.

*The Exchange Lists are the Basis of a meal planning system designed by a committee of the American Diabetes Association and The American Dietetic Association. While designed primary for people with diabetes and others who must follow special diets, the Exchange Lists are based on principles of good nutrition that apply to everyone.
© 2008 by the American Diabetes Association and The American Dietetic Association.

Then any food on a list can be "exchanged" for any other on that same list. Another group for alcohol has been included as a reminder that these beverages often deliver substantial carbohydrate and kcalories, and therefore warrant their own list.

Serving Sizes

The serving sizes have been carefully adjusted and defined so that a serving of any food on a given list provides roughly the same amount of carbohydrate, fat, and protein, and, therefore, total energy. Any food on a list can thus be exchanged, or traded, for any other food on the same list without significantly affecting the diet's energy-nutrient balance or total kcalories. For example, a person may select 17 small grapes or ½ large grapefruit as one fruit exchange, and either choice would provide roughly 15 grams of carbohydrate and 60 kcalories. A whole grapefruit, however, would count as 2 fruit exchanges.

To apply the system successfully, users must become familiar with the specified serving sizes. A convenient way to remember the serving sizes and energy values is to keep in mind a typical item from each list (review Table G-1).

The Foods on the Lists

Foods do not always appear on the exchange list where you might first expect to find them. They are grouped according to their energy-nutrient contents rather than by their source (such as milks), their outward appearance, or their vitamin and mineral contents. For example, cheeses are grouped with meats (not milk) because, like meats, cheeses contribute energy from protein and fat but provide negligible carbohydrate.

For similar reasons, starchy vegetables such as corn, green peas, and potatoes are found on the Starch list with breads and cereals, not with the vegetables. Likewise, bacon is grouped with the fats and oils, not with the meats.

Diet planners learn to view mixtures of foods, such as casseroles and soups, as combinations of foods from different exchange lists. They also learn to interpret food labels with the exchange system in mind.

Controlling Energy, Fat, and Sodium

The exchange lists help people control their energy intakes by paying close attention to serving sizes. People wanting to lose weight can limit foods from the Sweets, Desserts, and Other Carbohydrates and Fats lists, and they might choose to avoid the Alcohol list altogether. The Free Foods list provide low-kcalorie choices.

By assigning items like bacon to the Fats list, the exchange lists alert consumers to foods that are unexpectedly high in fat. Even the Starch list specifies which grain products contain added fat (such as biscuits, cornbread, and waffles) by marking them with a symbol to indicate added fat (the symbols are explained in the table keys). In addition, the exchange lists encourage users to think of fat-free milk as milk and of whole milk as milk with added fat, and to think of lean meats as meats and of medium-fat and high-fat meats as meats with added fat. To that end, foods on the milk and meat lists are separated into categories based on their fat contents (review Table G-1). The Milk list is subdivided for fat-free, reduced fat, and whole; the meat list is subdivided for lean, medium fat, and high fat. The meat list also includes plant-based proteins, which tend to be rich in fiber. Notice that many of these foods (p. G-11) bear the symbol for "high fiber."

People wanting to control the sodium in their diets can begin by eliminating any foods bearing the "high sodium" symbol. In most cases, the symbol identifies foods that, in one serving, provide 480 milligrams or more of sodium. Foods

on the Combination Foods or Fast Foods lists that bear the symbol provide more than 600 milligrams of sodium. Other foods may also contribute substantially to sodium (consult Chapter 12 for details).

Planning a Healthy Diet

To obtain a daily variety of foods that provide healthful amounts of carbohydrate, protein, and fat, as well as vitamins, minerals, and fiber, the meal plan for adults and teenagers should include at least:

- Two to three servings of nonstarchy vegetables
- Two servings of fruits
- Six servings of grains (at least three of whole grains), beans, and starchy vegetables
- Two servings of low-fat or fat-free milk
- About 6 ounces of meat or meat substitutes
- *Small* amounts of fat and sugar

The actual amounts are determined by age, gender, activity levels, and other factors that influence energy needs. Refer to Chapter 8 as you read through these sections to get an idea of how exchange lists can be useful in planning a diet.

TABLE G-2 Starch

The Starch list includes bread, cereals and grains, starchy vegetables, crackers and snacks, and legumes (dried beans, peas, and lentils). 1 starch choice = 15 grams carbohydrate, 0–3 grams protein, 0–1 grams fat, and 80 kcalories.

NOTE: In general, one starch exchange is ½ cup cooked cereal, grain, or starchy vegetable; ⅓ cup cooked rice or pasta; 1 ounce of bread product; ¾ ounce to 1 ounce of most snack foods.

Bread	
Food	Serving Size
Bagel, large (about 4 oz)	¼ (1 oz)
▽ Biscuit, 2½ inches across	1
Bread	
● reduced-kcalorie	2 slices (1½ oz)
white, whole-grain, pumpernickel, rye, unfrosted raisin	1 slice (1 oz)
Chapatti, small, 6 inches across	1
▽ Cornbread, 1¾ inch cube	1 (1½ oz)
English muffin	½
Hot dog bun or hamburger bun	½ (1 oz)
Naan, 8 inches by 2 inches	¼
Pancake, 4 inches across, ¼ inch thick	1
Pita, 6 inches across	½
Roll, plain, small	1 (1 oz)
▽ Stuffing, bread	⅓ cup
▽ Taco shell, 5 inches across	2
Tortilla, corn, 6 inches across	1
Tortilla, flour, 6 inches across	1
Tortilla, flour, 10 inches across	⅓
▽ Waffle, 4-inch square or 4 inches across	1

Cereals and Grains	
Food	Serving Size
Barley, cooked	⅓ cup
Bran, dry	
● oat	¼ cup
● wheat	½ cup
● Bulgur (cooked)	½ cup
Cereals	
● bran	½ cup
cooked (oats, oatmeal)	½ cup
puffed	1½ cups
shredded wheat, plain	½ cup
sugar-coated	½ cup
unsweetened, ready-to-eat	¾ cup
Couscous	⅓ cup
Granola	
low-fat	¼ cup
▽ regular	¼ cup
Grits, cooked	½ cup
Kasha	½ cup
Millet, cooked	⅓ cup

(*continued*)

KEY

● = More than 3 grams of dietary fiber per serving.

▽ = Extra fat, or prepared with added fat. (Count as 1 starch + 1 fat.)

🧂 = 480 milligrams or more of sodium per serving.

TABLE G-2 Starch (*continued*)

Cereals and Grains—continued	
Food	**Serving Size**
Muesli	¼ cup
Pasta, cooked	⅓ cup
Polenta, cooked	⅓ cup
Quinoa, cooked	⅓ cup
Rice, white or brown, cooked	⅓ cup
Tabbouleh (tabouli), prepared	½ cup
Wheat germ, dry	3 Tbsp
Wild rice, cooked	½ cup

Starchy Vegetables	
Food	**Serving Size**
Cassava	⅓ cup
Corn	½ cup
on cob, large	½ cob (5 oz)
Hominy, canned	¾ cup
Mixed vegetables with corn, peas, or pasta	1 cup
Parsnips	½ cup
Peas, green	½ cup
Plantain, ripe	⅓ cup
Potato	
baked with skin	¼ large (3 oz)
boiled, all kinds	½ cup or ½ medium (3 oz)
mashed, with milk and fat	½ cup
french fried (oven-baked)[a]	1 cup (2 oz)
Pumpkin, canned, no sugar added	1 cup
Spaghetti/pasta sauce	½ cup
Squash, winter (acorn, butternut)	1 cup
Succotash	½ cup
Yam, sweet potato, plain	½ cup

Crackers and Snacks[b]	
Food	**Serving Size**
Animal crackers	8
Crackers	
round-butter type	6
saltine-type	6
sandwich-style, cheese or peanut butter filling	3
whole-wheat regular	2–5 (¾ oz)
whole-wheat lower fat or crispbreads	2–5 (¾ oz)
Graham cracker, 2½-inch square	3
Matzoh	¾ oz
Melba toast, about 2-inch by 4-inch piece	4
Oyster crackers	20
Popcorn	3 cups
with butter	3 cups
no fat added	3 cups
lower fat	3 cups
Pretzels	¾ oz
Rice cakes, 4 inches across	2
Snack chips	
fat-free or baked (tortilla, potato), baked pita chips	15–20 (¾ oz)
regular (tortilla, potato)	9–13 (¾ oz)

Beans, Peas, and Lentils[c]	
The choices on this list count as 1 starch + 1 lean meat.	
Food	**Serving Size**
Baked beans	⅓ cup
Beans, cooked (black, garbanzo, kidney, lima, navy, pinto, white)	½ cup
Lentils, cooked (brown, green, yellow)	½ cup
Peas, cooked (black-eyed, split)	½ cup
Refried beans, canned	½ cup

KEY

= More than 3 grams of dietary fiber per serving.

= Extra fat, or prepared with added fat. (Count as 1 starch + 1 fat.)

= 480 milligrams or more of sodium per serving.

[a]Restaurant-style french fries are on the Fast Foods list.
[b]For other snacks, see the Sweets, Desserts, and Other Carbohydrates list. For a quick estimate of serving size, an open handful is equal to about 1 cup or 1 to 2 ounces of snack food.
[c]Beans, peas, and lentils are also found on the Meat and Meat Substitutes list.

TABLE G-3 Fruits

Fruit[a]

The Fruits list includes fresh, frozen, canned, and dried fruits and fruit juices. 1 fruit choice = 15 grams carbohydrate, 0 grams protein, 0 grams fat, and 60 kcalories.

NOTE: In general, one fruit exchange is ½ cup canned or fresh fruit or unsweetened fruit juice, 1 small fresh fruit (4 ounces), 2 tablespoons dried fruit.

Food	Serving Size
Apple, unpeeled, small	1 (4 oz)
Apples, dried	4 rings
Applesauce, unsweetened	½ cup
Apricots	
canned	½ cup
dried	8 halves
fresh	4 whole (5½ oz)
Banana, extra small	1 (4 oz)
Blackberries	¾ cup
Blueberries	¾ cup
Cantaloupe, small	⅓ melon or 1 cup cubed (11 oz)
Cherries	
sweet, canned	½ cup
sweet fresh	12 (3 oz)
Dates	3
Dried fruits (blueberries, cherries, cranberries, mixed fruit, raisins)	2 Tbsp
Figs	
dried	1½
fresh	1½ large or 2 medium (3½ oz)
Fruit cocktail	½ cup
Grapefruit	
large	½ (11 oz)
sections, canned	¾ cup
Grapes, small	17 (3 oz)
Honeydew melon	1 slice or 1 cup cubed (10 oz)
Kiwi	1 (3½ oz)
Mandarin oranges, canned	¾ cup
Mango, small	½ (5½ oz) or ½ cup
Nectarine, small	1 (5 oz)
Orange, small	1 (6½ oz)
Papaya	½ or 1 cup cubed (8 oz)
Peaches	
canned	½ cup
fresh, medium	1 (6 oz)
Pears	
canned	½ cup
fresh, large	½ (4 oz)
Pineapple	
canned	½ cup
fresh	¾ cup
Plums	
canned	½ cup
dried (prunes)	3
small	2 (5 oz)
Raspberries	1 cup
Strawberries	1¼ cup whole berries
Tangerines, small	2 (8 oz)
Watermelon	1 slice or 1¼ cups cubes (13½ oz)

Fruit Juice

Food	Serving Size
Apple juice/cider	½ cup
Fruit juice blends, 100% juice	⅓ cup
Grape juice	⅓ cup
Grapefruit juice	½ cup
Orange juice	½ cup
Pineapple juice	½ cup
Prune juice	⅓ cup

KEY

= More than 3 grams of dietary fiber per serving.

= Extra fat, or prepared with added fat. (Count as 1 starch + 1 fat.)

= 480 milligrams or more of sodium per serving.

[a]The weight listed includes skin, core, seeds, and rind.

TABLE G-4 Milk

The Milk list groups milks and yogurts based on the amount of fat they have (fat-free/low fat, reduced fat, and whole). Cheeses are found on the Meat and Meat Substitutes list and cream and other dairy fats are found on the Fats list.

NOTE: In general, one milk choice is 1 cup (8 fluid ounces or ½ pint) milk or yogurt.

Milk and Yogurts

Food	Serving Size
Fat-free or low-fat (1%)	
1 fat-free/low-fat milk choice = 12 g carbohydrate, 8 g protein, 0–3 g fat, and 100 kcal.	
Milk, buttermilk, acidophilus milk, Lactaid	1 cup
Evaporated milk	½ cup
Yogurt, plain or flavored with an artificial sweetener	⅔ cup (6 oz)
Reduced-fat (2%)	
1 reduced-fat milk choice = 12 g carbohydrate, 8 g protein, 5 g fat, and 120 kcal.	
Milk, acidophilus milk, kefir, Lactaid	1 cup
Yogurt, plain	⅔ cup (6 oz)
Whole	
1 whole milk choice = 12 g carbohydrate, 8 g protein, 8 g fat, and 160 kcal.	
Milk, buttermilk, goat's milk	1 cup
Evaporated milk	½ cup
Yogurt, plain	8 oz

Dairy-Like Foods

Food	Serving Size	Count as
Chocolate milk		
fat-free	1 cup	1 fat-free milk + 1 carbohydrate
whole	1 cup	1 whole milk + 1 carbohydrate
Eggnog, whole milk	½ cup	1 carbohydrate + 2 fats
Rice drink		
flavored, low fat	1 cup	2 carbohydrates
plain, fat-free	1 cup	1 carbohydrate
Smoothies, flavored, regular	10 oz	1 fat-free milk + 2½ carbohydrates
Soy milk		
light	1 cup	1 carbohydrate + ½ fat
regular, plain	1 cup	1 carbohydrate + 1 fat
Yogurt		
and juice blends	1 cup	1 fat-free milk + 1 carbohydrate
low carbohydrate (less than 6 grams carbohydrate per choice)	⅔ cup (6 oz)	½ fat-free milk
with fruit, low-fat	⅔ cup (6 oz)	1 fat-free milk + 1 carbohydrate

TABLE G-5 Sweets, Desserts, and Other Carbohydrates

1 other carbohydrate choice = 15 grams carbohydrate, variable grams protein, variable grams fat, and variable kcalories.

NOTE: In general, one choice from this list can substitute for foods on the Starch, Fruits, or Milk lists.

Beverages, Soda, and Energy/Sports Drinks

Food	Serving Size	Count as
Cranberry juice cocktail	½ cup	1 carbohydrate
Energy drink	1 can (8.3 oz)	2 carbohydrates
Fruit drink or lemonade	1 cup (8 oz)	2 carbohydrates

TABLE G-5 Sweets, Desserts, and Other Carbohydrates (*continued*)

Beverages: Soda and Energy/Sports Drinks—continued		
Food	**Serving Size**	**Count as**
Hot chocolate		
regular	1 envelope added to 8 oz water	1 carbohydrate + 1 fat
sugar-free or light	1 envelope added to 8 oz water	1 carbohydrate
Soft drink (soda), regular	1 can (12 oz)	2½ carbohydrates
Sports drink	1 cup (8 oz)	1 carbohydrate

Brownies, Cake, Cookies, Gelatin, Pie, and Pudding		
Food	**Serving Size**	**Count as**
Brownie, small, unfrosted	1¼-inch square, ⅞ inch high (about 1 oz)	1 carbohydrate + 1 fat
Cake		
angel food, unfrosted	1/12 of cake (about 2 oz)	2 carbohydrates
frosted	2-inch square (about 2 oz)	2 carbohydrates + 1 fat
unfrosted	2-inch square (about 2 oz)	1 carbohydrate + 1 fat
Cookies		
chocolate chip	2 cookies (2¼ inches across)	1 carbohydrate + 2 fats
gingersnap	3 cookies	1 carbohydrate
sandwich, with crème filling	2 small (about 2/3 oz)	1 carbohydrate + 1 fat
sugar-free	3 small or 1 large (¾-1 oz)	1 carbohydrate + 1–2 fats
vanilla wafer	5 cookies	1 carbohydrate + 1 fat
Cupcake, frosted	1 small (about 1¾ oz)	2 carbohydrates + 1–1½ fats
Fruit cobbler	½ cup (3½ oz)	3 carbohydrates + 1 fat
Gelatin, regular	½ cup	1 carbohydrate
Pie		
commercially prepared fruit, 2 crusts	1/6 of 8-inch pie	3 carbohydrates + 2 fats
pumpkin or custard	1/8 of 8-inch pie	1½ carbohydrates + 1½ fats
Pudding		
regular (made with reduced-fat milk)	½ cup	2 carbohydrates
sugar-free or sugar- and fat-free (made with fat-free milk)	½ cup	1 carbohydrate

Candy, Spreads, Sweets, Sweeteners, Syrups, and Toppings		
Food	**Serving Size**	**Count as**
Candy bar, chocolate/peanut	2 "fun size" bars (1 oz)	1½ carbohydrates + 1½ fats
Candy, hard	3 pieces	1 carbohydrate
Chocolate "kisses"	5 pieces	1 carbohydrate + 1 fat
Coffee creamer		
dry, flavored	4 tsp	½ carbohydrate + ½ fat
liquid, flavored	2 Tbsp	1 carbohydrate
Fruit snacks, chewy (pureed fruit concentrate)	1 roll (¾ oz)	1 carbohydrate
Fruit spreads, 100% fruit	1½ Tbsp	1 carbohydrate
Honey	1 Tbsp	1 carbohydrate
Jam or jelly, regular	1 Tbsp	1 carbohydrate
Sugar	1 Tbsp	1 carbohydrate
Syrup		
chocolate	2 Tbsp	2 carbohydrates
light (pancake type)	2 Tbsp	1 carbohydrate
regular (pancake type)	1 Tbsp	1 carbohydrate

(*continued*)

TABLE G-5 Sweets, Desserts, and Other Carbohydrates (*continued*)

Condiments and Sauces[a]

Food	Serving Size	Count as
Barbeque sauce	3 Tbsp	1 carbohydrate
Cranberry sauce, jellied	¼ cup	1½ carbohydrates
🧂 Gravy, canned or bottled	½ cup	½ carbohydrate + ½ fat
Salad dressing, fat-free, low-fat, cream-based	3 Tbsp	1 carbohydrate
Sweet and sour sauce	3 Tbsp	1 carbohydrate

Doughnuts, Muffins, Pastries, and Sweet Breads

Food	Serving Size	Count as
Banana nut bread	1-inch slice (1 oz)	2 carbohydrates + 1 fat
Doughnut		
cake, plain	1 medium (1½ oz)	1½ carbohydrates + 2 fats
yeast type, glazed	3¾ inches across (2 oz)	2 carbohydrates + 2 fats
Muffin (4 oz)	¼ muffin (1 oz)	1 carbohydrate + ½ fat
Sweet roll or Danish	1 (2½ oz)	2½ carbohydrates + 2 fats

Frozen Bars, Frozen Desserts, Frozen Yogurt, and Ice Cream

Food	Serving Size	Count as
Frozen pops	1	½ carbohydrate
Fruit juice bars, frozen, 100% juice	1 bar (3 oz)	1 carbohydrate
Ice cream		
fat-free	½ cup	1½ carbohydrates
light	½ cup	1 carbohydrate + 1 fat
no sugar added	½ cup	1 carbohydrate + 1 fat
regular	½ cup	1 carbohydrate + 2 fats
Sherbet, sorbet	½ cup	2 carbohydrates
Yogurt, frozen		
fat-free	⅓ cup	1 carbohydrate
regular	½ cup	1 carbohydrate + 0–1 fat

Granola Bars, Meal Replacement Bars/Shakes, and Trail Mix

Food	Serving Size	Count as
Granola or snack bar, regular or low-fat	1 bar (1 oz)	1½ carbohydrates
Meal replacement bar	1 bar (1⅓ oz)	1½ carbohydrates + 0–1 fat
Meal replacement bar	1 bar (2 oz)	2 carbohydrates + 1 fat
Meal replacement shake, reduced kcalorie	1 can (10–11 oz)	1½ carbohydrates + 0–1 fat
Trail mix		
candy/nut-based	1 oz	1 carbohydrate + 2 fats
dried fruit-based	1 oz	1 carbohydrate + 1 fat

KEY

🧂 = 480 milligrams or more of sodium per serving.

[a]You can also check the Fats list and Free Foods list for other condiments.

TABLE G-6 Nonstarchy Vegetables

The Nonstarchy Vegetables list includes vegetables that have few grams of carbohydrates or kcalories; starchy vegetables are found on the Starch list. 1 nonstarchy vegetable choice = 5 grams carbohydrate, 2 grams protein, 0 grams fat, and 25 kcalories.

NOTE: In general, one nonstarchy vegetable choice is ½ cup cooked vegetables or vegetable juice or 1 cup raw vegetables. Count 3 cups of raw vegetables or 1½ cups of cooked vegetables as one carbohydrate choice.

Nonstarchy Vegetables[a]	
Amaranth or Chinese spinach	Kohlrabi
Artichoke	Leeks
Artichoke hearts	Mixed vegetables (without corn, peas, or pasta)
Asparagus	Mung bean sprouts
Baby corn	Mushrooms, all kinds, fresh
Bamboo shoots	Okra
Beans (green, wax, Italian)	Onions
Bean sprouts	Oriental radish or daikon
Beets	Pea pods
Borscht	Peppers (all varieties)
Broccoli	Radishes
Brussels sprouts	Rutabaga
Cabbage (green, bok choy, Chinese)	Sauerkraut
Carrots	Soybean sprouts
Cauliflower	Spinach
Celery	Squash (summer, crookneck, zucchini)
Chayote	Sugar pea snaps
Coleslaw, packaged, no dressing	Swiss chard
Cucumber	Tomato
Eggplant	Tomatoes, canned
Gourds (bitter, bottle, luffa, bitter melon)	Tomato sauce
Green onions or scallions	Tomato/vegetable juice
Greens (collard, kale, mustard, turnip)	Turnips
Hearts of palm	Water chestnuts
Jicama	Yard-long beans

KEY

= More than 3 grams of dietary fiber per serving.

= 480 milligrams or more of sodium per serving.

[a]Salad greens (like chicory, endive, escarole, lettuce, romaine, spinach, arugula, radicchio, watercress) are on the Free Foods list

TABLE G-7 Meat and Meat Substitutes

The Meat and Meat Substitutes list groups foods based on the amount of fat they have (lean meat, medium-fat meat, high-fat meat, and plant-based proteins).

Lean Meats and Meat Substitutes

1 lean meat choice = 0 grams carbohydrate, 7 grams protein, 0–3 grams fat, and 100 kcalories.

Food	Amount
Beef: Select or Choice grades trimmed of fat: ground round, roast (chuck, rib, rump), round, sirloin, steak (cubed, flank, porterhouse, T-bone), tenderloin	1 oz
Beef jerky	1 oz
Cheeses with 3 grams of fat or less per oz	1 oz
Cottage cheese	¼ cup
Egg substitutes, plain	¼ cup
Egg whites	2
Fish, fresh or frozen, plain: catfish, cod, flounder, haddock, halibut, orange roughy, salmon, tilapia, trout, tuna	1 oz
Fish, smoked: herring or salmon (lox)	1 oz
Game: buffalo, ostrich, rabbit, venison	1 oz
Hot dog with 3 grams of fat or less per oz (8 dogs per 14 oz package) *Note: May be high in carbohydrate.*	1
Lamb: chop, leg, or roast	1 oz
Organ meats: heart, kidney, liver *Note: May be high in cholesterol.*	1 oz
Oysters, fresh or frozen	6 medium
Pork, lean	
Canadian bacon	1 oz
rib or loin chop/roast, ham, tenderloin	1 oz
Poultry, without skin: Cornish hen, chicken, domestic duck or goose (well-drained of fat), turkey	1 oz
Processed sandwich meats with 3 grams of fat or less per oz: chipped beef, deli thin-sliced meats, turkey ham, turkey kielbasa, turkey pastrami	1 oz
Salmon, canned	1 oz
Sardines, canned	2 medium
Sausage with 3 grams of fat or less per oz	1 oz
Shellfish: clams, crab, imitation shellfish, lobster, scallops, shrimp	1 oz
Tuna, canned in water or oil, drained	1 oz
Veal, lean chop, roast	1 oz

Medium-Fat Meat and Meat Substitutes

1 medium-fat meat choice = 0 grams carbohydrate, 7 grams protein, 4–7 grams fat, and 130 kcalories.

Food	Amount
Beef: corned beef, ground beef, meatloaf, Prime grades trimmed of fat (prime rib), short ribs, tongue	1 oz
Cheeses with 4–7 grams of fat per oz: feta, mozzarella, pasteurized processed cheese spread, reduced-fat cheeses, string	1 oz
Egg *Note: High in cholesterol, so limit to 3 per week.*	1
Fish, any fried product	1 oz
Lamb: ground, rib roast	1 oz
Pork: cutlet, shoulder roast	1 oz
Poultry: chicken with skin; dove, pheasant, wild duck, or goose; fried chicken; ground turkey	1 oz
Ricotta cheese	2 oz or ¼ cup
Sausage with 4–7 grams of fat per oz	1 oz
Veal, cutlet (no breading)	1 oz

High-Fat Meat and Meat Substitutes

1 high-fat meat choice = 0 grams carbohydrate, 7 grams protein, 8+ grams fat, and 150 kcalories. These foods are high in saturated fat, cholesterol, and kcalories and may raise blood cholesterol levels if eaten on a regular basis. Try to eat 3 or fewer servings from this group per week.

Food	Amount
Bacon	
pork	2 slices (16 slices per lb or 1 oz each, before cooking)
turkey	3 slices (½ oz each before cooking)
Cheese, regular: American, bleu, brie, cheddar, hard goat, Monterey jack, queso, and Swiss	1 oz
Hot dog: beef, pork, or combination (10 per lb-sized package)	1
Hot dog: turkey or chicken (10 per lb-sized package)	1
Pork: ground, sausage, spareribs	1 oz
Processed sandwich meats with 8 grams of fat or more per oz: bologna, pastrami, hard salami	1 oz
Sausage with 8 grams fat or more per oz: bratwurst, chorizo, Italian, knockwurst, Polish, smoked, summer	1 oz

(*continued*)

KEY

= More than 3 grams of dietary fiber per serving.

= Extra fat, or prepared with added fat. (Count as 1 starch + 1 fat.)

= 480 milligrams or more of sodium per serving.

TABLE G-7 Meat and Meat Substitutes (*continued*)

Plant-Based Proteins[a]

1 plant-based protein choice = variable grams carbohydrate, 7 grams protein, variable grams fat, and variable kcalories.
Because carbohydrate content varies among plant-based proteins, you should read the food label.

Food	Serving Size	Count as
"Bacon" strips, soy-based	3 strips	1 medium-fat meat
Baked beans	⅓ cup	1 starch + 1 lean meat
Beans, cooked: black, garbanzo, kidney, lima, navy, pinto, white[a]	½ cup	1 starch + 1 lean meat
"Beef" or "sausage" crumbles, soy-based	2 oz	½ carbohydrate + 1 lean meat
"Chicken" nuggets, soy-based	2 nuggets (1½ oz)	½ carbohydrate + 1 medium-fat meat
Edamame	½ cup	½ carbohydrate + 1 lean meat
Falafel (spiced chickpea and wheat patties)	3 patties (about 2 inches across)	1 carbohydrate + 1 high-fat meat
Hot dog, soy-based	1 (1½ oz)	½ carbohydrate + 1 lean meat
Hummus	⅓ cup	1 carbohydrate + 1 high-fat meat
Lentils, brown, green, or yellow	½ cup	1 carbohydrate + 1 lean meat
Meatless burger, soy-based	3 oz	½ carbohydrate + 2 lean meats
Meatless burger, vegetable- and starch-based	1 patty (about 2½ oz)	1 carbohydrate + 2 lean meats
Nut spreads: almond butter, cashew butter, peanut butter, soy nut butter	1 Tbsp	1 high-fat meat
Peas, cooked: black-eyed and split peas	½ cup	1 starch + 1 lean meat
Refried beans, canned	½ cup	1 starch + 1 lean meat
"Sausage" patties, soy-based	1 (1½ oz)	1 medium-fat meat
Soy nuts, unsalted	¾ oz	½ carbohydrate + 1 medium-fat meat
Tempeh	¼ cup	1 medium-fat meat
Tofu	4 oz (½ cup)	1 medium-fat meat
Tofu, light	4 oz (½ cup)	1 lean meat

KEY

= More than 3 grams of dietary fiber per serving.

= Extra fat, or prepared with added fat. (Add an additional fat choice to this food.)

= 480 milligrams or more of sodium per serving (based on the sodium content of a typical 3-oz serving of meat, unless 1 or 2 oz is the normal serving size).

[a]Beans, peas, and lentils are also found on the Starch list; nut butters in smaller amounts are found in the Fats list.

TABLE G-8 Fats

Fats and oils have mixtures of unsaturated (polyunsaturated and monounsaturated) and saturated fats. Foods on the Fats list are grouped together based on the major type of fat they contain. 1 fat choice = 0 grams carbohydrate, 0 grams protein, 5 grams fat, and 45 kcalories.

NOTE: In general, one fat exchange is 1 teaspoon of regular margarine, vegetable oil, or butter; 1 tablespoon of regular salad dressing.
When used in large amounts, bacon and peanut butter are counted as high-fat meat choices (see Meat and Meat Substitutes list). Fat-free salad dressings are found on the Sweets, Desserts, and Other Carbohydrates list. Fat-free products such as margarines, salad dressings, mayonnaise, sour cream, and cream cheese are found on the Free Foods list.

Monounsaturated Fats

Food	Serving Size
Avocado, medium	2 Tbsp (1 oz)
Nut butters (trans fat-free): almond butter, cashew butter, peanut butter (smooth or crunchy)	1½ tsp
Nuts	
almonds	6 nuts
Brazil	2 nuts
cashews	6 nuts
filberts (hazelnuts)	5 nuts
macadamia	3 nuts
mixed (50% peanuts)	6 nuts
peanuts	10 nuts
pecans	4 halves
pistachios	16 nuts
Oil: canola, olive, peanut	1 tsp
Olives	
black (ripe)	8 large
green, stuffed	10 large

Polyunsaturated Fats

Food	Serving Size
Margarine: lower-fat spread (30%–50% vegetable oil, *trans* fat-free)	1 Tbsp
Margarine: stick, tub (*trans* fat-free) or squeeze (*trans* fat-free)	1 tsp
Mayonnaise	
reduced-fat	1 Tbsp
regular	1 tsp
Mayonnaise-style salad dressing	
reduced-fat	1 Tbsp
regular	2 tsp
Nuts	
Pignolia (pine nuts)	1 Tbsp
walnuts, English	4 halves
Oil: corn, cottonseed, flaxseed, grape seed, safflower, soybean, sunflower	1 tsp
Oil: made from soybean and canola oil—Enova	1 tsp
Plant stanol esters	
light	1 Tbsp
regular	2 tsp

Polyunsaturated Fats—continued

Food	Serving Size
Salad dressing	
🧂 reduced-fat *Note: May be high in carbohydrate.*	2 Tbsp
🧂 regular	1 Tbsp
Seeds	
flaxseed, whole	1 Tbsp
pumpkin, sunflower	1 Tbsp
sesame seeds	1 Tbsp
Tahini or sesame paste	2 tsp

Saturated Fats

Food	Serving Size
Bacon, cooked, regular or turkey	1 slice
Butter	
reduced-fat	1 Tbsp
stick	1 tsp
whipped	2 tsp
Butter blends made with oil	
reduced-fat or light	1 Tbsp
regular	1½ tsp
Chitterlings, boiled	2 Tbsp (½ oz)
Coconut, sweetened, shredded	2 Tbsp
Coconut milk	
light	⅓ cup
regular	1½ Tbsp
Cream	
half and half	2 Tbsp
heavy	1 Tbsp
light	1½ Tbsp
whipped	2 Tbsp
whipped, pressurized	¼ cup
Cream cheese	
reduced-fat	1½ Tbsp (¾ oz)
regular	1 Tbsp (½ oz)
Lard	1 tsp
Oil: coconut, palm, palm kernel	1 tsp
Salt pork	¼ oz
Shortening, solid	1 tsp
Sour cream	
reduced-fat or light	3 Tbsp
regular	2 Tbsp

KEY

🧂 = 480 milligrams or more of sodium per serving.

TABLE G-9 Free Foods

A "free" food is any food or drink choice that has less than 20 kcalories and 5 grams or less of carbohydrate per serving.

- Most foods on this list should be limited to 3 servings (as listed here) per day. Spread out the servings throughout the day. If you eat all 3 servings at once, it could raise your blood glucose level.
- Food and drink choices listed here without a serving size can be eaten whenever you like.

Low Carbohydrate Foods

Food	Serving Size
Cabbage, raw	½ cup
Candy, hard (regular or sugar-free)	1 piece
Carrots, cauliflower, or green beans, cooked	¼ cup
Cranberries, sweetened with sugar substitute	½ cup
Cucumber, sliced	½ cup
Gelatin	
dessert, sugar-free	
unflavored	
Gum	
Jam or jelly, light or no sugar added	2 tsp
Rhubarb, sweetened with sugar substitute	½ cup
Salad greens	
Sugar substitutes (artificial sweeteners)	
Syrup, sugar-free	2 Tbsp

Modified Fat Foods with Carbohydrate

Food	Serving Size
Cream cheese, fat-free	1 Tbsp (½ oz)
Creamers	
nondairy, liquid	1 Tbsp
nondairy, powdered	2 tsp
Margarine spread	
fat-free	1 Tbsp
reduced-fat	1 tsp
Mayonnaise	
fat-free	1 Tbsp
reduced-fat	1 tsp
Mayonnaise-style salad dressing	
fat-free	1 Tbsp
reduced-fat	1 tsp
Salad dressing	
fat-free or low-fat	1 Tbsp
fat-free, Italian	2 Tbsp
Sour cream, fat-free or reduced-fat	1 Tbsp
Whipped topping	
light or fat-free	2 Tbsp
regular	1 Tbsp

Condiments

Food	Serving Size
Barbecue sauce	2 tsp
Catsup (ketchup)	1 Tbsp
Honey mustard	1 Tbsp

KEY

🧂 = 480 milligrams or more of sodium per serving.

Condiments—continued

Food	Serving Size
Horseradish	
Lemon juice	
Miso	1½ tsp
Mustard	
Parmesan cheese, freshly grated	1 Tbsp
Pickle relish	1 Tbsp
Pickles	
🧂 dill	1½ medium
sweet, bread and butter	2 slices
sweet, gherkin	¾ oz
Salsa	¼ cup
🧂 Soy sauce, light or regular	1 Tbsp
Sweet and sour sauce	2 tsp
Sweet chili sauce	2 tsp
Taco sauce	1 Tbsp
Vinegar	
Yogurt, any type	2 Tbsp

Drinks/Mixes

Any food on the list—without a serving size listed—can be consumed in any moderate amount.

- 🧂 Bouillon, broth, consommé
- Bouillon or broth, low-sodium
- Carbonated or mineral water
- Club soda
- Cocoa powder, unsweetened (1 Tbsp)
- Coffee, unsweetened or with sugar substitute
- Diet soft drinks, sugar-free
- Drink mixes, sugar-free
- Tea, unsweetened or with sugar substitute
- Tonic water, diet
- Water
- Water, flavored, carbohydrate free

Seasonings

Any food on this list can be consumed in any moderate amount.

- Flavoring extracts (for example, vanilla, almond, peppermint)
- Garlic
- Herbs, fresh or dried
- Nonstick cooking spray
- Pimento
- Spices
- Hot pepper sauce
- Wine, used in cooking
- Worcestershire sauce

TABLE G-10 Combination Foods

Many foods are eaten in various combinations, such as casseroles. Because "combination" foods do not fit into any one choice list, this list of choices provides some typical combination foods.

Entrees

Food	Serving Size	Count as
Casserole type (tuna noodle, lasagna, spaghetti with meatballs, chili with beans, macaroni and cheese)	1 cup (8 oz)	2 carbohydrates + 2 medium-fat meats
Stews (beef/other meats and vegetables)	1 cup (8 oz)	1 carbohydrate + 1 medium-fat meat + 0–3 fats
Tuna salad or chicken salad	½ cup (3½ oz)	½ carbohydrate + 2 lean meats + 1 fat

Frozen Meals/Entrees

Food	Serving Size	Count as
Burrito (beef and bean)	1 (5 oz)	3 carbohydrates + 1 lean meat + 2 fats
Dinner-type meal	generally 14–17 oz	3 carbohydrates + 3 medium-fat meats + 3 fats
Entrée or meal with less than 340 kcalories	about 8–11 oz	2–3 carbohydrates + 1–2 lean meats
Pizza		
cheese/vegetarian, thin crust	¼ of a 12 inch (4½–5 oz)	2 carbohydrates + 2 medium-fat meats
meat topping, thin crust	¼ of a 12 inch (5 oz)	2 carbohydrates + 2 medium-fat meats + 1½ fats
Pocket sandwich	1 (4½ oz)	3 carbohydrates + 1 lean meat + 1–2 fats
Pot pie	1 (7 oz)	2½ carbohydrates + 1 medium-fat meat + 3 fats

Salads (Deli-Style)

Food	Serving Size	Count as
Coleslaw	½ cup	1 carbohydrate + 1½ fats
Macaroni/pasta salad	½ cup	2 carbohydrates + 3 fats
Potato salad	½ cup	1½–2 carbohydrates + 1–2 fats

Soups

Food	Serving Size	Count as
Bean, lentil, or split pea	1 cup	1 carbohydrate + 1 lean meat
Chowder (made with milk)	1 cup (8 oz)	1 carbohydrate + 1 lean meat + 1½ fats
Cream (made with water)	1 cup (8 oz)	1 carbohydrate + 1 fat
Instant	6 oz prepared	1 carbohydrate
with beans or lentils	8 oz prepared	2½ carbohydrates + 1 lean meat
Miso soup	1 cup	½ carbohydrate + 1 fat
Oriental noodle	1 cup	2 carbohydrates + 2 fats
Rice (congee)	1 cup	1 carbohydrate
Tomato (made with water)	1 cup (8 oz)	1 carbohydrate
Vegetable beef, chicken noodle, or other broth-type	1 cup (8 oz)	1 carbohydrate

KEY

= More than 3 grams of dietary fiber per serving.

= Extra fat, or prepared with added fat.

= 600 milligrams or more of sodium per serving (for combination food main dishes/meals).

TABLE G-11 Fast Foods

The choices on the Fast Foods list are not specific fast-food meals or items, but are estimates based on popular foods. Ask the restaurant or check its website for nutrition information about your favorite fast foods.

Breakfast Sandwiches		
Food	**Serving Size**	**Count as**
Egg, cheese, meat, English muffin	1 sandwich	2 carbohydrates + 2 medium-fat meats
Sausage biscuit sandwich	1 sandwich	2 carbohydrates + 2 high-fat meats + 3½ fats

Main Dishes/Entrees		
Food	**Serving Size**	**Count as**
Burrito (beef and beans)	1 (about 8 oz)	3 carbohydrates + 3 medium-fat meats + 3 fats
Chicken breast, breaded and fried	1 (about 5 oz)	1 carbohydrate + 4 medium-fat meats
Chicken drumstick, breaded and fried	1 (about 2 oz)	2 medium-fat meats
Chicken nuggets	6 (about 3½ oz)	1 carbohydrate + 2 medium-fat meats + 1 fat
Chicken thigh, breaded and fried	1 (about 4 oz)	½ carbohydrate + 3 medium-fat meats + 1½ fats
Chicken wings, hot	6 (5 oz)	5 medium-fat meats + 1½ fats

Oriental		
Food	**Serving Size**	**Count as**
Beef/chicken/shrimp with vegetables in sauce	1 cup (about 5 oz)	1 carbohydrate + 1 lean meat + 1 fat
Egg roll, meat	1 (about 3 oz)	1 carbohydrate + 1 lean meat + 1 fat
Fried rice, meatless	½ cup	1½ carbohydrates + 1½ fats
Meat and sweet sauce (orange chicken)	1 cup	3 carbohydrates + 3 medium-fat meats + 2 fats
Noodles and vegetables in sauce (chow mein, lo mein)	1 cup	2 carbohydrates + 1 fat

Pizza		
Food	**Serving Size**	**Count as**
Pizza		
cheese, pepperoni, regular crust	⅛ of a 14 inch (about 4 oz)	2½ carbohydrates + 1 medium-fat meat + 1½ fats
cheese/vegetarian, thin crust	¼ of a 12 inch (about 6 oz)	2½ carbohydrates + 2 medium-fat meats + 1½ fats

Sandwiches		
Food	**Serving Size**	**Count as**
Chicken sandwich, grilled	1	3 carbohydrates + 4 lean meats
Chicken sandwich, crispy	1	3½ carbohydrates + 3 medium-fat meats + 1 fat
Fish sandwich with tartar sauce	1	2½ carbohydrates + 2 medium-fat meats + 2 fats
Hamburger		
large with cheese	1	2½ carbohydrates + 4 medium-fat meats + 1 fat
regular	1	2 carbohydrates + 1 medium-fat meat + 1 fat
Hot dog with bun	1	1 carbohydrate + 1 high-fat meat + 1 fat
Submarine sandwich		
less than 6 grams fat	6-inch sub	3 carbohydrates + 2 lean meats
regular	6-inch sub	3½ carbohydrates + 2 medium-fat meats + 1 fat
Taco, hard or soft shell (meat and cheese)	1 small	1 carbohydrate + 1 medium-fat meat + 1½ fats

(continued)

KEY

= More than 3 grams of dietary fiber per serving.

= Extra fat, or prepared with added fat.

= 600 milligrams or more of sodium per serving (for fast-food main dishes/meals).

TABLE G-11 Fast Foods (*continued*)

Salads		
Food	**Serving Size**	**Count as**
Salad, main dish (grilled chicken type, no dressing or croutons)		1 carbohydrate + 4 lean meats
Salad, side, no dressing or cheese	Small (about 5 oz)	1 vegetable
Sides/Appetizers		
Food	**Serving Size**	**Count as**
French fries, restaurant style	small	3 carbohydrates + 3 fats
	medium	4 carbohydrates + 4 fats
	large	5 carbohydrates + 6 fats
Nachos with cheese	small (about 4½ oz)	2½ carbohydrates + 4 fats
Onion rings	1 serving (about 3 oz)	2½ carbohydrates + 3 fats
Desserts		
Food	**Serving Size**	**Count as**
Milkshake, any flavor	12 oz	6 carbohydrates + 2 fats
Soft-serve ice cream cone	1 small	2½ carbohydrates + 1 fat

KEY

= More than 3 grams of dietary fi ber per serving.

= Extra fat, or prepared with added fat.

= 600 milligrams or more of sodium per serving (for fast-food main dishes/meals).

TABLE G-12 Alcohol

1 alcohol equivalent = variable grams carbohydrate, 0 grams protein, 0 grams fat, and 100 kcalories.

NOTE: In general, one alcohol choice (½ ounce absolute alcohol) has about 100 kcalories. For those who choose to drink alcohol, guidelines suggest limiting alcohol intake to 1 drink or less per day for women, and 2 drinks or less per day for men. To reduce your risk of low blood glucose (hypoglycemia), especially if you take insulin or a diabetes pill that increases insulin, always drink alcohol with food. While alcohol, by itself, does not directly affect blood glucose, be aware of the carbohydrate (for example, in mixed drinks, beer, and wine) that may raise your blood glucose.

Alcoholic Beverage	Serving Size	Count as
Beer		
light (4.2%)	12 fl oz	1 alcohol equivalent + ½ carbohydrate
regular (4.9%)	12 fl oz	1 alcohol equivalent + 1 carbohydrate
Distilled spirits: vodka, rum, gin, whiskey, 80 or 86 proof	1½ fl oz	1 alcohol equivalent
Liqueur, coffee (53 proof)	1 fl oz	1 alcohol equivalent + 1 carbohydrate
Sake	1 fl oz	½ alcohol equivalent
Wine		
dessert (sherry)	3½ fl oz	1 alcohol equivalent + 1 carbohydrate
dry, red or white (10%)	5 fl oz	1 alcohol equivalent

Appendix H Table of Food Composition

This edition of the table of food composition includes a wide variety of foods. It is updated with each edition to reflect current nutrient data for foods, to remove outdated foods, and to add foods that are new to the marketplace.* The nutrient database for this appendix is compiled from a variety of sources, including the USDA Nutrient Database and manufacturers' data. The USDA database provides data for a wider variety of foods and nutrients than other sources. Because laboratory analysis for each nutrient can be quite costly, manufacturers tend to provide data only for those nutrients mandated on food labels. Consequently, data for their foods are often incomplete; any missing information on this table is designated as a dash. Keep in mind that a dash means only that the information is unknown and should not be interpreted as a zero. A zero means that the nutrient is not present in the food.

Whenever using nutrient data, remember that many factors influence the nutrient contents of foods. These factors include the mineral content of the soil, the diet fed to the animal or the fertilizer used on the plant, the season of harvest, the method of processing, the length and method of storage, the method of cooking, the method of analysis, and the moisture content of the sample analyzed. With so many influencing factors, users should view nutrient data as a close approximation of the actual amount.

For updates, corrections, and a list of more than 22,000 foods and codes found in the diet analysis software that accompanies this text, visit **www.cengagebrain.com/shop/ISBN0538495081**.

- ***Fats*** Total fats, as well as the breakdown of total fats to saturated, monounsaturated, polyunsaturated, and *trans* fats, are listed in the table. The fatty acids seldom add up to the total in part due to rounding but also because values may include some non-fatty acids, such as glycerol, phosphate, or sterols.
- ***Trans Fats*** *Trans* fat data have been listed in the table. Because food manufacturers have been required to report only *trans* fats on food labels since January 2006, much of the data is incomplete. Missing *trans* fat data are designated with a dash. As additional *trans* fat data become available, the table will be updated.
- ***Vitamin A and Vitamin E*** In keeping with the 2001 RDA for vitamin A, this appendix presents data for vitamin A in micrograms (μg) RAE. Similarly because the 2000 RDA for vitamin E is based only on the alpha-tocopherol form of vitamin E, this appendix reports vitamin E data in milligrams (mg) alpha-tocopherol, listed on the table as Vit E (mg α).
- ***Bioavailability*** Keep in mind that the availability of nutrients from foods depends not only on the quantity provided by a food, but also on the amount absorbed and used by the body—the bioavailability. The bioavailability of folate from fortified foods, for example, is greater than from naturally occurring sources. Similarly, the body can make niacin from the amino acid tryptophan, but niacin values in this table (and most databases) report preformed niacin only. Chapter 10 provides conversion factors and additional details.

*This food composition table has been prepared by Cengage Learning. The nutritional data are supplied by Axxya Systems.

- *Using the Table* The foods and beverages in this table are organized into several categories, which are listed at the head of each right-hand page. Page numbers are provided, and each group is color-coded to make it easier to find individual foods.
- *Caffeine Sources* Caffeine occurs in several plants, including the familiar coffee bean, the tea leaf, and the cocoa bean from which chocolate is made. Most human societies use caffeine regularly, most often in beverages, for its stimulant effect and flavor. Caffeine contents of beverages vary depending on the plants they are made from, the climates and soils where the plants are grown, the grind or cut size, the method and duration of brewing, and the amounts served. The accompanying table shows that, in general, a cup of coffee contains the most caffeine; a cup of tea, less than half as much; and cocoa or chocolate, less still. As for cola beverages, they are made from kola nuts, which contain caffeine, but most of their caffeine is added, using the purified compound obtained from decaffeinated coffee beans. The FDA lists caffeine as a multipurpose GRAS substance ♦ that may be added to foods and beverages. Drug manufacturers also use caffeine in many products.

♦ A GRAS substance is one that is "generally recognized as safe."

TABLE Caffeine Content of Selected Beverages, Foods, and Medications

Beverages and Foods	Serving Size	Average (mg)
Coffee		
Brewed	8 oz	95
Decaffeinated	8 oz	2
Instant	8 oz	64
Tea		
Brewed, green	8 oz	30
Brewed, herbal	8 oz	0
Brewed, leaf or bag	8 oz	47
Instant	8 oz	26
Lipton Brisk iced tea	12 oz	7
Nestea Cool iced tea	12 oz	12
Snapple iced tea (all flavors)	16 oz	42

Beverages and Foods	Serving Size	Average (mg)
Soft Drinks		
A&W Creme Soda	12 oz	29
Barq's Root Beer	12 oz	18
Coca-Cola	12 oz	30
Dr. Pepper, Mr. Pibb, Sunkist Orange	12 oz	36
A&W Root Beer, club soda, Fresca, ginger ale, 7-Up, Sierra Mist, Sprite, Squirt, tonic water, caffeine-free soft drinks	12 oz	0
Mello Yello	12 oz	51
Mountain Dew	12 oz	45
Pepsi	12 oz	32

TABLE Caffeine Content of Selected Beverages, Foods, and Medications (*continued*)

Beverages and Foods	Serving Size	Average (mg)
Energy Drinks		
Amp	8.4 oz	70
Aqua Blast	0.5 L	90
Aqua Java	0.5 L	55
E Maxx	8.4 oz	74
Java Water	0.5 L	125
KMX	8.4 oz	33
Krank	0.5 L	100
Red Bull	8.3 oz	67
Red Devil	8.4 oz	42
Sobe Adrenaline Rush	8.3 oz	77
Sobe No Fear	16 oz	141
Water Joe	0.5 L	65
Other Beverages		
Chocolate milk or hot cocoa	8 oz	5
Starbucks Frappuccino Mocha	9.5 oz	72
Starbucks Frappuccino Vanilla	9.5 oz	64
Yoohoo chocolate drink	9 oz	3
Candies		
Baker's chocolate	1 oz	26
Dark chocolate covered coffee beans	1 oz	235
Dark chocolate, semisweet	1 oz	18
Milk chocolate	1 oz	6
Milk chocolate covered coffee beans	1 oz	224
White chocolate	1 oz	0
Foods		
Frozen yogurt, Ben & Jerry's coffee fudge	1 cup	85
Frozen yogurt, Häagen-Dazs coffee	1 cup	40
Ice cream, Starbucks coffee	1 cup	50
Ice cream, Starbucks Frappuccino bar	1 bar	15
Yogurt, Dannon coffee flavored	1 cup	45
Drugs[a]	**Serving Size**	**Average (mg)**
Cold Remedies		
Coryban-D, Dristan	1 tablet	30
Diuretics		
Aqua-Ban	1 tablet	100
Pre-Mens Forte	1 tablet	100
Pain Relievers		
Anacin, BC Fast Pain Reliever	1 tablet	32
Excedrin, Midol, Midol Max Strength	1 tablet	65
Stimulants		
Awake, NoDoz	1 tablet	100
Awake Maximum Strength, Caffedrine, NoDoz Maximum Strength, Stay Awake, Vivarin	1 tablet	200
Weight Control Aids		
Dexatrim	1 tablet	200

[a]A pharmacologically active dose of caffiene is defined as 200 milligrams

NOTE: The FDA suggests a maximum of 65 milligrams per 12-ounce cola beverage but does not regulate the caffeine contents of other beverages. Because products change, contact the manufacturer for an update on products you use regularly

SOURCE: Adapted from USDA database Release 18 (www.nal.usda.gov/fnic/foodcomp/Data/). Caffeine content of foods and drugs. Center for Science and the Public Interest (www.cspinet.org/new/cafchart.htm), and R. R. McCusker, B. A. Goldberger, and E. J. Cone, Caffeine content of energy drinks, carbonated sodas, and other beverages, *Journal of Analytical Toxicology* 30 (2006): 112–114

TABLE H-1 Table of Food Composition

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Trans
Breads, Baked Goods, Cakes, Cookies, Crackers, Chips, Pies														
	Bagels													
8534	Cinnamon and raisin	1	item(s)	71	22.7	194	7.0	39.2	1.6	1.2	0.2	0.1	0.5	—
14395	Multi-grain	1	item(s)	61	—	170	6.0	35.0	1.0	1.5	0.5	0.1	0.4	—
8538	Oat bran	1	item(s)	71	23.4	181	7.6	37.8	2.6	0.9	0.1	0.2	0.3	—
4910	Plain, enriched	1	item(s)	71	25.8	182	7.1	35.9	1.6	1.2	0.3	0.4	0.5	0
4911	Plain, enriched, toasted	1	item(s)	66	18.7	190	7.4	37.7	1.7	1.1	0.2	0.3	0.6	0
	Biscuits													
25008	Biscuits	1	item(s)	41	15.8	121	2.6	16.4	0.5	4.9	1.4	1.4	1.8	—
16729	Scone	1	item(s)	42	11.5	148	3.8	19.1	0.6	6.2	2.0	2.5	1.3	—
25166	Wheat biscuits	1	item(s)	55	21.0	162	3.6	21.9	1.4	6.7	1.9	1.9	2.5	—
	Bread													
325	Boston brown, canned	1	slice(s)	45	21.2	88	2.3	19.5	2.1	0.7	0.1	0.1	0.3	—
8716	Bread sticks, plain	4	item(s)	24	1.5	99	2.9	16.4	0.7	2.3	0.3	0.9	0.9	—
25176	Cornbread	1	piece(s)	55	25.9	141	4.7	18.3	0.9	5.4	2.1	1.4	1.5	0
327	Cracked wheat	1	slice(s)	25	9.0	65	2.2	12.4	1.4	1.0	0.2	0.5	0.2	—
9079	Croutons, plain	¼	cup(s)	8	0.4	31	0.9	5.5	0.4	0.5	0.1	0.2	0.1	—
8582	Egg	1	slice(s)	40	13.9	113	3.8	19.1	0.9	2.4	0.6	0.9	0.4	—
8585	Egg, toasted	1	slice(s)	37	10.5	117	3.9	19.5	0.9	2.4	0.6	1.1	0.4	—
329	French	1	slice(s)	32	8.9	92	3.8	18.1	0.8	0.6	0.2	0.1	0.3	—
8591	French, toasted	1	slice(s)	23	4.7	73	3.0	14.2	0.7	0.5	0.1	0.1	0.2	—
42096	Indian fry, made with lard (Navajo)	3	ounce(s)	85	26.9	281	5.7	41.0	—	10.4	3.9	3.8	0.9	—
332	Italian	1	slice(s)	30	10.7	81	2.6	15.0	0.8	1.1	0.3	0.2	0.4	—
1393	Mixed grain	1	slice(s)	26	9.6	69	3.5	11.3	1.9	1.1	0.2	0.2	0.5	0
8604	Mixed grain, toasted	1	slice(s)	24	7.6	69	3.5	11.3	1.9	1.1	0.2	0.2	0.5	0
8605	Oat bran	1	slice(s)	30	13.2	71	3.1	11.9	1.4	1.3	0.2	0.5	0.5	—
8608	Oat bran, toasted	1	slice(s)	27	10.4	70	3.1	11.8	1.3	1.3	0.2	0.5	0.5	—
8609	Oatmeal	1	slice(s)	27	9.9	73	2.3	13.1	1.1	1.2	0.2	0.4	0.5	—
8613	Oatmeal, toasted	1	slice(s)	25	7.8	73	2.3	13.2	1.1	1.2	0.2	0.4	0.5	—
1409	Pita	1	item(s)	60	19.3	165	5.5	33.4	1.3	0.7	0.1	0.1	0.3	—
7905	Pita, whole wheat	1	item(s)	64	19.6	170	6.3	35.2	4.7	1.7	0.3	0.2	0.7	—
338	Pumpernickel	1	slice(s)	32	12.1	80	2.8	15.2	2.1	1.0	0.1	0.3	0.4	—
334	Raisin, enriched	1	slice(s)	26	8.7	71	2.1	13.6	1.1	1.1	0.3	0.6	0.2	—
8625	Raisin, toasted	1	slice(s)	24	6.7	71	2.1	13.7	1.1	1.2	0.3	0.6	0.2	—
10168	Rice, white, gluten free, wheat free	1	slice(s)	38	—	130	1.0	18.0	0.5	6.0	0	—	—	0
8653	Rye	1	slice(s)	32	11.9	83	2.7	15.5	1.9	1.1	0.2	0.4	0.3	—
8654	Rye, toasted	1	slice(s)	29	9.0	82	2.7	15.4	1.9	1.0	0.2	0.4	0.3	—
336	Rye, light	1	slice(s)	25	9.3	65	2.0	12.0	1.6	1.0	0.2	0.3	0.3	—
8588	Sourdough	1	slice(s)	25	7.0	72	2.9	14.1	0.6	0.5	0.1	0.1	0.2	—
8592	Sourdough, toasted	1	slice(s)	23	4.7	73	3.0	14.2	0.7	0.5	0.1	0.1	0.2	—
491	Submarine or hoagie roll	1	item(s)	135	40.6	400	11.0	72.0	3.8	8.0	1.8	3.0	2.2	—
8596	Vienna, toasted	1	slice(s)	23	4.7	73	3.0	14.2	0.7	0.5	0.1	0.1	0.2	—
8670	Wheat	1	slice(s)	25	8.9	67	2.7	11.9	0.9	0.9	0.2	0.2	0.4	—
8671	Wheat, toasted	1	slice(s)	23	5.6	72	3.0	12.8	1.1	1.0	0.2	0.2	0.4	—
340	White	1	slice(s)	25	9.1	67	1.9	12.7	0.6	0.8	0.2	0.2	0.3	—
1395	Whole wheat	1	slice(s)	46	15.0	128	3.9	23.6	2.8	2.5	0.4	0.5	1.4	—
	Cakes													
386	Angel food, prepared from mix	1	piece(s)	50	16.5	129	3.1	29.4	0.1	0.2	0	0	0.1	—
8772	Butter pound, ready to eat, commercially prepared	1	slice(s)	75	18.5	291	4.1	36.6	0.4	14.9	8.7	4.4	0.8	—
28517	Carrot	1	slice(s)	131	56.6	339	4.8	56.5	1.9	11.1	1.0	5.7	3.8	—
4931	Chocolate with chocolate icing, commercially prepared	1	slice(s)	64	14.7	235	2.6	34.9	1.8	10.5	3.1	5.6	1.2	—
8756	Chocolate, prepared from mix	1	slice(s)	95	23.2	352	5.0	50.7	1.5	14.3	5.2	5.7	2.6	—
393	Devil's food cupcake with chocolate frosting	1	item(s)	35	8.4	120	2.0	20.0	0.7	4.0	1.8	1.6	0.6	—
8757	Fruitcake, ready to eat, commercially prepared	1	piece(s)	43	10.9	139	1.2	26.5	1.6	3.9	0.5	1.8	1.4	—
1397	Pineapple upside down, prepared from mix	1	slice(s)	115	37.1	367	4.0	58.1	0.9	13.9	3.4	6.0	3.8	—
411	Sponge, prepared from mix	1	slice(s)	63	18.5	187	4.6	36.4	0.3	2.7	0.8	1.0	0.4	—
8817	White with coconut frosting, prepared from mix	1	slice(s)	112	23.2	399	4.9	70.8	1.1	11.5	4.4	4.1	2.4	—
8819	Yellow with chocolate frosting, ready to eat, commercially prepared	1	slice(s)	64	14.0	243	2.4	35.5	1.2	11.1	3.0	6.1	1.4	—

rol (g)	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
0	13	2.69	19.9	105.1	228.6	0.80	14.9	0.27	0.22	0.19	2.18	0.04	78.8	0.5	0	22.0
0	60	1.08	—	—	310.0	—	0	—	—	—	—	—	—	0	—	—
0	9	2.18	22.0	81.7	360 0	0 63	0.7	0.23	0.23	0.24	2.10	0.03	69.6	0.1	0	24.3
0	63	4.29	15.6	53.3	318.1	1.34	0	0.42	0.07	0.18	2.82	0.04	103.0	0.7	0	16.2
0	65	2.97	15.8	56.1	316.8	0.85	0	0.39	0.07	0.17	2.88	0.04	86.5	0	0	16.6
0	38	0.94	6.0	47.4	206.0	0.20	—	0.16	0 01	0.12	1.20	0 01	31.7	0.1	0.1	7.1
49	79	1.35	7.1	48.7	277.2	0.29	64.7	0.14	0.42	0.15	1.19	0.02	32.3	0	0.1	10.9
0	57	1.21	16.1	81.0	321.1	0.42	—	0.19	0.01	0.14	1.65	0.03	35.3	0.1	0.1	0
0	32	0.94	28.4	143.1	284.0	0.22	11.3	0 01	0.14	0.05	0.50	0.03	5.0	0	0	9.9
0	5	1.02	7.7	29.8	157.7	0.21	0	0.14	0.24	0.13	1 26	0.01	38.9	0	0	9.0
21	94	0.91	10.5	71.5	209.8	0.48	—	0.14	0.32	0.15	1.03	0.04	34.6	1.7	0.2	6 2
0	11	0.70	13.0	44.3	134.5	0.31	0	0 09	—	0 06	0.92	0.08	15.3	0	0	6.3
0	6	0.30	2.3	9.3	52.4	0.06	0	0.04	—	0.02	0.40	0 00	9.9	0	0	2.8
20	37	1.21	7.6	46.0	196.8	0.31	25.2	0.17	0 10	0.17	1.93	0.02	42.0	0	0	12.0
21	38	1.23	7.8	46.6	199.8	0.31	25.5	0.14	0 10	0.16	1.77	0.02	36.3	0	0	12.2
0	14	1.16	9.0	41.0	208 0	0.29	0	0.13	0.05	0 09	1.52	0.03	47.4	0.1	0	8.7
0	11	0.89	7.1	32.2	165.6	0.24	0	0 10	0 04	0.09	1.24	0.02	32.2	0	0	6.8
6	48	3.43	15.3	65.5	279.8	0.29	0	0.36	0.00	0.18	3.91	0.03	103.8	—	0	15.8
0	23	0.88	8.1	33.0	175.2	0.25	0	0 14	0 08	0 08	1 31	0.01	57.3	0	0	8.2
0	27	0.65	20.3	59.8	109.2	0 44	0	0 07	0 09	0.03	1.05	0.06	19.5	0	0	8.6
0	27	0.65	20.4	60.0	109.7	0.44	0	0.06	0 10	0.03	1.05	0.07	16.8	0	0	8.6
0	20	0.93	10.5	44.1	122.1	0.26	0.6	0.15	0.13	0.10	1.44	0.02	24.3	0	0	9.0
0	19	0.92	9.2	33.2	121.0	0.28	0.5	0.12	0.13	0.09	1.29	0.01	18.6	0	0	8.9
0	18	0.72	10.0	38 3	161.7	0.27	1.4	0.10	0.13	0.06	0.84	0.01	16.7	0	0	6.6
0	18	0.74	10.3	38.5	162.8	0.28	1.3	0.09	0.13	0.06	0.77	0.02	13.3	0.1	0	6.7
0	52	1.57	15.6	72.0	321 6	0.50	0	0.35	0.18	0.19	2.77	0.02	64.2	0	0	16.3
0	10	1.95	44.2	108.8	340.5	0.97	0	0.21	0.39	0.05	1.81	0.17	22.4	0	0	28.2
0	22	0.91	17.3	66.6	214.7	0.47	0	0.10	0.13	0.09	0.98	0.04	29.8	0	0	7.8
0	17	0.75	6 8	59.0	101 4	0.18	0	0.08	0.07	0.10	0.90	0.01	27.6	0	0	5.2
0	17	0.76	6.7	59.0	101.8	0.19	0	0.07	0.07	0.09	0.81	0.02	23.5	0.1	0	5.2
0	100	1.08	—	—	140	—	—	0.15	—	0.10	1.20	—	32.0	0	—	—
0	23	0.90	12.8	53.1	211.2	0.36	0	0.13	0.10	0.10	1.21	0.02	35.2	0.1	0	9.9
0	23	0.89	12.5	53.1	210 3	0.36	0	0.11	0.10	0.09	1.09	0.02	29.9	0.1	0	9.9
0	20	0.70	3.9	51.0	175.0	0.18	0	0.10	—	0.08	0.80	0.01	5.3	0	0	8.0
0	11	0.91	7.0	32.0	162.5	0.23	0	0.11	0.05	0.07	1.19	0.03	37.0	0.1	0	6.8
0	11	0.89	7.1	32.2	165.6	0.24	0	0.10	0.04	0.09	1.24	0.02	32.2	0	0	6.8
0	100	3.80	—	128.0	683.0	—	0	0.54	—	0.33	4.50	0.04	—	0	—	42.0
0	11	0.89	7.1	32.2	165.6	0.24	0	0.10	0.04	0.09	1.24	0.02	32.2	0	0	6.8
0	36	0.87	12.0	46.0	130.3	0.30	0	0.09	0.05	0.08	1.30	0.03	21.3	0.1	0	7.2
0	38	0.94	13.6	51.3	140.5	0.34	0	0.10	0.06	0.09	1.44	0.04	19.8	0	0	7.7
0	38	0.94	5 8	25.0	170 3	0.19	0	0.11	0.06	0.08	1.10	0.02	27.8	0	0	4.3
0	15	1.42	37.3	144.4	159.2	0.69	0	0.13	0.35	0.10	1.83	0.09	29.9	0	0	17.8
0	42	0.11	4.0	67.5	254.5	0.06	0	0.04	0.01	0.10	0.08	0.00	9.5	0	0	7.7
166	26	1.03	8.3	89.3	298.5	0.34	111.8	0.10	—	0.17	0.98	0.03	30.8	0	0.2	6.6
0	65	2.18	23.0	279.6	367.7	0.44	—	0.25	0.01	0.19	1.73	0.10	43.4	4.6	0	14.7
27	28	1.40	21.8	128.0	213.8	0.44	16.6	0.01	0.62	0.08	0.36	0.02	10.9	0.1	0.1	2.1
55	57	1.53	30.4	133.0	299.3	0.65	38.0	0.13	—	0.20	1.08	0.03	25.7	0.2	0.2	11.3
19	21	0.70	—	46.0	92.0	—	—	0.04	—	0.05	0.30	—	2.1	0	—	2.0
2	14	0.89	6.9	65.8	116.1	0.11	3.0	0.02	0.38	0.04	0.34	0.02	8.6	0.2	0	0.9
25	138	1.70	15.0	128.8	366.9	0.35	71.3	0.17	—	0.17	1.36	0.03	29.9	1.4	0.1	10.8
107	26	0.99	5.7	88.8	143.6	0.37	48.5	0.10	—	0.19	0.75	0.03	24.6	0	0.2	11.7
1	101	1.29	13.4	110.9	318.1	0.37	13.4	0.14	0.13	0.21	1.19	0.03	34.7	0.1	0.1	12.0
35	24	1.33	19.2	113.9	215.7	0.39	21.1	0.07	—	0.10	0.79	0.02	14.1	0	0.1	2.2

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tra
	Breads, Baked Goods, Cakes, Cookies, Crackers, Chips, Pies—*continued*													
8822	Yellow with vanilla frosting, ready to eat, commercially prepared	1	slice(s)	64	14.1	239	2.2	37.6	0.2	9.3	1.5	3.9	3.3	—
	Snack cakes													
8791	Chocolate snack cake, creme filled, with frosting	1	item(s)	50	9.3	200	1.8	30.2	1.6	8.0	2.4	4.3	0.9	—
25010	Cinnamon coffee cake	1	piece(s)	72	22.6	231	3.6	35.8	0.7	8.3	2.2	2.6	3.0	—
16777	Funnel cake	1	item(s)	90	37.6	276	7.3	29.1	0.9	14.4	2.7	4.7	6.1	—
8794	Sponge snack cake, creme filled	1	item(s)	43	8.6	155	1.3	27.2	0.2	4.8	1.1	1.7	1.4	—
	Snacks, chips, pretzels													
29428	Bagel chips, plain	3	item(s)	29	—	130	3.0	19.0	1.0	4.5	0.5	—	—	—
29429	Bagel chips, toasted onion	3	item(s)	29	—	130	4.0	20.0	1.0	4.5	0.5	—	—	—
38192	Chex traditional snack mix	1	cup(s)	45	—	197	3.0	33.3	1.5	6.1	0.8	—	—	—
654	Potato chips, salted	1	ounce(s)	28	0.6	155	1.9	14.1	1.2	10.6	3.1	2.8	3.5	—
8816	Potato chips, unsalted	1	ounce(s)	28	0.5	152	2.0	15.0	1.4	9.8	3.1	2.8	3.5	—
5096	Pretzels, plain, hard, twists	5	item(s)	30	1.0	114	2.7	23.8	1.0	1.1	0.2	0.4	0.4	—
4632	Pretzels, whole wheat	1	ounce(s)	28	1.1	103	3.1	23.0	2.2	0.7	0.2	0.3	0.2	—
4641	Tortilla chips, plain	6	item(s)	11	0.2	53	0.8	7.1	0.6	2.5	0.3	0.8	0.5	0.3
	Cookies													
8859	Animal crackers	12	item(s)	30	1.2	134	2.1	22.2	0.3	4.1	1.0	2.3	0.6	—
8876	Brownie, prepared from mix	1	item(s)	24	3.0	112	1.5	12.0	0.5	7.0	1.8	2.6	2.3	—
25207	Chocolate chip cookies	1	item(s)	30	3.7	140	2.0	16.2	0.6	7.9	2.1	3.3	2.1	—
8915	Chocolate sandwich cookie with extra creme filling	1	item(s)	13	0.2	65	0.6	8.9	0.4	3.2	0.7	2.1	0.3	1.1
14145	Fig Newtons cookies	1	item(s)	16	—	55	0.5	11.0	0.5	1.3	0	—	—	0
8920	Fortune cookie	1	item(s)	8	0.6	30	0.3	6.7	0.1	0.2	0.1	0.1	0	—
25208	Oatmeal cookies	1	item(s)	69	12.3	234	5.7	45.1	3.1	4.2	0.7	1.3	1.8	—
25213	Peanut butter cookies	1	item(s)	35	4.1	163	4.2	16.9	0.9	9.2	1.7	4.7	2.3	—
33095	Sugar cookies	1	item(s)	16	4.1	61	1.1	7.4	0.1	3.0	0.6	1.3	0.9	—
9002	Vanilla sandwich cookie with creme filling	1	item(s)	10	0.2	48	0.5	7.2	0.2	2.0	0.3	0.8	0.8	—
	Crackers													
9012	Cheese cracker sandwich with peanut butter	4	item(s)	28	0.9	139	3.5	15.9	1.0	7.0	1.2	3.6	1.4	—
9008	Cheese crackers (mini)	30	item(s)	30	0.9	151	3.0	17.5	0.7	7.6	2.8	3.6	0.7	—
33362	Cheese crackers, low sodium	1	serving(s)	30	0.9	151	3.0	17.5	0.7	7.6	2.9	3.6	0.7	—
8928	Honey graham crackers	4	item(s)	28	1.2	118	1.9	21.5	0.8	2.8	0.4	1.1	1.1	—
9016	Matzo crackers, plain	1	item(s)	28	1.2	112	2.8	23.8	0.9	0.4	0.1	0	0.2	—
9024	Melba toast	3	item(s)	15	0.8	59	1.8	11.5	0.9	0.5	0.1	0.1	0.2	—
9028	Melba toast, rye	3	item(s)	15	0.7	58	1.7	11.6	1.2	0.5	0.1	0.1	0.2	—
14189	Ritz crackers	5	item(s)	16	0.5	80	1.0	10.0	0	4.0	1.0	—	—	0
9014	Rye crispbread crackers	1	item(s)	10	0.6	37	0.8	8.2	1.7	0.1	0	0	0.1	—
9040	Rye wafer	1	item(s)	11	0.6	37	1.1	8.8	2.5	0.1	0	0	0	—
432	Saltine crackers	5	item(s)	15	0.8	64	1.4	10.6	0.5	1.7	0.2	1.1	0.2	0.5
9046	Saltine crackers, low salt	5	item(s)	15	0.6	65	1.4	10.7	0.5	1.8	0.4	1.0	0.3	—
9052	Snack cracker sandwich with cheese filling	4	item(s)	28	1.1	134	2.6	17.3	0.5	5.9	1.7	3.2	0.7	—
9054	Snack cracker sandwich with peanut butter filling	4	item(s)	28	0.8	138	3.2	16.3	0.6	6.9	1.4	3.9	1.3	—
9048	Snack crackers, round	10	item(s)	30	1.1	151	2.2	18.3	0.5	7.6	1.1	3.2	2.9	—
9050	Snack crackers, round, low salt	10	item(s)	30	1.1	151	2.2	18.3	0.5	7.6	1.1	3.2	2.9	—
9044	Soda crackers	5	item(s)	15	0.8	64	1.4	10.6	0.5	1.7	0.2	1.1	0.2	0.5
9059	Wheat cracker sandwich with cheese filling	4	item(s)	28	0.9	139	2.7	16.3	0.9	7.0	1.2	2.9	2.6	—
9061	Wheat cracker sandwich with peanut butter filling	4	item(s)	28	1.0	139	3.8	15.1	1.2	7.5	1.3	3.3	2.5	—
9055	Wheat crackers	10	item(s)	30	0.9	142	2.6	19.5	1.4	6.2	1.6	3.4	0.8	—
9057	Wheat crackers, low salt	10	item(s)	30	0.9	142	2.6	19.5	1.4	6.2	1.6	3.4	0.8	—
9022	Whole wheat crackers	7	item(s)	28	0.8	124	2.5	19.2	2.9	4.8	1.0	1.6	1.8	—
	Pastry													
16754	Apple fritter	1	item(s)	17	6.4	61	1.0	5.5	0.2	3.9	0.9	1.7	1.1	—
41565	Cinnamon rolls with icing, refrigerated dough	1	serving(s)	44	12.3	145	2.0	23.0	0.5	5.0	1.5	—	—	2.0
4945	Croissant, butter	1	item(s)	57	13.2	231	4.7	26.1	1.5	12.0	6.6	3.1	0.6	—
9096	Danish, nut	1	item(s)	65	13.3	280	4.6	29.7	1.3	16.4	3.8	8.9	2.8	—
9115	Doughnut with creme filling	1	item(s)	85	32.5	307	5.4	25.5	0.7	20.8	4.6	10.3	2.6	—

H-4 = Breads/Baked Goods H-10 = Cereal/Rice/Pasta H-14 = Fruit H-18 = Vegetables/Legumes H-28 = Nuts/Seeds H-30 = Vegetarian H-32 = Dairy H-40 = Eggs H-40 = Seafood H-42 = Meats H-46 = Poultry
ressed Meats H-48 = Beverages H-52 = Fats/Oils H-54 = Sweets H-56 = Spices/Condiments/Sauces H-60 = Mixed Foods/Soups/Sandwiches H-64 = Fast Food H-84 = Convenience H-86 = Baby Foods

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
5	40	0.68	3.8	33.9	220.2	0.16	12.2	0.06	—	0.04	0.32	0.01	17.3	0	0.1	3.5
0	58	1.80	18.0	88.0	194.5	0.52	0.5	0.01	0.54	0.03	0.46	0.07	13.0	1.0	0	1.7
6	55	1.36	9.9	91.9	277.6	0.30	—	0.17	0.23	0.16	1.29	0.02	36.1	0.3	0.1	9.6
2	126	1.90	16.2	152.1	269.1	0.65	49.5	0.23	1.54	0.32	1.86	0.04	50.4	0	0.3	17.7
7	19	0.54	3.4	37.0	155.1	0.12	2.1	0.06	0.50	0.05	0.52	0.01	17.0	0	0	1.3
0	0	0.72	—	45.0	70.0	—	0	—	—	—	—	—	—	0	0	—
0	0	0.72	—	50.0	300.0	—	0	—	—	—	—	—	—	0	0	—
0	0	0.55	—	75.8	621.2	—	0	0.09	—	0.05	1.21	—	12.1	0	—	—
0	7	0.45	19.8	465.5	148.8	0.67	0	0.01	1.91	0.06	1.18	0.20	21.3	5.3	0	2.3
0	7	0.46	19.0	361.5	2.3	0.30	0	0.04	2.58	0.05	1.08	0.18	12.8	8.8	0	2.3
0	11	1.29	10.5	43.8	514.5	0.25	0	0.13	0.10	0.18	1.57	0.03	51.3	0	0	1.7
0	8	0.76	8.5	121.9	57.6	0.17	0	0.12	—	0.08	1.85	0.07	15.3	0.3	0	—
0	19	0.25	15.8	23.2	45.5	0.26	0	0.00	0.46	0.01	0.13	0.02	2.2	0	0	0.7
0	13	0.82	5.4	30.0	117.9	0.19	0	0.10	0.03	0.09	1.04	0.01	30.9	0	0	2.1
8	14	0.44	12.7	42.2	82.3	0.23	42.2	0.03	—	0.05	0.24	0.02	7.0	0.1	0	2.8
3	11	0.69	12.4	62.1	108.8	0.24	—	0.08	0.54	0.06	0.87	0.01	17.8	0	0	4.1
0	2	1.01	4.7	17.8	45.6	0.10	0	0.02	0.25	0.02	0.25	0.00	6.0	0	0	1.1
0	10	0.36	—	—	57.5	—	0	—	—	—	—	—	—	0	—	—
0	1	0.12	0.6	3.3	21.9	0.01	0.1	0.01	0.00	0.01	0.15	0.00	5.3	0	0	0.2
0	26	1.93	48.8	176.7	311.1	1.42	—	0.26	0.23	0.13	1.35	0.09	34.9	0.3	0	17.4
3	27	0.65	21.1	112.8	154.1	0.46	—	0.08	0.73	0.09	1.85	0.05	23.5	0.1	0.1	4.8
8	5	0.30	1.7	12.2	49.4	0.08	—	0.04	0.28	0.05	0.31	0.01	9.5	0	0	3.1
0	3	0.22	1.4	9.1	34.9	0.04	0	0.02	0.16	0.02	0.27	0.00	5.0	0	0	0.3
0	14	0.76	15.7	61.0	198.8	0.29	0.[illegible]	0.15	0.66	0.08	1.63	0.04	26.3	0	0.1	2.3
4	45	1.43	10.8	43.5	298.5	0.33	8.7	0.17	0.01	0.12	1.40	0.16	45.6	0	0.1	2.6
4	45	1.43	10.8	31.8	137.4	0.33	5.1	0.17	0.09	0.12	1.40	0.16	26.7	0	0.1	2.6
0	7	1.04	8.4	37.8	169.4	0.22	0	0.06	0.09	0.08	1.15	0.01	12.9	0	0	2.9
0	4	0.89	7.1	31.8	0.6	0.19	0	0.11	0.01	0.08	1.10	0.03	4.8	0	0	10.5
0	14	0.55	8.9	30.3	124.4	0.30	0	0.06	0.06	0.04	0.61	0.01	18.6	0	0	5.2
0	12	0.55	5.9	29.0	134.9	0.20	0	0.07	—	0.04	0.70	0.01	12.8	0	0	5.8
0	20	0.72	—	10.0	135.0	—	—	—	—	—	—	—	—	0	—	—
0	3	0.24	7.8	31.9	26.4	0.23	0	0.02	0.08	0.01	0.10	0.02	4.7	0	0	3.7
0	4	0.65	13.3	54.5	87.3	0.30	0	0.04	0.08	0.03	0.17	0.03	5.0	0	0	2.6
0	10	0.84	3.3	23.1	160.8	0.12	0	0.01	0.14	0.06	0.78	0.01	20.9	0	0	1.5
0	18	0.81	4.1	108.6	95.4	0.11	0	0.08	0.01	0.06	0.78	0.01	18.6	0	0	2.9
,1	72	0.66	10.1	120.1	392.3	0.17	4.8	0.12	0.06	0.19	1.05	0.01	28.0	0	0	6.0
0	23	0.77	15.4	60.2	201.0	0.31	0.3	0.13	0.57	0.07	1.71	0.04	24.1	0	0	3.0
0	36	1.08	8.1	39.9	254.1	0.20	0	0.12	0.60	0.10	1.21	0.01	27.0	0	0	2.0
0	36	1.08	8.1	106.5	111.9	0.20	0	0.12	0.60	0.10	1.21	0.01	27.0	0	0	2.0
0	10	0.84	3.3	23.1	160.8	0.12	0	0.01	0.14	0.06	0.78	0.01	20.9	0	0	1.5
2	57	0.73	15.1	85.7	255.6	0.24	4.8	0.10	—	0.12	0.89	0.07	17.9	0.4	0	6.8
0	48	0.74	10.6	83.2	226.0	0.23	0	0.10	—	0.08	1.64	0.03	19.6	0	0	6.1
0	15	1.32	18.6	54.9	238.5	0.48	0	0.15	0.15	0.09	1.48	0.04	35.1	0	0	1.9
0	15	1.32	18.6	60.9	84.9	0.48	0	0.15	0.15	0.09	1.48	0.04	15.0	0	0	10.1
0	14	0.86	27.7	83.2	184.5	0.60	0	0.05	0.24	0.02	1.26	0.05	7.8	0	0	4.1
14	9	0.26	2.2	22.4	6.8	0.09	7.1	0.03	0.07	0.04	0.23	0.01	6.3	0.2	0.1	2.6
0	—	0.72	—	—	340.1	—	0	—	—	—	—	—	—	—	—	—
38	21	1.15	9.1	67.3	424.1	0.42	117.4	0.22	0.47	0.13	1.24	0.03	50.2	0.1	0.1	12.9
30	61	1.17	20.8	61.8	236.0	0.56	5.9	0.14	0.53	0.15	1.49	0.06	54.0	1.1	0.1	9.2
20	21	1.55	17.0	68.0	262.7	0.68	9.4	0.28	0.24	0.12	1.90	0.05	59.5	0	0.1	9.2

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DAI Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tr
Breads, Baked Goods, Cakes, Cookies, Crackers, Chips, Pies—*continued*														
9117	Doughnut with jelly filling	1	item(s)	85	30.3	289	5.0	33.2	0.8	15.9	4.1	8.7	2.0	
4947	Doughnut, cake	1	item(s)	47	9.8	198	2.4	23.4	0.7	10.8	1.7	4.4	3.7	
9105	Doughnut, cake, chocolate glazed	1	item(s)	42	6.8	175	1.9	24.1	0.9	8.4	2.2	4.7	1.0	
437	Doughnut, glazed	1	item(s)	60	15.2	242	3.8	26.6	0.7	13.7	3.5	7.7	1.7	
10617	Toaster pastry, brown sugar cinnamon	1	item(s)	50	5.3	210	3.0	35.0	1.0	6.0	1.0	4.0	1.0	
30928	Toaster pastry, cream cheese	1	item(s)	54	—	200	3.0	23.0	0	11.0	4.5	—	—	1
	Muffins													
25015	Blueberry	1	item(s)	63	29.7	160	3.4	23.0	0.8	6.0	0.9	1.5	3.3	
9189	Corn, ready to eat	1	item(s)	57	18.6	174	3.4	29.0	1.9	4.8	0.8	1.2	1.8	
9121	English muffin, plain, enriched	1	item(s)	57	24.0	134	4.4	26.2	1.5	1.0	0.1	0.2	0.5	
29582	English muffin, toasted	1	item(s)	50	18.6	128	4.2	25.0	1.5	1.0	0.1	0.2	0.5	
9145	English muffin, wheat	1	item(s)	57	24.1	127	5.0	25.5	2.6	1.1	0.2	0.2	0.5	
8894	Oat bran	1	item(s)	57	20.0	154	4.0	27.5	2.6	4.2	0.6	1.0	2.4	
	Granola bars													
38161	Kudos milk chocolate granola bars w/fruit and nuts	1	item(s)	28	—	90	2.0	15.0	1.0	3.0	1.0	—	—	
38196	Nature Valley banana nut crunchy granola bars	2	item(s)	42	—	190	4.0	28.0	2.0	7.0	1.0	—	—	
38187	Nature Valley fruit 'n' nut trail mix bar	1	item(s)	35	—	140	3.0	25.0	2.0	4.0	0.5	—	—	
1383	Plain, hard	1	item(s)	25	1.0	115	2.5	15.8	1.3	4.9	0.6	1.1	3.0	
4606	Plain, soft	1	item(s)	28	1.8	126	2.1	19.1	1.3	4.9	2.1	1.1	1.5	
	Pies													
454	Apple pie, prepared from home recipe	1	slice(s)	155	73.3	411	3.7	57.5	2.3	19.4	4.7	8.4	5.2	
470	Pecan pie, prepared from home recipe	1	slice(s)	122	23.8	503	6.0	63.7	—	27.1	4.9	13.6	7.0	
33356	Pie crust mix, prepared, baked	1	slice(s)	20	2.1	100	1.3	10.1	0.4	6.1	1.5	3.5	0.8	
9007	Pie crust, ready to bake, frozen, enriched, baked	1	slice(s)	16	1.8	82	0.7	7.9	0.2	5.2	1.7	2.5	0.6	
472	Pumpkin pie, prepared from home recipe	1	slice(s)	155	90.7	316	7.0	40.9	—	14.4	4.9	5.7	2.8	
	Rolls													
8555	Crescent dinner roll	1	item(s)	28	9.7	78	2.7	13.8	0.6	1.2	0.3	0.3	0.6	
489	Hamburger roll or bun, plain	1	item(s)	43	14.9	120	4.1	21.3	0.9	1.9	0.5	0.5	0.8	
490	Hard roll	1	item(s)	57	17.7	167	5.6	30.0	1.3	2.5	0.3	0.6	1.0	
5127	Kaiser roll	1	item(s)	57	17.7	167	5.6	30.0	1.3	2.5	0.3	0.6	1.0	
5130	Whole wheat roll or bun	1	item(s)	28	9.4	75	2.5	14.5	2.1	1.3	0.2	0.3	0.6	
	Sport bars													
37026	Balance original chocolate bar	1	item(s)	50	—	200	14.0	22.0	0.5	6.0	3.5	—	—	
37024	Balance original peanut butter bar	1	item(s)	50	—	200	14.0	22.0	1.0	6.0	2.5	—	—	
36580	Clif Bar chocolate brownie energy bar	1	item(s)	68	—	240	10.0	45.0	5.0	4.5	1.5	—	—	0
36583	Clif Bar crunchy peanut butter energy bar	1	item(s)	68	—	250	12.0	40.0	5.0	6.0	1.5	—	—	0
36589	Clif Luna Nutz over Chocolate energy bar	1	item(s)	48	—	180	10.0	25.0	3.0	4.5	2.5	—	—	0
12005	PowerBar apple cinnamon	1	item(s)	65	—	230	9.0	45.0	3.0	2.5	0.5	1.5	0.5	0
16078	PowerBar banana	1	item(s)	65	—	230	9.0	45.0	3.0	2.5	0.5	1.0	0.5	0
16080	PowerBar chocolate	1	item(s)	65	6.4	230	10.0	45.0	3.0	2.0	0.5	0.5	1.0	0
29092	PowerBar peanut butter	1	item(s)	65	—	240	10.0	45.0	3.0	3.5	0.5	—	—	0
	Tortillas													
1391	Corn tortillas, soft	1	item(s)	26	11.9	57	1.5	11.6	1.6	0.7	0.1	0.2	0.4	
1669	Flour tortilla	1	item(s)	32	9.7	100	2.7	16.4	1.0	2.5	0.6	1.2	0.5	
	Pancakes, waffles													
8926	Pancakes, blueberry, prepared from recipe	3	item(s)	114	60.6	253	7.0	33.1	0.8	10.5	2.3	2.6	4.7	
5037	Pancakes, prepared from mix with egg and milk	3	item(s)	114	60.3	249	8.9	32.9	2.1	8.8	2.3	2.4	3.3	
1390	Taco shells, hard	1	item(s)	13	1.0	62	0.9	8.3	0.6	2.8	0.6	1.6	0.5	0.6
30311	Waffle, 100% whole grain	1	item(s)	75	32.3	200	6.9	25.0	1.9	8.4	2.3	3.3	2.1	
9219	Waffle, plain, frozen, toasted	2	item(s)	66	20.2	206	4.7	32.5	1.6	6.3	1.1	3.2	1.5	
500	Waffle, plain, prepared from recipe	1	item(s)	75	31.5	218	5.9	24.7	1.7	10.6	2.1	2.6	5.1	

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	[illegible] (µg)
2	21	1.49	17.0	67.2	249.1	0.63	14.5	0.26	0.36	0.12	1.81	0.08	57.8	0	0.2	10.6
7	21	0.91	9.4	59.7	256.6	0.25	17.9	0.10	0.90	0.11	0.87	0.02	24.4	0.1	0.1	4.4
4	89	0.95	14.3	44.5	142.8	0.23	5.0	0.01	0.08	0.02	0.19	0.01	18.9	0	0	1.7
4	26	0.36	13.2	64.8	205.2	0.46	2.4	0.53	—	0.04	0.39	0.03	13.2	0.1	0.1	5.0
0	0	1.80	—	70.0	190.0	—	—	0.15	—	0.17	2.00	0.20	40.0	0	0	—
0	100	1.80	—	—	220.0	—	—	0.15	—	0.17	2.00	—	40.0	0	0.6	—
0	56	1.02	7.8	70.2	289.4	0.28	—	0.17	0.75	0.15	1.25	0.02	34.0	0.4	0.1	8.8
5	42	1.60	18.2	39.3	297.0	0.30	29.6	0.15	0.45	0.18	1.16	0.04	45.6	0	0.1	8.7
0	30	1.42	12.0	74.7	264.5	0.39	0	0.25	—	0.16	2.21	0.02	42.2	0	0	—
0	95	1.36	11.0	71.5	252.0	0.38	0	0.19	0.16	0.14	1.90	0.02	43.5	0.1	0	13.5
0	101	1.63	21.1	106.0	217.7	0.61	0	0.24	0.25	0.16	1.91	0.05	36.5	0	0	16.6
0	36	2.39	89.5	289.0	224.0	1.04	0	0.14	0.37	0.05	0.23	0.09	50.7	0	0	6.3
0	200	0.36	—	—	60.0	—	0	—	—	—	—	—	—	0	0	—
0	20	1.08	—	120.0	160.0	—	0	—	—	—	—	—	—	0	—	—
0	0	0.00	—	—	95.0	—	0	—	—	—	—	—	—	0	—	—
0	15	0.72	23.8	82.3	72.0	0.50	0	0.06	—	0.03	0.39	0.02	5.6	0.2	0	4.0
0	30	0.72	21.0	92.3	79.0	0.42	0	0.08	—	0.04	0.14	0.02	6.8	0	0.1	4.6
0	11	1.73	10.9	122.5	327.1	0.29	17.1	0.22	—	0.16	1.90	0.05	37.2	2.6	0	12.1
06	39	1.80	31.7	162.3	319.6	1.24	100.0	0.22	—	0.22	1.03	0.07	31.7	0.2	0.2	14.6
0	12	0.43	3.0	12.4	145.8	0.07	0	0.06	—	0.03	0.47	0.01	14.0	0	0	4.4
0	3	0.36	2.9	17.6	103.5	0.05	0	0.04	0.42	0.06	0.39	0.01	8.8	0	0	0.5
65	146	1.96	29.5	288.3	348.8	0.71	660.3	0.14	—	0.31	1.21	0.07	32.6	2.6	0.1	11.0
0	39	0.93	5.9	26.3	134.1	0.18	0	0.11	0.02	0.09	1.16	0.02	31.1	0	0.1	5.5
0	59	1.42	9.0	40.4	206.0	0.28	0	0.17	0.03	0.13	1.78	0.03	47.7	0	0.1	8.4
0	54	1.87	15.4	61.6	310.1	0.53	0	0.27	0.23	0.19	2.41	0.02	54.2	0	0	22.3
0	54	1.86	15.4	61.6	310.1	0.53	0	0.27	0.23	0.19	2.41	0.01	54.2	0	0	22.3
0	30	0.69	24.1	77.1	135.5	0.57	0	0.07	0.26	0.04	1.04	0.06	8.5	0	0	14.0
3	100	4.50	40.0	160.0	180.0	3.75	—	0.37	—	0.42	5.00	0.50	100.0	60.0	1.5	17.5
3	100	4.50	40.0	130.0	230.0	3.75	—	0.37	—	0.42	5.00	0.50	100.0	60.0	1.5	17.5
0	250	4.50	100.0	370.0	150.0	3.00	—	0.37	—	0.25	3.00	0.40	80.0	60.0	0.9	14.0
0	250	4.50	100.0	230.0	250.0	3.00	—	0.37	—	0.25	3.00	0.40	80.0	60.0	0.9	14.0
0	350	5.40	80.0	190.0	190.0	5.25	—	1.20	—	1.36	16.00	2.00	400.0	60.0	6.0	24.5
0	300	6.30	140.0	125.0	100.0	5.25	—	1.50	—	1.70	20.00	2.00	400.0	60.0	6.0	—
0	300	6.30	140.0	190.0	100.0	5.25	0	1.50	—	1.70	20.00	2.00	400.0	60.0	6.0	—
0	300	6.30	140.0	200.0	95.0	5.25	0	1.50	—	1.70	20.00	2.00	400.0	60.0	6.0	5.1
0	300	6.30	140.0	130.0	120.0	5.25	0	1.50	—	1.70	20.00	2.00	400.0	60.0	6.0	—
0	21	0.32	18.7	48.4	11.7	0.34	0	0.02	0.07	0.02	0.39	0.06	1.3	0	0	1.6
0	41	1.06	7.0	49.6	203.5	0.17	0	0.17	0.06	0.08	1.14	0.01	33.3	0	0	7.1
64	235	1.96	18.2	157.3	469.7	0.61	57.0	0.22	—	0.31	1.73	0.05	41.0	2.5	0.2	16.0
81	245	1.48	25.1	226.9	575.7	0.85	82.1	0.22	—	0.35	1.40	0.12	104.6	0.7	0.4	—
0	13	0.25	11.3	29.7	51.7	0.21	0.1	0.03	0.09	0.01	0.25	0.03	9.2	0	0	0.6
71	194	1.60	28.5	171.0	371.3	0.87	48.8	0.15	0.32	0.25	1.47	0.08	28.5	0	0.4	20.0
10	203	4.56	15.8	95.0	481.8	0.35	262.7	0.34	0.64	0.46	5.86	0.68	49.5	0	1.9	8.3
52	191	1.73	14.3	119.3	383.3	0.51	48.8	0.19	—	0.26	1.55	0.04	34.5	0.3	0.2	34.7

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DAI Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Trans
Cereal, Flour, Grain, Pasta, Noodles, Popcorn														
	Grain													
2861	Amaranth, dry	½	cup(s)	98	9.6	365	14.1	64.5	9.1	6.3	1.6	1.4	2.8	—
1953	Barley, pearled, cooked	½	cup(s)	79	54.0	97	1.8	22.2	3.0	0.3	0.1	0	0.2	—
1956	Buckwheat groats, cooked, roasted	½	cup(s)	84	63.5	77	2.8	16.8	2.3	0.5	0.1	0.2	0.2	—
1957	Bulgur, cooked	½	cup(s)	91	70.8	76	2.8	16.9	4.1	0.2	0	0	0.1	—
1963	Couscous, cooked	½	cup(s)	79	57.0	88	3.0	18.2	1.1	0.1	0	0	0.1	—
1967	Millet, cooked	½	cup(s)	120	85.7	143	4.2	28.4	1.6	1.2	0.2	0.2	0.6	—
1969	Oat bran, dry	½	cup(s)	47	3.1	116	8.1	31.1	7.2	3.3	0.6	1.1	1.3	—
1972	Quinoa, dry	½	cup(s)	85	11.3	313	12.0	54.5	5.9	5.2	0.6	1.4	2.8	—
	Rice													
129	Brown, long grain, cooked	½	cup(s)	98	71.3	108	2.5	22.4	1.8	0.9	0.2	0.3	0.3	—
2863	Brown, medium grain, cooked	½	cup(s)	98	71.1	109	2.3	22.9	1.8	0.8	0.2	0.3	0.3	—
37488	Jasmine, saffroned, cooked	½	cup(s)	280	—	340	8.0	78.0	0	0	0	0	0	0
30280	Pilaf, cooked	½	cup(s)	103	74.0	129	2.1	22.2	0.6	3.3	0.6	1.5	1.0	—
28066	Spanish, cooked	½	cup(s)	244	184.2	241	5.7	50.2	3.3	1.9	0.4	0.6	0.7	0
2867	White glutinous, cooked	½	cup(s)	87	66.7	84	1.8	18.3	0.9	0.2	0	0.1	0.1	—
484	White, long grain, boiled	½	cup(s)	79	54.1	103	2.1	22.3	0.3	0.2	0.1	0.1	0.1	—
482	White, long grain, enriched, instant, boiled	½	cup(s)	83	59.4	97	1.8	20.7	0.5	0.4	0	0.1	0	—
486	White, long grain, enriched, parboiled, cooked	½	cup(s)	79	55.6	97	2.3	20.6	0.7	0.3	0.1	0.1	0.1	—
1194	Wild brown, cooked	½	cup(s)	82	60.6	83	3.3	17.5	1.5	0.3	0	0	0.2	—
	Flour and grain fractions													
505	All purpose flour, self-rising, enriched	½	cup(s)	63	6.6	221	6.2	46.4	1.7	0.6	0.1	0	0.2	—
503	All purpose flour, white, bleached, enriched	½	cup(s)	63	7.4	228	6.4	47.7	1.7	0.6	0.1	0	0.2	—
1643	Barley flour	½	cup(s)	56	5.5	198	4.2	44.7	2.1	0.8	0.2	0.1	0.4	—
383	Buckwheat flour, whole groat	½	cup(s)	60	6.7	201	7.6	42.3	6.0	1.9	0.4	0.6	0.6	—
504	Cake wheat flour, enriched	½	cup(s)	69	8.6	248	5.6	53.5	1.2	0.6	0.1	0.1	0.3	—
426	Cornmeal, degermed, enriched	½	cup(s)	69	7.8	255	5.0	54.6	2.8	1.2	0.1	0.2	0.5	0
424	Cornmeal, yellow whole grain	½	cup(s)	61	6.2	221	4.9	46.9	4.4	2.2	0.3	0.6	1.0	—
1978	Dark rye flour	½	cup(s)	64	7.1	207	9.0	44.0	14.5	1.7	0.2	0.2	0.8	—
1644	Masa corn flour, enriched	½	cup(s)	57	5.1	208	5.3	43.5	5.5	2.1	0.3	0.6	1.0	—
1976	Rice flour, brown	½	cup(s)	79	9.4	287	5.7	60.4	3.6	2.2	0.4	0.8	0.8	—
1645	Rice flour, white	½	cup(s)	79	9.4	289	4.7	63.3	1.9	1.1	0.3	0.3	0.3	—
1980	Semolina, enriched	½	cup(s)	84	10.6	301	10.6	60.8	3.2	0.9	0.1	0.1	0.4	—
2827	Soy flour, raw	½	cup(s)	42	2.2	185	14.7	14.9	4.1	8.8	1.3	1.9	4.9	—
1990	Wheat germ, crude	2	tablespoon(s)	14	1.6	52	3.3	7.4	1.9	1.4	0.2	0.2	0.9	—
506	Whole wheat flour	½	cup(s)	60	6.2	203	8.2	43.5	7.3	1.1	0.2	0.1	0.5	—
	Breakfast bars													
39230	Atkins Morning Start apple crisp breakfast bar	1	item(s)	37	—	170	11.0	12.0	6.0	9.0	4.0	—	—	—
10571	Nutri-Grain apple cinnamon cereal bar	1	item(s)	37	—	140	2.0	27.0	1.0	3.0	0.5	2.0	0.5	—
10647	Nutri-Grain blueberry cereal bar	1	item(s)	37	5.4	140	2.0	27.0	1.0	3.0	0.5	2.0	0.5	—
10648	Nutri-Grain raspberry cereal bar	1	item(s)	37	5.4	140	2.0	27.0	1.0	3.0	0.5	2.0	0.5	—
10649	Nutri-Grain strawberry cereal bar	1	item(s)	37	5.4	140	2.0	27.0	1.0	3.0	0.5	2.0	0.5	—
	Breakfast cereals, hot													
1260	Cream of Wheat, instant, prepared	½	cup(s)	121	—	388	12.9	73.3	4.3	0	0	0	0	0
365	Farina, enriched, cooked w/water and salt	½	cup(s)	117	102.4	56	1.7	12.2	0.3	0.1	0	0	0	—
363	Grits, white corn, regular and quick, enriched, cooked w/water and salt	½	cup(s)	121	103.3	71	1.7	15.6	0.4	0.2	0	0.1	0.1	—
8636	Grits, yellow corn, regular and quick, enriched, cooked w/salt	½	cup(s)	121	103.3	71	1.7	15.6	0.4	0.2	0	0.1	0.1	—
8657	Oatmeal, cooked w/water	½	cup(s)	117	97.8	83	3.0	14.0	2.0	1.8	0.4	0.5	0.7	0
5500	Oatmeal, maple and brown sugar, instant, prepared	1	item(s)	198	150.2	200	4.8	40.4	2.4	2.2	0.4	0.7	0.8	—
5510	Oatmeal, ready to serve, packet, prepared	1	item(s)	186	158.7	112	4.1	19.8	2.7	2.0	0.4	0.7	0.8	—
	Breakfast cereals, ready to eat													
1197	All-Bran	1	cup(s)	62	1.3	160	8.1	46.0	18.2	2.0	0.4	0.4	1.3	0
1200	All-Bran Buds	1	cup(s)	91	2.7	212	6.4	72.7	39.1	1.9	0.4	0.5	1.2	0

ol (g)	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	VitA (µg)	VitC (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	VitB$_6$ (mg)	Fola (µg)	VitD (µg)	VitB$_{12}$ (µg)	Sele (µg)
0	149	7.40	259.3	356.8	20.5	3.10	0	0.06	—	0.20	1.24	0.20	47.8	4.1	0	—
0	9	1.04	17.3	73.0	2.4	0.64	0	0.06	0.01	0.04	1.61	0.09	12.6	0	0	6.8
0	6	0.67	42.8	73.9	3.4	0.51	0	0.03	0.07	0.03	0.79	0.06	11.8	0	0	1.8
0	9	0.87	29.1	61.9	4.6	0.51	0	0.05	0.01	0.02	0.91	0.07	16.4	0	0	0.5
0	6	0.30	6.3	45.5	3.9	0.20	0	0.05	0.10	0.02	0.77	0.04	11.8	0	0	21.6
0	4	0.75	52.8	74.4	2.4	1.09	0	0.12	0.02	0.09	1.59	0.13	22.8	0	0	1.1
0	27	2.54	110.5	266.0	1.9	1.46	0	0.55	0.47	0.10	0.43	0.07	24.4	0	0	21.2
0	40	3.88	167.4	478.5	4.2	2.62	0.8	0.30	2.06	0.26	1.28	0.40	156.4	0	0	7.2
0	10	0.41	41.9	41.9	4.9	0.61	0	0.09	0.02	0.02	1.49	0.14	3.9	0	0	9.6
0	10	0.51	42.9	77.0	1.0	0.60	0	0.09	—	0.01	1.29	0.14	3.9	0	0	38.0
0	—	2.16	—	—	780 0	—	—	—	—	—	—	—	—	—	—	—
0	11	1.16	9.3	54.6	390.4	0.37	33.0	0.13	0.28	0.02	1.23	0.06	44.3	0.4	0	4.3
0	37	1.52	95.4	330.5	97.1	1 40	—	0 27	0 12	0.05	3.24	0.38	19.0	22.6	0	14.3
0	2	0.12	4.4	8.7	4.4	0.35	0	0 01	0.03	0.01	0.25	0.02	0.9	0	0	4.9
0	8	0.94	9.5	27.7	0.8	0.38	0	0 12	0.03	0.01	1.16	0.07	45 8	0	0	5.9
0	7	1.46	4.1	7.4	3.3	0.40	0	0.06	0.01	0.01	1.43	0.04	57 8	0	0	4.0
0	15	1.43	7.1	44.2	1.6	0.29	0	0.16	0.01	0.01	1.82	0.12	64.0	0	0	7.3
0	2	0.49	26.2	82.8	2.5	1.09	0	0.04	0.19	0.07	1.05	0.11	21 3	0	0	0.7
0	211	2.90	11.9	77.5	793.7	0.38	0	0.42	0.02	0.24	3.64	0.02	122.5	0	0	21.5
0	9	2.90	13.7	66.9	1.2	0.42	0	0.48	0.02	0.30	3.68	0.02	114.4	0	0	21.2
0	16	0 70	45.4	185.9	4.5	1.04	0	0 06	—	0.02	2 56	0.14	12 9	0	0	2.0
0	25	2.42	150.6	346.2	6.6	1.86	0	0.24	0 18	0.10	3.68	0.34	32 4	0	0	3 4
0	10	5.01	11.0	71.9	1.4	0.42	0	0.61	0.01	0.29	4.65	0 02	127 4	0	0	3.4
0	2	2.98	24.1	104.9	4.8	0.48	7.6	0.42	0.10	0.28	3.66	0.12	148.3	0	0	8.0
0	4	2.10	77.5	175.1	21.3	1.10	6.7	0.22	0.24	0.12	2.20	0 18	15.2	0	0	9.4
0	36	4.12	158.7	467.2	0.6	3.58	0.6	0 20	0 90	0.16	2.72	0.28	38 4	0	0	22.8
0	80	4.10	62.7	169.9	2.8	1.00	0	0 80	0.08	0.42	5.60	0.20	132.8	0	0	8.5
0	9	1 56	88.5	228.3	6.3	1.92	0	0 34	0.94	0.06	5.00	0.58	12.6	0	0	—
0	8	0.26	27.6	60.0	0	0.62	0	0.10	0 08	0.02	2.04	0.34	3.2	0	0	11.9
0	14	3.64	39.2	155.3	0.8	0.86	0	0.66	0 20	0.46	5.00	0.08	152.8	0	0	74.6
0	87	2.70	182.0	1067.0	5.5	1.65	2.5	0.24	0.82	0.48	1.83	0.18	146.4	0	0	3.2
0	6	0.90	34.4	128.2	1.7	1.76	0	0 27	—	0.07	0.97	0.18	40.4	0	0	11.4
0	20	2.32	82.8	243.0	3.0	1.74	0	0.26	0.48	0.12	3 82	0.20	26.4	0	0	42.4
0	200	—	—	90.0	70.0	—	—	0.22	—	0.25	3.00	—	—	9.0	—	—
0	200	1.80	8.0	75.0	110.0	1.50	—	0.37	—	0.42	5.00	0.50	40.0	0	—	—
0	200	1.80	8.0	75.0	110.0	1.50	—	0 37	—	0.42	5.00	0.50	40.0	0	0	—
0	200	1.80	8.0	70.0	110.0	1.50	—	0 37	—	0.42	5.00	0 50	40.0	0	0	—
0	200	1.80	8.0	55.0	110.0	1.50	—	0.37	—	0.42	5.00	0.50	40.0	0	0	—
0	862	34.91	21.4	150.8	732.6	0.86	—	1.59	—	1.47	21.55	2.15	431.0	0	0	—
0	5	0.58	2.3	15.1	383.3	0.09	0	0.07	0.01	0.05	0.57	0.01	39.6	0	0	10.6
0	4	0.73	6.1	25.4	269.8	0.08	0	0.10	0.02	0.07	0.87	0.03	39.9	0	0	3.8
0	4	0.73	6.1	25.4	269.8	0.08	2.4	0.10	0.02	0.07	0.87	0.03	39.9	0	0	3.3
0	11	1.05	31.6	81.9	4.7	1.17	0	0.09	0.09	0.02	0.26	0.01	7.0	0	0	6.3
0	26	6.83	49.9	126.4	403.5	1.03	0	1.02	—	0.05	1.56	0.30	42.2	0	0	11.1
0	21	3.96	44.7	112.4	240.9	0.92	0	0.60	—	0.04	0.77	0.18	18.7	0	0	3.8
0	241	10.90	224.4	632.4	150.0	3.00	300.1	1.40	—	1.68	9.16	7.44	800.0	12.4	12.0	5.8
0	57	13.64	186.4	909.1	614.5	4.55	464.5	1.09	1.42	1.27	15.45	6.09	1222.7	18.2	18.2	26.3

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA† Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Trans
Cereal, Flour, Grain, Pasta, Noodles, Popcorn—*continued*														
1199	Apple Jacks	1	cup(s)	33	0.9	130	1.0	30.0	0.5	0.5	0	—	—	0
1204	Cap'n Crunch	1	cup(s)	36	0.9	147	1.3	30.7	1.3	2.0	0.5	0.4	0.3	—
1205	Cap'n Crunch Crunchberries	1	cup(s)	35	0.9	133	1.3	29.3	1.3	2.0	0.5	0.4	0.3	—
1206	Cheerios	1	cup(s)	30	1.0	110	3.0	22.0	3.0	2.0	0	0.5	0.5	—
3415	Cocoa Puffs	1	cup(s)	30	0.6	120	1.0	26.0	0.2	1.0	—	—	—	—
1207	Cocoa Rice Krispies	1	cup(s)	41	1.0	160	1.3	36.0	1.3	1.3	0.7	0	0	—
5522	Complete wheat bran flakes	1	cup(s)	39	1.4	120	4.0	30.7	6.7	0.7	—	—	—	0
1211	Corn Flakes	1	cup(s)	28	0.9	100	2.0	24.0	1.0	0	0	0	0	0
1247	Corn Pops	1	cup(s)	31	0.9	120	1.0	28.0	0.3	0	0	0	0	0
1937	Cracklin' Oat Bran	1	cup(s)	65	2.3	267	5.3	46.7	8.0	9.3	4.0	4.7	1.3	0
1220	Froot Loops	1	cup(s)	32	0.8	120	1.0	28.0	1.0	1.0	0.5	0	0	—
38214	Frosted Cheerios	1	cup(s)	37	—	149	2.5	31.1	1.2	1.2	—	—	—	—
372	Frosted Flakes	1	cup(s)	41	1.1	160	1.3	37.3	1.3	0	0	0	0	0
38215	Frosted Mini Chex	1	cup(s)	40	—	147	1.3	36.0	0	0	0	0	0	0
10268	Frosted Mini-Wheats	1	cup(s)	59	3.1	208	5.8	47.4	5.8	1.2	0	0	0.6	0
38216	Frosted Wheaties	1	cup(s)	40	—	147	1.3	36.0	0.3	0	0	0	0	0
1223	Granola, prepared	½	cup(s)	61	3.3	298	9.1	32.5	5.5	14.7	2.5	5.8	5.6	0
2415	Honey Bunches of Oats honey roasted	1	cup(s)	40	0.9	160	2.7	33.3	1.3	2.0	0.7	1.2	0.1	—
1227	Honey Nut Cheerios	1	cup(s)	37	0.9	149	3.7	29.9	2.5	1.9	0	0.6	0.6	—
2424	Honeycomb	1	cup(s)	22	0.3	83	1.5	19.5	0.8	0.4	0	—	—	—
10286	Kashi whole grain puffs	1	cup(s)	19	—	70	2.0	15.0	1.0	0.5	0	—	—	0
41142	Kellogg's Mueslix	1	cup(s)	83	7.2	298	7.6	60.8	6.1	4.6	0.7	2.4	1.5	0
1231	Kix	1	cup(s)	24	0.5	96	1.6	20.8	0.8	0.4	—	—	—	—
30569	Life	1	cup(s)	43	1.7	160	4.0	33.3	2.7	2.0	0.3	0.6	0.6	—
1233	Lucky Charms	1	cup(s)	24	0.6	96	1.6	20.0	0.8	0.8	—	—	—	—
38220	Multi Grain Cheerios	1	cup(s)	30	—	110	3.0	24.0	3.0	1.0	—	—	—	—
1201	Multi-Bran Chex	1	cup(s)	63	1.3	216	4.3	52.9	8.6	1.6	0	0	0.5	0
13633	Post Bran Flakes	1	cup(s)	40	1.5	133	4.0	32.0	6.7	0.7	0	—	—	—
1241	Product 19	1	cup(s)	30	1.0	100	2.0	25.0	1.0	0	0	0	0	0
32432	Puffed rice, fortified	1	cup(s)	14	0.4	56	0.9	12.6	0.2	0.1	0	—	—	—
32433	Puffed wheat, fortified	1	cup(s)	12	0.4	44	1.8	9.6	0.5	0.1	0	—	—	—
13334	Quaker 100% natural granola oats and honey	½	cup(s)	48	—	220	5.0	31.0	3.0	9.0	3.8	4.1	1.2	—
13335	Quaker 100% natural granola oats, honey, and raisins	½	cup(s)	51	—	230	5.0	34.0	3.0	9.0	3.6	3.8	1.1	—
2420	Raisin Bran	1	cup(s)	59	5.0	190	4.0	46.0	8.0	1.0	0	0.1	0.4	—
1244	Rice Chex	1	cup(s)	31	0.8	120	2.0	27.0	0.3	0	0	0	0	0
1245	Rice Krispies	1	cup(s)	26	0.8	96	1.6	23.2	0	0	0	0	0	0
5593	Shredded Wheat	1	cup(s)	49	0.4	177	5.8	40.9	6.9	1.1	0.1	0	0.2	0
1248	Smacks	1	cup(s)	36	1.1	133	2.7	32.0	1.3	0.7	—	—	—	—
1246	Special K	1	cup(s)	31	0.9	110	7.0	22.0	0.5	0	0	0	0	0
3428	Total corn flakes	1	cup(s)	23	0.6	83	1.5	18.0	0.6	0	0	0	0	0
1253	Total whole grain	1	cup(s)	40	1.1	147	2.7	30.7	4.0	1.3	—	—	—	—
1254	Trix	1	cup(s)	30	0.6	120	1.0	27.0	1.0	1.0	—	—	—	—
382	Wheat germ, toasted	2	tablespoon(s)	14	0.8	54	4.1	7.0	2.1	1.5	0.3	0.2	0.9	—
1257	Wheaties	1	cup(s)	36	1.2	132	3.6	28.8	3.6	1.2	—	—	—	—
	Pasta, noodles													
449	Chinese chow mein noodles, cooked	½	cup(s)	23	0.2	119	1.9	12.9	0.9	6.9	1.0	1.7	3.9	—
1995	Corn pasta, cooked	½	cup(s)	70	47.8	88	1.8	19.5	3.4	0.5	0.1	0.1	0.2	—
448	Egg noodles, enriched, cooked	½	cup(s)	80	54.2	110	3.6	20.1	1.0	1.7	0.3	0.5	0.4	0
1563	Egg noodles, spinach, enriched, cooked	½	cup(s)	80	54.8	106	4.0	19.4	1.8	1.3	0.3	0.4	0.3	—
440	Macaroni, enriched, cooked	½	cup(s)	70	43.5	111	4.1	21.6	1.3	0.7	0.1	0.1	0.2	0
2000	Macaroni, tricolor vegetable, enriched, cooked	½	cup(s)	67	45.8	86	3.0	17.8	2.9	0.1	0	0	0	—
1996	Plain pasta, fresh-refrigerated, cooked	½	cup(s)	64	43.9	84	3.3	16.0	—	0.7	0.1	0.1	0.3	—
1725	Ramen noodles, cooked	½	cup(s)	114	94.5	104	3.0	15.4	1.0	4.3	0.2	0.2	0.2	—
2878	Soba noodles, cooked	½	cup(s)	95	69.4	94	4.8	20.4	—	0.1	0	0	0	—
2879	Somen noodles, cooked	½	cup(s)	88	59.8	115	3.5	24.2	—	0.2	0	0	0.1	—
493	Spaghetti, al dente, cooked	½	cup(s)	65	41.6	95	3.5	19.5	1.0	0.5	0.1	0.1	0.2	—
2884	Spaghetti, whole wheat, cooked	½	cup(s)	70	47.0	87	3.7	18.6	3.2	0.4	0.1	0.1	0.1	—
	Popcorn													
476	Air popped	1	cup(s)	8	0.3	31	1.0	6.2	1.2	0.4	0	0.1	0.2	—
4619	Caramel	1	cup(s)	35	1.0	152	1.3	27.8	1.8	4.5	1.3	1.0	1.6	—

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	0	4.50	8.0	30.0	130.0	1.50	150.2	0.37	—	0.42	5.00	0.50	100.0	15.0	1.5	2.4
	5	6.80	20.0	73.3	266.7	5.00	2.5	0.51	—	0.57	6.68	0.67	133.5	0	0	6.7
	7	6.53	18.7	73.3	240.0	5.13	2.4	0.51	—	0.57	6.68	0.67	133.7	0	0	6.7
	100	8.10	40.0	95.0	280.0	3.75	150.3	0.37	—	0.42	5.00	0.50	200.0	6.0	1.5	11.3
	100	4.50	8.0	50.0	170.0	3.75	0	0.37	—	0.42	5.00	0.50	100.0	6.0	1.5	2.0
	53	6.00	10.7	66.7	253.3	2.00	200.1	0.49	—	0.56	6.67	0.67	133.3	20.0	2.0	5.8
	0	24.00	53.3	226.7	280.0	20.00	300.1	2.00	—	2.27	26.67	2.67	533.3	80.0	8.0	4.1
	0	8.10	3.4	25.0	200.0	0.16	149.8	0.37	—	0.42	5.00	0.50	100.0	6.0	1.5	1.4
	0	1.80	2.5	25.0	120.0	1.50	150.0	0.37	—	0.42	5.00	0.50	100.0	6.0	1.5	2.0
	27	2.40	80.0	293.3	200.0	2.00	299.9	0.49	—	0.56	6.67	0.67	133.3	20.0	2.0	14.4
	0	4.50	8.0	35.0	150.0	1.50	150.1	0.37	—	0.42	5.00	0.50	100.0	15.0	1.5	2.3
	124	5.60	19.9	68.4	261.3	4.67	—	0.46	—	0.52	6.22	0.62	124.4	7.5	1.9	—
	0	6.00	3.7	26.7	200.0	0.20	200.1	0.49	—	0.56	6.67	0.67	133.3	8.0	2.0	1.8
	133	12.00	—	33.3	266.7	4.00	—	0.49	—	0.56	6.67	0.67	266.7	8.0	2.0	—
	0	16.66	69.4	196.7	5.8	1.74	0	0.43	—	0.49	5.78	0.58	115.7	0	1.7	2.4
	133	10.80	0	46.7	266.7	10.00	—	1.00	—	1.13	13.33	1.33	533.3	8.0	4.0	—
	48	2.58	106.8	329.4	15.3	2.45	0.6	0.44	6.77	0.17	1.30	0.17	50.0	0.7	0	17.0
	0	10.80	21.3	0	253.3	0.40	—	0.49	—	0.56	6.67	0.67	133.0	0	2.0	—
	124	5.60	39.8	112.0	336.0	4.67	—	0.46	—	0.52	6.22	0.62	248.9	7.5	1.9	8.8
	0	2.03	6.0	26.3	165.4	1.13	—	0.28	—	0.32	3.74	0.37	75.0	0	1.1	—
	0	0.36	—	60.0	0	—	0	0.03	—	0.03	0.80	0.00	—	0	—	—
	48	6.83	74.2	363.3	257.5	5.67	136.7	0.67	6.00	0.67	8.33	3.08	615.0	0.3	9.2	14.4
	120	6.48	6.4	28.0	216.0	3.00	120.2	0.30	—	0.34	4.00	0.40	160.0	4.8	1.2	4.8
	149	11.87	41.3	120.0	213.3	5.33	0.9	0.53	—	0.60	7.12	0.71	142.4	0	0	10.7
	80	3.60	12.8	48.0	168.0	3.00	—	0.30	—	0.34	4.00	0.40	160.0	4.8	1.2	4.8
	100	18.00	24.0	85.0	200.0	15.00	—	1.50	—	1.70	20.00	2.00	400.0	15.0	6.0	—
	108	17.50	64.8	237.7	410.6	4.05	171.1	0.40	—	0.45	5.40	0.54	432.2	6.5	1.6	4.9
	0	10.80	80.0	266.7	280.0	2.00	—	0.49	—	0.56	6.67	0.67	133.3	0	2.0	—
	0	18.00	16.0	50.0	210.0	15.00	225.3	1.50	—	1.70	20.00	2.00	400.0	60.0	6.0	3.6
	1	4.43	3.5	15.8	0.4	0.14	0	0.36	—	0.25	4.94	0.01	2.7	0	0	1.5
	3	3.80	17.4	41.8	0.5	0.28	0	0.31	—	0.21	4.23	0.02	3.8	0	0	14.8
	61	1.20	51.0	220.0	20.0	1.05	0.5	0.13	—	0.12	0.82	0.07	15.0	0.2	0.1	8.3
	59	1.20	49.0	250.0	20.0	0.99	0.5	0.13	—	0.12	0.80	0.08	14.1	0.4	0.1	8.8
	20	10.80	80.0	360.0	360.0	2.25	—	0.37	—	0.42	5.00	0.50	100.0	0	2.1	—
	100	9.00	9.3	35.0	290.0	3.75	—	0.37	—	0.42	5.00	0.50	200.0	6.0	1.5	1.2
	0	1.44	12.8	32.0	256.0	0.48	120.1	0.30	—	0.34	4.80	0.40	80.0	4.8	1.2	4.1
	18	2.90	60.3	179.3	1.1	1.37	0	0.14	—	0.12	3.47	0.18	21.1	0	0	2.0
	0	0.48	10.7	53.3	66.7	0.40	200.2	0.49	—	0.56	6.67	0.67	133.3	8.0	2.0	17.5
	0	8.10	16.0	60.0	220.0	0.90	225.1	0.52	—	0.59	7.00	2.00	400.0	21.0	6.0	7.0
	752	13.53	0	22.6	157.9	11.28	112.8	1.13	22.56	1.28	15.04	1.50	300.8	45.1	4.5	1.2
	1333	24.00	32.0	120.0	253.3	20.00	200.4	2.00	31.32	2.27	26.67	2.67	533.3	80.0	8.0	1.9
	100	4.50	0	15.0	190.0	3.75	150.3	0.37	—	0.42	5.00	0.50	100.0	6.0	1.5	6.0
	6	1.28	45.2	133.8	0.6	2.35	0.7	0.23	2.25	0.11	0.79	0.13	49.7	0.8	0	9.2
	24	9.72	38.4	126.0	264.0	9.00	180.4	0.90	—	1.02	12.00	1.20	240.0	7.2	3.6	1.7
	5	1.06	11.7	27.0	98.8	0.31	0	0.13	0.78	0.09	1.33	0.02	20.3	0	0	9.7
	1	0.18	25.2	21.7	0	0.44	2.1	0.04	—	0.02	0.39	0.04	4.2	0	0	2.0
3	10	1.17	16.8	30.4	4.0	0.52	4.8	0.23	0.13	0.11	1.66	0.03	67.2	0	0.1	19.1
6	15	0.87	19.2	29.6	9.6	0.50	8.0	0.19	0.46	0.09	1.17	0.09	51.2	0	0.1	17.4
	5	0.90	12.6	30.8	0.7	0.36	0	0.19	0.04	0.10	1.18	0.03	51.1	0	0	18.5
	7	0.33	12.7	20.8	4.0	0.30	3.4	0.08	0.14	0.04	0.72	0.02	43.6	0	0	13.3
1	4	0.73	11.5	15.4	3.8	0.36	3.8	0.13	—	0.10	0.64	0.02	41.0	0	0.1	—
8	9	0.89	8.5	34.5	414.5	0.30	—	0.08	—	0.04	0.71	0.03	4.0	0.1	0	—
	4	0.45	8.5	33.2	57.0	0.11	0	0.09	—	0.02	0.48	0.03	6.6	0	0	—
	7	0.45	1.8	25.5	141.7	0.19	0	0.01	—	0.03	0.08	0.01	1.8	0	0	—
	7	1.00	12.4	51.5	0.5	0.35	0	0.12	0.04	0.07	0.90	0.04	7.8	0	0	40.0
	11	0.74	21.0	30.8	2.1	0.57	0	0.08	0.21	0.03	0.50	0.06	3.5	0	0	18.1
	1	0.25	11.5	26.3	0.6	0.25	0.8	0.01	0.02	0.01	0.18	0.01	2.5	0	0	0
2	15	0.61	12.3	38.4	72.5	0.20	0.7	0.02	0.42	0.02	0.77	0.01	1.8	0	0	1.3

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

BAN Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g) Sat	Mono	Poly
Cereal, Flour, Grain, Pasta, Noodles, Popcorn—*continued*													
4620	Cheese flavored	1	cup(s)	36	0.9	188	3.3	18.4	3.5	11.8	2.3	3.5	5.5
477	Popped in oil	1	cup(s)	11	0.1	64	0.8	5.0	0.9	4.8	0.8	1.1	2.6
Fruit and Fruit Juices													
	Apples												
952	Juice, prepared from frozen concentrate	½	cup(s)	120	105.0	56	0.2	13.8	0.1	0.1	0	0	0
225	Juice, unsweetened, canned	½	cup(s)	124	109.0	58	0.1	14.5	0.1	0.1	0	0	0
224	Slices	½	cup(s)	55	47.1	29	0.1	7.6	1.3	0.1	0	0	0
946	Slices without skin, boiled	½	cup(s)	86	73.1	45	0.2	11.7	2.1	0.3	0	0	0.1
223	Raw medium, with peel	1	item(s)	138	118.1	72	0.4	19.1	3.3	0.2	0	0	0.1
948	Dried, sulfured	¼	cup(s)	22	6.8	52	0.2	14.2	1.9	0.1	0	0	0
226	Applesauce, sweetened, canned	½	cup(s)	128	101.5	97	0.2	25.4	1.5	0.2	0	0	0.1
227	Applesauce, unsweetened, canned	½	cup(s)	122	107.8	52	0.2	13.8	1.5	0.1	0	0	0
38492	Crabapples	1	item(s)	35	27.6	27	0.1	7.0	0.9	0.1	0	0	0
	Apricot												
228	Fresh without pits	4	item(s)	140	120.9	67	2.0	15.6	2.8	0.5	0	0.2	0.1
229	Halves with skin, canned in heavy syrup	½	cup(s)	129	100.1	107	0.7	27.7	2.1	0.1	0	0	0
230	Halves, dried, sulfured	¼	cup(s)	33	10.1	79	1.1	20.6	2.4	0.2	0	0	0
	Avocado												
233	California, whole, without skin or pit	½	cup(s)	115	83.2	192	2.2	9.9	7.8	17.7	2.4	11.3	2.1
234	Florida, whole, without skin or pit	½	cup(s)	115	90.6	138	2.5	9.0	6.4	11.5	2.2	6.3	1.9
2998	Pureed	⅛	cup(s)	28	20.2	44	0.5	2.4	1.8	4.0	0.6	2.7	0.5
	Banana												
4580	Dried chips	¼	cup(s)	55	2.4	285	1.3	32.1	4.2	18.5	15.9	1.1	0.3
235	Fresh whole, without peel	1	item(s)	118	88.4	105	1.3	27.0	3.1	0.4	0.1	0	0.1
	Blackberries												
237	Raw	½	cup(s)	72	63.5	31	1.0	6.9	3.8	0.4	0	0	0.2
958	Unsweetened, frozen	½	cup(s)	76	62.1	48	0.9	11.8	3.8	0.3	0	0	0.2
	Blueberries												
959	Canned in heavy syrup	½	cup(s)	128	98.3	113	0.8	28.2	2.0	0.4	0	0.1	0.2
238	Raw	½	cup(s)	73	61.1	41	0.5	10.5	1.7	0.2	0	0	0.1
960	Unsweetened, frozen	½	cup(s)	78	67.1	40	0.3	9.4	2.1	0.5	0	0.1	0.2
	Boysenberries												
961	Canned in heavy syrup	½	cup(s)	128	97.6	113	1.3	28.6	3.3	0.2	0	0	0.1
962	Unsweetened, frozen	½	cup(s)	66	56.7	33	0.7	8.0	3.5	0.2	0	0	0.1
35576	**Breadfruit**	1	item(s)	384	271.3	396	4.1	104.1	18.8	0.9	0.2	0.1	0.3
	Cherries												
967	Sour red, canned in water	½	cup(s)	122	109.7	44	0.9	10.9	1.3	0.1	0	0	0
3000	Sour red, raw	½	cup(s)	78	66.8	39	0.8	9.4	1.2	0.2	0.1	0.1	0.1
3004	Sweet, canned in heavy syrup	½	cup(s)	127	98.2	105	0.8	26.9	1.9	0.2	0	0.1	0.1
969	Sweet, canned in water	½	cup(s)	124	107.9	57	1.0	14.6	1.9	0.2	0	0	0
240	Sweet, raw	½	cup(s)	73	59.6	46	0.8	11.6	1.5	0.1	0	0	0
	Cranberries												
3007	Chopped, raw	½	cup(s)	55	47.9	25	0.2	6.7	2.5	0.1	0	0	0
1717	Cranberry apple juice drink	½	cup(s)	123	102.6	77	0	19.4	0	0.1	0	0	0.1
1638	Cranberry juice cocktail	½	cup(s)	127	109.0	68	0	17.1	0	0.1	0	0	0.1
241	Cranberry juice cocktail, low calorie, with saccharin	½	cup(s)	119	112.8	23	0	5.5	0	0	0	0	0
242	Cranberry sauce, sweetened, canned	¼	cup(s)	69	42.0	105	0.1	26.9	0.7	0.1	0	0	0
	Dates												
244	Domestic, chopped	¼	cup(s)	45	9.1	125	1.1	33.4	3.6	0.2	0	0	0
243	Domestic, whole	¼	cup(s)	45	9.1	125	1.1	33.4	3.6	0.2	0	0	0
	Figs												
975	Canned in heavy syrup	½	cup(s)	130	98.8	114	0.5	29.7	2.8	0.1	0	0	0.1
974	Canned in water	½	cup(s)	124	105.7	66	0.5	17.3	2.7	0.1	0	0	0.1
973	Raw, medium	2	item(s)	100	79.1	74	0.7	19.2	2.9	0.3	0.1	0.1	0.1
	Fruit cocktail and salad												
245	Fruit cocktail, canned in heavy syrup	½	cup(s)	124	99.7	91	0.5	23.4	1.2	0.1	0	0	0
978	Fruit cocktail, canned in juice	½	cup(s)	119	103.6	55	0.5	14.1	1.2	0	0	0	0
977	Fruit cocktail, canned in water	½	cup(s)	119	107.6	38	0.5	10.1	1.2	0.1	0	0	0
979	Fruit salad, canned in water	½	cup(s)	123	112.1	37	0.4	9.6	1.2	0.1	0	0	0

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	40	0.79	32.5	93.2	317.4	0.71	13.6	0.04	—	0.08	0.52	0.08	3.9	0.2	0.2	4.3
	0	0.22	8.7	20.0	116.4	0.34	0.9	0.01	0.27	0.00	0.13	0.01	2.8	0	0	0.2
	7	0.31	6.0	150.6	8.4	0.05	0	0.00	0.01	0.02	0.05	0.04	0	0.7	0	0.1
	9	0.46	3.7	147.6	3.7	0.04	0	0.03	0.01	0.02	0.12	0.04	0	1.1	0	0.1
	3	0.06	2.7	58.8	0.5	0.02	1.6	0.01	0.10	0.01	0.05	0.02	1.6	2.5	0	0
	4	0.16	2.6	75.2	0.9	0.03	1.7	0.01	0.04	0.01	0.08	0.04	0.9	0.2	0	0.3
	8	0.16	6.9	147.7	1.4	0.05	4.1	0.02	0.24	0.03	0.12	0.05	4.1	6.3	0	0
	3	0.30	3.4	96.8	18.7	0.04	0	0.00	0.11	0.03	0.20	0.03	0	0.8	0	0.3
	5	0.44	3.8	77.8	3.8	0.05	1.3	0.01	0.26	0.03	0.24	0.03	1.3	2.2	0	0.4
	4	0.14	3.7	91.5	2.4	0.03	1.2	0.01	0.25	0.03	0.22	0.03	1.2	1.5	0	0.4
	6	0.12	2.5	67.9	0.4	—	0.7	0.01	0.20	0.01	0.03	—	2.0	2.8	0	—
	18	0.54	14.0	362.6	1.4	0.28	134.4	0.04	1.24	0.05	0.84	0.07	12.6	14.0	0	0.1
	12	0.38	9.0	180.6	5.2	0.14	80.0	0.02	0.77	0.02	0.48	0.07	2.6	4.0	0	0.1
	18	0.87	10.5	381.5	3.3	0.12	59.1	0.00	1.42	0.02	0.85	0.05	3.3	0.3	0	0.7
	15	0.66	33.3	583.0	9.2	0.78	8.0	0.08	2.23	0.16	2.19	0.31	102.3	10.1	0	0.4
	12	0.19	27.6	403.6	2.3	0.45	8.0	0.02	3.03	0.04	0.76	0.08	40.3	20.0	0	—
	3	0.14	8.0	134.1	1.9	0.17	1.9	0.01	0.57	0.03	0.48	0.07	22.4	2.8	0	0.1
	10	0.69	41.8	294.8	3.3	0.40	2.2	0.04	0.13	0.01	0.39	0.14	7.7	3.5	0	0.8
	6	0.30	31.9	422.4	1.2	0.17	3.5	0.03	0.11	0.08	0.78	0.43	23.6	10.3	0	1.2
	21	0.45	14.4	116.6	0.7	0.38	7.9	0.01	0.84	0.02	0.47	0.02	18.0	15.1	0	0.3
	22	0.60	16.6	105.7	0.8	0.19	4.5	0.02	0.88	0.03	0.91	0.05	25.7	2.3	0	0.3
	6	0.42	5.1	51.2	3.8	0.09	2.6	0.04	0.49	0.07	0.14	0.05	2.6	1.4	0	0.1
	4	0.20	4.4	55.8	0.7	0.12	2.2	0.03	0.41	0.03	0.30	0.04	4.4	7.0	0	0.1
	6	0.14	3.9	41.9	0.8	0.05	1.6	0.03	0.37	0.03	0.40	0.05	5.4	1.9	0	0.1
	23	0.55	14.1	115.2	3.8	0.24	2.6	0.03	—	0.04	0.29	0.05	43.5	7.9	0	0.5
	18	0.56	10.6	91.7	0.7	0.15	2.0	0.04	0.57	0.02	0.51	0.04	41.6	2.0	0	0.1
	65	2.07	96.0	1881.6	7.7	0.46	0	0.42	0.38	0.11	3.45	0.38	53.8	111.4	0	2.3
	13	1.67	7.3	119.6	8.5	0.09	46.4	0.02	0.28	0.05	0.22	0.05	9.8	2.6	0	0
	12	0.25	7.0	134.1	2.3	0.08	49.6	0.02	0.05	0.03	0.31	0.03	6.2	7.8	0	0
	11	0.44	11.4	183.4	3.8	0.12	10.1	0.02	0.29	0.05	0.50	0.03	5.1	4.6	0	0
	14	0.45	11.2	162.4	1.2	0.10	9.9	0.03	0.29	0.05	0.51	0.04	5.0	2.7	0	0
	9	0.26	8.0	161.0	0	0.05	2.2	0.02	0.05	0.02	0.11	0.04	2.9	5.1	0	0
	4	0.13	3.3	46.8	1.1	0.05	1.7	0.01	0.66	0.01	0.05	0.03	0.6	7.3	0	0.1
	4	0.09	1.2	20.8	2.5	0.02	0	0.00	0.15	0.00	0.00	0.00	0	48.4	0	0
	4	0.13	1.3	17.7	2.5	0.04	0	0.00	0.28	0.00	0.05	0.00	0	53.5	0	0.3
	11	0.05	2.4	29.6	3.6	0.02	0	0.00	0.06	0.00	0.00	0.00	0	38.2	0	0
	3	0.15	2.1	18.0	20.1	0.03	1.4	0.01	0.57	0.01	0.06	0.01	0.7	1.4	0	0.2
	17	0.45	19.1	291.9	0.9	0.12	0	0.02	0.02	0.02	0.56	0.07	8.5	0.2	0	1.3
	17	0.45	19.1	291.9	0.9	0.12	0	0.02	0.02	0.02	0.56	0.07	8.5	0.2	0	1.3
	35	0.36	13.0	128.2	1.3	0.14	2.6	0.03	0.16	0.05	0.55	0.09	2.6	1.3	0	0.3
	35	0.36	12.4	127.7	1.2	0.15	2.5	0.03	0.10	0.05	0.55	0.09	2.5	1.2	0	0.1
	35	0.36	17.0	232.0	1.0	0.14	7.0	0.06	0.10	0.04	0.40	0.10	6.0	2.0	0	0.2
	7	0.36	6.2	109.1	7.4	0.09	12.4	0.02	0.49	0.02	0.46	0.06	3.7	2.4	0	0.6
	9	0.25	8.3	112.6	4.7	0.11	17.8	0.01	0.47	0.02	0.48	0.06	3.6	3.2	0	0.6
	6	0.30	8.3	111.4	4.7	0.11	15.4	0.02	0.47	0.01	0.43	0.06	3.6	2.5	0	0.6
	9	0.37	6.1	95.6	3.7	0.10	27.0	0.02	—	0.03	0.46	0.04	3.7	2.3	0	1.0

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tra
Fruit and Fruit Juices—*continued*														
	Gooseberries													
982	Canned in light syrup	½	cup(s)	126	100.9	92	0.8	23.6	3.0	0.3	0	0	0.1	
981	Raw	½	cup(s)	75	65.9	33	0.7	7.6	3.2	0.4	0	0	0.2	
	Grapefruit													
251	Juice, pink, sweetened, canned	½	cup(s)	125	109.1	57	0.7	13.9	0.1	0.1	0	0	0	
249	Juice, white	½	cup(s)	124	111.2	48	0.6	11.4	0.1	0.1	0	0	0	
3022	Pink or red, raw	½	cup(s)	114	100.8	48	0.9	12.2	1.8	0.2	0	0	0	
248	Sections, canned in light syrup	½	cup(s)	127	106.2	76	0.7	19.6	0.5	0.1	0	0	0	
983	Sections, canned in water	½	cup(s)	122	109.6	44	0.7	11.2	0.5	0.1	0	0	0	
247	White, raw	½	cup(s)	115	104.0	38	0.8	9.7	1.3	0.1	0	0	0	
	Grapes													
255	American, slip skin	½	cup(s)	46	37.4	31	0.3	7.9	0.4	0.2	0.1	0	0	
256	European, red or green, adherent skin	½	cup(s)	76	60.8	52	0.5	13.7	0.7	0.1	0	0	0	
3159	Grape juice drink, canned	½	cup(s)	125	106.6	71	0	18.2	0.1	0	0	0	0	0
259	Grape juice, sweetened, with added vitamin C, prepared from frozen concentrate	½	cup(s)	125	108.6	64	0.2	15.9	0.1	0.1	0	0	0	
3060	Raisins, seeded, packed	¼	cup(s)	41	6.8	122	1.0	32.4	2.8	0.2	0.1	0	0.1	
987	**Guava, raw**	1	item(s)	55	44.4	37	1.4	7.9	3.0	0.5	0.2	0	0.2	
35593	**Guavas, strawberry**	1	item(s)	6	4.8	4	0	1.0	0.3	0	0	0	0	
3027	**Jackfruit**	½	cup(s)	83	60.4	78	1.2	19.8	1.3	0.2	0	0	0.1	
990	**Kiwi fruit or Chinese gooseberries**	1	item(s)	76	63.1	46	0.9	11.1	2.3	0.4	0	0	0.2	
	Lemon													
262	Juice	1	tablespoon(s)	15	13.8	4	0.1	1.3	0.1	0	0	0	0	0
993	Peel	1	teaspoon(s)	2	1.6	1	0	0.3	0.2	0	0	0	0	
992	Raw	1	item(s)	108	94.4	22	1.3	11.6	5.1	0.3	0	0	0.1	
	Lime													
269	Juice	1	tablespoon(s)	15	14.0	4	0.1	1.3	0.1	0	0	0	0	
994	Raw	1	item(s)	67	59.1	20	0.5	7.1	1.9	0.1	0	0	0	
995	**Loganberries, frozen**	½	cup(s)	74	62.2	40	1.1	9.6	3.9	0.2	0	0	0.1	
	Mandarin orange													
1038	Canned in juice	½	cup(s)	125	111.4	46	0.8	11.9	0.9	0	0	0	0	
1039	Canned in light syrup	½	cup(s)	126	104.7	77	0.6	20.4	0.9	0.1	0	0	0	
999	**Mango**	½	cup(s)	83	67.4	54	0.4	14.0	1.5	0.2	0.1	0.1	0	
1005	**Nectarine, raw, sliced**	½	cup(s)	69	60.4	30	0.7	7.3	1.2	0.2	0	0.1	0.1	
	Melons													
271	Cantaloupe	½	cup(s)	80	72.1	27	0.7	6.5	0.7	0.1	0	0	0.1	
1000	Casaba melon	½	cup(s)	85	78.1	24	0.9	5.6	0.8	0.1	0	0	0	
272	Honeydew	½	cup(s)	89	79.5	32	0.5	8.0	0.7	0.1	0	0	0	
318	Watermelon	½	cup(s)	76	69.5	23	0.5	5.7	0.3	0.1	0	0	0	
	Orange													
14412	Juice with calcium and vitamin D	½	cup(s)	120	—	55	1.0	13.0	0	0	0	0	0	0
29630	Juice, fresh squeezed	½	cup(s)	124	109.5	56	0.9	12.9	0.2	0.2	0	0	0	
14411	Juice, not from concentrate	½	cup(s)	120	—	55	1.0	13.0	0	0	0	0	0	0
278	Juice, unsweetened, prepared from frozen concentrate	½	cup(s)	125	109.7	56	0.8	13.4	0.2	0.1	0	0	0	
3040	Peel	1	teaspoon(s)	2	1.5	2	0	0.5	0.2	0	0	0	0	
273	Raw	1	item(s)	131	113.6	62	1.2	15.4	3.1	0.2	0	0	0	
274	Sections	½	cup(s)	90	78.1	42	0.8	10.6	2.2	0.1	0	0	0	
	Papaya, raw													
16830	Dried, strips	2	item(s)	46	12.0	119	1.9	29.9	5.5	0.4	0.1	0.1	0.1	
282	Papaya	½	cup(s)	70	62.2	27	0.4	6.9	1.3	0.1	0	0	0	
35640	**Passion fruit, purple**	1	item(s)	18	13.1	17	0.4	4.2	1.9	0.1	0	0	0.1	
	Peach													
285	Halves, canned in heavy syrup	½	cup(s)	131	103.9	97	0.6	26.1	1.7	0.1	0	0	0.1	
286	Halves, canned in water	½	cup(s)	122	113.6	29	0.5	7.5	1.6	0.1	0	0	0	
290	Slices, sweetened, frozen	½	cup(s)	125	93.4	118	0.8	30.0	2.3	0.2	0	0.1	0.1	
283	Raw, medium	1	item(s)	150	133.3	59	1.4	14.3	2.3	0.4	0	0.1	0.1	
	Pear													
8672	Asian	1	item(s)	122	107.7	51	0.6	13.0	4.4	0.3	0	0.1	0.1	
293	D'Anjou	1	item(s)	200	168.0	120	1.0	30.0	5.2	1.0	0	0.2	0.2	
294	Halves, canned in heavy syrup	½	cup(s)	133	106.9	98	0.3	25.5	2.1	0.2	0	0	0	
1012	Halves, canned in juice	½	cup(s)	124	107.2	62	0.4	16.0	2.0	0.1	0	0	0	
291	Raw	1	item(s)	166	139.0	96	0.6	25.7	5.1	0.2	0	0	0	

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-TE)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	20	0.42	7.6	97.0	2.5	0.14	8.8	0.03	—	0.07	0.19	0.02	3.8	12.6	0	0.5
	19	0.23	7.5	148.5	0.8	0.09	11.3	0.03	0.28	0.02	0.23	0.06	4.5	20.8	0	0.5
	10	0.45	12.5	202.2	2.5	0.08	0	0.05	0.05	0.03	0.40	0.03	12.5	33.6	0	0.1
	11	0.25	14.8	200.1	1.2	0.06	1.2	0 05	0.27	0.02	0.25	0.05	12.4	46.9	0	0.1
	25	0.09	10.3	154.5	0	0.07	66.4	0.04	0.14	0.03	0.23	0.06	14.9	35.7	0	0.1
	18	0.50	12.7	163.8	2.5	0.10	0	0.04	0.11	0.02	0.30	0.02	11.4	27.1	0	1.1
	18	0.50	12.2	161.0	2.4	0.11	0	0.05	0.11	0.03	0 30	0.02	11 0	26.6	0	1.1
	14	0.07	10.4	170.2	0	0.08	2.3	0.04	0.15	0.02	0.30	0.05	11.5	38.3	0	1.6
	6	0.13	2.3	87.9	0.9	0.02	2.3	0.04	0.09	0.02	0.14	0.05	1.8	1.8	0	0
	8	0.27	5.3	144.2	1.5	0.05	2.3	0.05	0.14	0.05	0.14	0.07	1.5	8.2	0	0.1
	9	0.16	7.5	41.3	11.3	0.04	0	0.28	0.00	0.44	0.18	0.04	1.3	33.1	0	0.1
	5	0.13	5.0	26.3	2.5	0.05	0	0.02	0.00	0.03	0.16	0.05	1.3	29.9	0	0.1
	12	1.06	12.4	340.3	11.6	0.07	0	0.04	—	0 07	0 46	0.07	1 2	2.2	0	0.2
	10	0.14	12.1	229.4	1.1	0.12	17.1	0.03	0.40	0.02	0.59	0.06	27.0	125.6	0	0.3
	1	0.01	1.0	17.5	2.2	—	0.3	0 00	—	0 00	0 03	0 00	—	2.2	0	
	28	0.49	30.5	250.0	2.5	0.35	12 4	0 02	—	0 09	0 33	0 09	11.5	5.5	0	0.5
	26	0.23	12.9	237.1	2.3	0.10	3.0	0.02	1.11	0.01	0.25	0.04	19.0	70.5	0	0.2
	1	0.00	0.9	18.9	0.2	0.01	0.2	0.00	0.02	0.00	0.02	0.01	2.0	7.0	0	0
	3	0.01	0.3	3.2	0.1	0 01	0.1	0 00	0.01	0.00	0 01	0 00	0.3	2.6	0	0
	66	0.75	13.0	156.6	3.2	0 10	2.2	0.05	—	0 04	0.21	0.11	—	83 2	0	1.0
	2	0.02	1.2	18.0	0.3	0.01	0.3	0.00	0.03	0.00	0.02	0.01	1.5	4.6	0	0
	22	0.40	4.0	68 3	1.3	0.07	1.3	0 02	0.14	0.01	0 13	0 02	5.4	19.5	0	0.3
	19	0.47	15.4	106.6	0.7	0.25	1.5	0.04	0.64	0.03	0.62	0.05	19.1	11.2	0	0.1
	14	0 34	13.7	165.6	6.2	0.64	53 5	0 10	0 12	0 04	0 55	0 05	6.2	42 6	0	0.5
	9	0.47	10.1	98.3	7.6	0.30	52.9	0 07	0.13	0.06	0 56	0 05	6.3	24 9	0	0.5
	8	0 10	7.4	128.7	1.7	0 03	31.4	0 05	0 92	0 04	0.48	0.11	11.6	22.8	0	0.5
	4	0.19	6.2	138.7	0	0.12	11.7	0.02	0.53	0.02	0.78	0.02	3.5	3.7	0	0
	7	0.17	9.6	213.6	12.8	0.14	135.2	0.03	0.04	0.01	0 59	0.05	16.8	29.4	0	0.3
	9	0.29	9.4	154.7	7 7	0.06	0	0.01	0.04	0 03	0 20	0.14	6 8	18 5	0	0.3
	5	0.15	8.8	201 8	15.9	0.07	2.7	0 03	0 01	0.01	0.37	0.07	16 8	15 9	0	0.6
	5	0.18	7.6	85.1	0.8	0.07	21.3	0.02	0.04	0.01	0.13	0.03	2.3	6.2	0	0.3
	175	0.00	12.0	225.0	0	—	0	0.08	—	0.03	0.40	0.06	30.0	36.0	0	—
	14	0 25	13.6	248.0	1.2	0.06	12.4	0.11	0.05	0.04	0.50	0.05	37.2	62.0	0	0.1
	10	0.00	12.5	225.0	0	0.06	0	0.08	—	0 03	0.40	0 06	30.0	36.0	0	0.1
	11	0.12	12.5	236.6	1.2	0.06	6.2	0.10	0.25	0.02	0.25	0.06	54.8	48.4	0	0.1
	3	0.01	0.4	4.2	0.1	0.01	0.4	0.00	0.01	0.00	0.01	0.00	0.6	2.7	0	0
	52	0.13	13.1	237.1	0	0.09	14.4	0.11	0.23	0.05	0.36	0.07	39.3	69.7	0	0.7
	36	0.09	9.0	162.9	0	0.06	9.9	0.07	0.16	0.03	0.25	0.05	27.0	47.9	0	0.4
	73	0.30	30.4	782.9	9.2	0.21	83.7	0.06	2.22	0.08	0.93	0.05	58.0	37.7	0	1.8
	17	0.07	7.0	179.9	2.1	0.05	38.5	0.02	0.51	0.02	0.24	0.01	26.6	43.3	0	0.4
	2	0.28	5.2	62.6	5.0	0.01	11.5	0.00	0.00	0.02	0.27	0.01	2.5	5.4	0	0.1
	4	0.35	6.6	120.5	7.9	0.11	22.3	0.01	0.64	0.03	0.80	0.02	3.9	3.7	0	0.4
	2	0.39	6.1	120.8	3.7	0.11	32.9	0.01	0.59	0.02	0.63	0.02	3.7	3.5	0	0.4
	4	0.46	6.3	162.5	7.5	0.06	17.5	0.01	0.77	0.04	0.81	0.02	3.8	117.8	0	0.5
	9	0.37	13.5	285.0	0	0.25	24.0	0.03	1.09	0.04	1.20	0.03	6.0	9.9	0	0.2
	5	0.00	9.8	147.6	0	0.02	0	0.01	0.14	0.01	0.26	0.02	9.8	4.6	0	0.1
	22	0.50	12.0	250.0	0	0.24	—	0.04	1.00	0 08	0.20	0.03	14.6	8.0	0	1.0
	7	0.29	5.3	86.5	6.7	0.10	0	0.01	0.10	0.02	0.32	0.01	1.3	1.5	0	0
	11	0.36	8.7	119.0	5.0	0.11	0	0.01	0.10	0.01	0.25	0.02	1.2	2.0	0	0
	15	0.28	11.6	197.5	1.7	0.16	1.7	0.02	0.19	0.04	0.26	0.04	11.6	7.0	0	0.2

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tr
Fruit and Fruit Juices—*continued*														
1017	**Persimmon**	1	item(s)	25	16.1	32	0.2	8.4	—	0.1	0	0	0	—
	Pineapple													
3053	Canned in extra heavy syrup	½	cup(s)	130	101.0	108	0.4	28.0	1.0	0.1	0	0	0	—
1019	Canned in juice	½	cup(s)	125	104.0	75	0.5	19.5	1.0	0.1	0	0	0	—
296	Canned in light syrup	½	cup(s)	126	108.0	66	0.5	16.9	1.0	0.2	0	0	0.1	—
1018	Canned in water	½	cup(s)	123	111.7	39	0.5	10.2	1.0	0.1	0	0	0	—
299	Juice, unsweetened, canned	½	cup(s)	125	108.0	66	0.5	16.1	0.3	0.2	0	0	0.1	—
295	Raw, diced	½	cup(s)	78	66.7	39	0.4	10.2	1.1	0.1	0	0	0	—
1024	**Plantain, cooked**	½	cup(s)	77	51.8	89	0.6	24.0	1.8	0.1	0.1	0	0	—
300	**Plum, raw, large**	1	item(s)	66	57.6	30	0.5	7.5	0.9	0.2	0	0.1	0	—
1027	**Pomegranate**	1	item(s)	154	124.7	105	1.5	26.4	0.9	0.5	0.1	0.1	0.1	—
	Prunes													
5644	Dried	2	item(s)	17	5.2	40	0.4	10.7	1.2	0.1	0	0	0	—
305	Dried, stewed	½	cup(s)	124	86.5	133	1.2	34.8	3.8	0.2	0	0.1	0	—
306	Juice, canned	1	cup(s)	256	208.0	182	1.6	44.7	2.6	0.1	0	0.1	0	—
	Raspberries													
309	Raw	½	cup(s)	62	52.7	32	0.7	7.3	4.0	0.4	0	0	0.2	—
310	Red, sweetened, frozen	½	cup(s)	125	90.9	129	0.9	32.7	5.5	0.2	0	0	0.1	—
311	**Rhubarb, cooked with sugar**	½	cup(s)	120	81.5	140	0.5	37.5	2.7	0.1	0	0	0.1	—
	Strawberries													
313	Raw	½	cup(s)	72	65.5	23	0.5	5.5	1.4	0.2	0	0	0.1	—
315	Sweetened, frozen, thawed	½	cup(s)	128	99.5	99	0.7	26.8	2.4	0.2	0	0	0.1	—
16828	**Tangelo**	1	item(s)	95	82.4	45	0.9	11.2	2.3	0.1	0	0	0	—
	Tangerine													
1040	Juice	½	cup(s)	124	109.8	53	0.6	12.5	0.2	0.2	0	0	0	—
316	Raw	1	item(s)	88	74.9	47	0.7	11.7	1.6	0.3	0	0.1	0.1	—
Vegetables, Legumes														
	Amaranth													
1043	Leaves, boiled, drained	½	cup(s)	66	60.4	14	1.4	2.7	—	0.1	0	0	0.1	—
1042	Leaves, raw	1	cup(s)	28	25.7	6	0.7	1.1	—	0.1	0	0	0	—
8683	**Arugula leaves, raw**	1	cup(s)	20	18.3	5	0.5	0.7	0.3	0.1	0	0	0.1	—
	Artichoke													
1044	Boiled, drained	1	item(s)	120	100.9	64	3.5	14.3	10.3	0.4	0.1	0	0.2	—
2885	Hearts, boiled, drained	½	cup(s)	84	70.6	45	2.4	10.0	7.2	0.3	0.1	0	0.1	—
	Asparagus													
566	Boiled, drained	½	cup(s)	90	83.4	20	2.2	3.7	1.8	0.2	0	0	0.1	—
568	Canned, drained	½	cup(s)	121	113.7	23	2.6	3.0	1.9	0.8	0.2	0	0.3	—
565	Tips, frozen, boiled, drained	½	cup(s)	90	84.7	16	2.7	1.7	1.4	0.4	0.1	0	0.2	—
	Bamboo shoots													
1048	Boiled, drained	½	cup(s)	60	57.6	7	0.9	1.2	0.6	0.1	0	0	0.1	—
1049	Canned, drained	½	cup(s)	66	61.8	12	1.1	2.1	0.9	0.3	0.1	0	0.1	—
	Beans													
1801	Adzuki beans, boiled	½	cup(s)	115	76.2	147	8.6	28.5	8.4	0.1	0	—	—	—
511	Baked beans with franks, canned	½	cup(s)	130	89.8	184	8.7	19.9	8.9	8.5	3.0	3.7	1.1	—
513	Baked beans with pork in sweet sauce, canned	½	cup(s)	127	89.3	142	6.7	26.7	5.3	1.8	0.6	0.6	0.5	0
512	Baked beans with pork in tomato sauce, canned	½	cup(s)	127	93.0	119	6.5	23.6	5.1	1.2	0.5	0.7	0.3	—
1805	Black beans, boiled	½	cup(s)	86	56.5	114	7.6	20.4	7.5	0.5	0.1	0	0.2	—
14597	Chickpeas, garbanzo beans or bengal gram, boiled	½	cup(s)	82	49.4	134	7.3	22.5	6.2	2.1	0.2	0.5	0.9	—
569	Fordhook lima beans, frozen, boiled, drained	½	cup(s)	85	62.0	88	5.2	16.4	4.9	0.3	0.1	0	0.1	—
1806	French beans, boiled	½	cup(s)	89	58.9	114	6.2	21.3	8.3	0.7	0.1	0	0.4	—
2773	Great northern beans, boiled	½	cup(s)	89	61.1	104	7.4	18.7	6.2	0.4	0.1	0	0.2	—
2736	Hyacinth beans, boiled, drained	½	cup(s)	44	37.8	22	1.3	4.0	—	0.1	0.1	0.1	0	—
570	Lima beans, baby, frozen, boiled, drained	½	cup(s)	90	65.1	95	6.0	17.5	5.4	0.3	0.1	0	0.1	—
515	Lima beans, boiled, drained	½	cup(s)	85	57.1	105	5.8	20.1	4.5	0.3	0.1	0	0.1	—
579	Mung beans, sprouted, boiled, drained	½	cup(s)	62	57.9	13	1.3	2.6	0.5	0.1	0	0	0	—
510	Navy beans, boiled	½	cup(s)	91	58.1	127	7.5	23.7	9.6	0.6	0.1	0.1	0.4	0
32816	Pinto beans, boiled, drained, no salt added	½	cup(s)	63	58.8	14	1.2	2.6	—	0.2	0	0	0.1	—

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg αT)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	7	0.62	—	77.5	0.3	—	0	—	—	—	—	—	—	16.5	0	—
	18	0.49	19.5	132.6	1.3	0 14	1.3	0.11	—	0.03	0.36	0.09	6.5	9.5	0	—
	17	0.35	17.4	151.9	1.2	0.12	2.5	0.12	0.01	0.02	0.35	0.09	6.2	11.8	0	0.5
	18	0.49	20.2	132.3	1.3	0.15	2.5	0.11	0.01	0.03	0.36	0.09	6.3	9.5	0	0.5
	18	0.49	22.1	156.2	1.2	0.15	2.5	0.11	0.01	0 03	0.37	0.09	6.2	9.5	0	0.5
	16	0.39	15.0	162.5	2.5	0.14	0	0.07	0.03	0 03	0.25	0.13	22.5	12.5	0	0.1
	10	0.22	9.3	84.5	0.8	0 09	2.3	0.06	0.02	0.03	0.39	0.09	14.0	37.0	0	0.1
	2	0.45	24.6	358 1	3.9	0 10	34 7	0.04	0.10	0 04	0.58	0.19	20.0	8.4	0	1.1
	4	0 11	4.6	103.6	0	0.06	11.2	0 02	0 17	0.02	0.27	0.02	3.3	6.3	0	0
	5	0.46	4.6	398.9	4.6	0.18	7.7	0.04	0.92	0.04	0.46	0 16	9.2	9.4	0	0.9
	7	0.16	6.9	123.0	0.3	0.07	6.6	0.01	0.07	0.03	0.32	0.03	0.7	0.1	0	0
	24	0.51	22.3	398 0	1.2	0.24	21.1	0.03	0.24	0.12	0.90	0.27	0	3.6	0	0.1
	31	3.02	35.8	706.6	10.2	0.53	0	0.04	0.30	0.17	2.01	0.55	0	10.5	0	1.5
	15	0.42	13.5	92.9	0.6	0 26	1.2	0.02	0.54	0.02	0.37	0 03	12.9	16.1	0	0.1
	19	0.81	16.3	142.5	1.3	0.22	3.8	0.02	0.90	0.05	0.28	0.04	32.5	20.6	0	0.4
	174	0.25	16.2	115.0	1.0	—	—	0.02	—	0.03	0.25	—	—	4.0	0	—
	12	0.30	9.4	110.2	0.7	0.10	0.7	0.02	0 21	0.02	0 28	0.03	17.3	42.3	0	0.3
	14	0.59	7.7	125.0	1.3	0.06	1.3	0 01	0.30	0.09	0 37	0 03	5.1	50.4	0	0.9
	38	0.09	9.5	172.0	0	0.06	10.5	0.08	0.17	0.03	0.26	0.05	28.5	50.5	0	0.5
	22	0.25	9 9	219.8	1.2	0 04	16.1	0 07	0.16	0 02	0.12	0.05	6.2	38 3	0	0.1
	33	0.13	10.6	146.1	1.8	0.06	29.9	0.05	0.18	0.03	0.33	0.07	14.1	23.5	0	0.1
	138	1.49	36.3	423.1	13.9	0 58	91 7	0.01	—	0 09	0 37	0.12	37.6	27.1	0	0.6
	60	0.65	15.4	171.1	5.6	0.25	40.9	0.01	—	0.04	0.18	0.05	23.8	12.1	0	0.3
	32	0.29	9.4	73.8	5.4	0.09	23.8	0.01	0.09	0.02	0.06	0.01	19.4	3.0	0	0.1
	25	0.73	50.4	343.2	72.0	0 48	1.2	0 06	0 22	0.10	1 33	0.09	106.8	8.9	0	0.2
	18	0.51	35.3	240.2	50 4	0 33	0.8	0.04	0 16	0.07	0.93	0.06	74.8	6.2	0	0.2
	21	0.81	12.6	201.6	12.6	0.54	45.0	0.14	1.35	0.12	0.97	0.07	134.1	6.9	0	5.5
	19	2.21	12.1	208.1	347.3	0.48	49.6	0.07	1.47	0.12	1.15	0 13	116.2	22.3	0	2.1
	16	0.50	9.0	154.8	2.7	0.36	36.0	0.05	1.08	0.09	0.93	0.01	121.5	22.0	0	3.5
	7	0.14	1.8	319 8	2.4	0 28	0	0.01	—	0.03	0 18	0.06	1.2	0	0	0.2
	5	0.21	2.6	52 4	4.6	0.43	0.7	0.02	0 41	0.02	0.09	0.09	2.0	0.7	0	0.3
	32	2.30	59.8	611.8	9 2	2.03	0	0 13	—	0 07	0.82	0.11	139.2	0	0	1.4
	62	2.24	36.3	304.3	556.9	2.42	5.2	0.08	0.21	0.07	1.17	0.06	38.9	3.0	0.4	8.4
	75	2.08	41.7	326.4	422.5	1.73	0	0.05	0.03	0.07	0.44	0.07	10.1	3.5	0	6.3
	71	4.09	43.0	373.2	552.8	6.93	5.1	0.06	0.12	0.05	0.62	0.08	19.0	3.8	0	5.9
	23	1.80	60.2	305.3	0.9	0.96	0	0.21	—	0.05	0 43	0.05	128.1	0	0	1.0
	40	2.36	39.4	238.6	5.7	1.25	0.8	0.09	0.28	0.05	0.43	0.11	141.0	1.1	0	3.0
	26	1.54	35.7	258.4	58.7	0.62	8.5	0.06	0.24	0.05	0.90	0.10	17.9	10.9	0	0.5
	56	0.95	49.6	327 5	5.3	0 56	0	0.11	—	0.05	0 48	0 09	66.4	1.1	0	1.1
	60	1.88	44.3	346.0	1.8	0.77	0	0.14	—	0.05	0.60	0.10	90 3	1.2	0	3.6
	18	0.33	18.3	114.0	0.9	0.16	3.0	0.02	—	0.03	0.20	0.01	20.4	2.2	0	0.7
	25	1.76	50.4	369.9	26.1	0.49	7.2	0.06	0.57	0.04	0.69	0.10	14.4	5.2	0	1.5
	27	2.08	62.9	484.5	14.5	0.67	12.8	0.11	0.11	0.08	0.88	0.16	22.1	8.6	0	1.7
	7	0.40	8.7	62.6	6.2	0.29	0.6	0.03	0.04	0.06	0.51	0.03	18.0	7.1	0	0.4
	63	2.14	48.2	354.0	0	0.93	0	0.21	0.01	0.06	0.59	0.12	127.4	0.8	0	2.6
	9	0.41	11.3	61.7	32.1	0.10	0	0.04	—	0.03	0.45	0.03	18.3	3.8	0	0.4

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Vegetables, Legumes—*continued*													
1052	Pinto beans, frozen, boiled, drained	½	cup(s)	47	27.3	76	4.4	14.5	4.0	0.2	0	0	0.1
514	Red kidney beans, canned	½	cup(s)	128	99.0	108	6.7	19.9	6.9	0.5	0.1	0.2	0.2
1810	Refried beans, canned	½	cup(s)	127	96.1	119	6.9	19.6	6.7	1.6	0.6	0.7	0.2
1053	Shell beans, canned	½	cup(s)	123	111.1	37	2.2	7.6	4.2	0.2	0	0	0.1
1670	Soybeans, boiled	½	cup(s)	86	53.8	149	14.3	8.5	5.2	7.7	1.1	1.7	4.4
1108	Soybeans, green, boiled, drained	½	cup(s)	90	61.7	127	11.1	9.9	3.8	5.8	0.7	1.1	2.7
1807	White beans, small, boiled	½	cup(s)	90	56.6	127	8.0	23.1	9.3	0.6	0.1	0.1	0.2
575	Yellow snap, string or wax beans, boiled, drained	½	cup(s)	63	55.8	22	1.2	4.9	2.1	0.2	0	0	0.1
576	Yellow snap, string or wax beans, frozen, boiled, drained	½	cup(s)	68	61.7	19	1.0	4.4	2.0	0.1	0	0	0.1
	Beets												
584	Beet greens, boiled, drained	½	cup(s)	72	64.2	19	1.9	3.9	2.1	0.1	0	0	0.1
2730	Pickled, canned with liquid	½	cup(s)	114	92.9	74	0.9	18.5	3.0	0.1	0	0	0
581	Sliced, boiled, drained	½	cup(s)	85	74.0	37	1.4	8.5	1.7	0.2	0	0	0.1
583	Sliced, canned, drained	½	cup(s)	85	77.3	26	0.8	6.1	1.5	0.1	0	0	0
580	Whole, boiled, drained	2	item(s)	100	87.1	44	1.7	10.0	2.0	0.2	0	0	0.1
585	**Cowpeas or black-eyed peas, boiled, drained**	½	cup(s)	83	62.3	80	2.6	16.8	4.1	0.3	0.1	0	0.1
	Broccoli												
588	Chopped, boiled, drained	½	cup(s)	78	69.6	27	1.9	5.6	2.6	0.3	0.1	0	0.1
590	Frozen, chopped, boiled, drained	½	cup(s)	92	83.5	26	2.9	4.9	2.8	0.1	0	0	0.1
587	Raw, chopped	½	cup(s)	46	40.6	15	1.3	3.0	1.2	0.2	0	0	0
16848	**Broccoflower, raw, chopped**	½	cup(s)	32	28.7	10	0.9	1.9	1.0	0.1	0	0	0
	Brussels sprouts												
591	Boiled, drained	½	cup(s)	78	69.3	28	2.0	5.5	2.0	0.4	0.1	0	0.2
592	Frozen, boiled, drained	½	cup(s)	78	67.2	33	2.8	6.4	3.2	0.3	0.1	0	0.2
	Cabbage												
595	Boiled, drained, no salt added	1	cup(s)	150	138.8	35	1.9	8.3	2.8	0.1	0	0	0
35611	Chinese (pak choi or bok choy), boiled with salt, drained	1	cup(s)	170	162.4	20	2.6	3.0	1.7	0.3	0	0	0.1
16869	Kim chee	1	cup(s)	150	137.5	32	2.5	6.1	1.8	0.3	0	0	0.2
594	Raw, shredded	1	cup(s)	70	64.5	17	0.9	4.1	1.7	0.1	0	0	0
596	Red, shredded, raw	1	cup(s)	70	63.3	22	1.0	5.2	1.5	0.1	0	0	0.1
597	Savoy, shredded, raw	1	cup(s)	70	63.7	19	1.4	4.3	2.2	0.1	0	0	0
35417	**Capers**	1	teaspoon(s)	4	—	2	0	0	0	0	0	0	0
	Carrots												
8691	Baby, raw	8	item(s)	80	72.3	28	0.5	6.6	2.3	0.1	0	0	0.1
601	Grated	½	cup(s)	55	48.6	23	0.5	5.3	1.5	0.1	0	0	0.1
1055	Juice, canned	½	cup(s)	118	104.9	47	1.1	11.0	0.9	0.2	0	0	0.1
600	Raw	½	cup(s)	61	53.9	25	0.6	5.8	1.7	0.1	0	0	0.1
602	Sliced, boiled, drained	½	cup(s)	78	70.3	27	0.6	6.4	2.3	0.1	0	0	0.1
32725	**Cassava or manioc**	½	cup(s)	103	61.5	165	1.4	39.2	1.9	0.3	0.1	0.1	0
	Cauliflower												
606	Boiled, drained	½	cup(s)	62	57.7	14	1.1	2.5	1.4	0.3	0	0	0.1
607	Frozen, boiled, drained	½	cup(s)	90	84.6	17	1.4	3.4	2.4	0.2	0	0	0.1
605	Raw, chopped	½	cup(s)	50	46.0	13	1.0	2.6	1.2	0	0	0	0
	Celery												
609	Diced	½	cup(s)	51	48.2	8	0.3	1.5	0.8	0.1	0	0	0
608	Stalk	2	item(s)	80	76.3	13	0.6	2.4	1.3	0.1	0	0	0.1
	Chard												
1057	Swiss chard, boiled, drained	½	cup(s)	88	81.1	18	1.6	3.6	1.8	0.1	0	0	0
1056	Swiss chard, raw	1	cup(s)	36	33.4	7	0.6	1.3	0.6	0.1	0	0	0
	Collard greens												
610	Boiled, drained	½	cup(s)	95	87.3	25	2.0	4.7	2.7	0.3	0	0	0.2
611	Frozen, chopped, boiled, drained	½	cup(s)	85	75.2	31	2.5	6.0	2.4	0.3	0.1	0	0.2
	Corn												
29614	Yellow corn, fresh, cooked	1	item(s)	100	69.2	107	3.3	25.0	2.8	1.3	0.2	0.4	0.6
615	Yellow creamed sweet corn, canned	½	cup(s)	128	100.8	92	2.2	23.2	1.5	0.5	0.1	0.2	0.3
612	Yellow sweet corn, boiled, drained	½	cup(s)	82	57.0	89	2.7	20.6	2.3	1.1	0.2	0.3	0.5

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	24	1.27	25.4	303.6	39.0	0.32	0	0.12	—	0.05	0.29	0.09	16.0	0.3	0	0.7
	32	1.62	35.8	327.7	330.2	2.09	0	0.13	0.02	0.11	0.57	0.10	25.6	1.4	0	0.6
	44	2.10	41.7	337.8	378.2	1.48	0	0 03	0.00	0.02	0.39	0 18	13.9	7.6	0	1.6
	36	1.21	18.4	133.5	409.2	0.33	13.5	0 04	0 04	0 07	0.25	0 06	22 1	3.8	0	2.6
	88	4.42	74.0	442.9	0.9	0.98	0	0.13	0.30	0.24	0.34	0.20	46.4	1.5	0	6.3
	131	2.25	54.0	485.1	12.6	0.82	7.2	0.23	—	0.14	1.13	0.05	99.9	15.3	0	1.3
	65	2.54	60.9	414.4	1.8	0.97	0	0.21	—	0.05	0.24	0.11	122.6	0	0	1.2
	29	0.80	15.6	186.9	1.9	0.23	2.5	0.05	0 28	0.06	0.38	0.04	20.6	6.1	0	0.3
	33	0.59	16.2	85.1	6.1	0.32	4.1	0.02	0.03	0.06	0.26	0.04	15.5	2.8	0	0.3
	82	1.36	49.0	654.5	173.5	0.36	275.8	0.08	1.30	0.20	0.35	0 09	10 1	17 9	0	0.6
	12	0.46	17.0	168.0	299.6	0 29	1.1	0 01	—	0 05	0 28	0 05	30 6	2.6	0	1.1
	14	0.67	19.6	259.3	65.5	0 30	1.7	0.02	0 03	0 03	0 28	0.05	68.0	3.1	0	0.6
	13	1.54	14.5	125 8	164.9	0 17	0.9	0 01	0 02	0 03	0.13	0 04	25 5	3.5	0	0.4
	16	0.79	23 0	305.0	77 0	0 35	2 0	0 02	0 04	0 04	0.33	0 06	80 0	3.6	0	0.7
	106	0.92	42.9	344.9	3 3	0 85	33.0	0.08	0.18	0.12	1 15	0 05	104.8	1.8	0	2.1
	31	0.52	16.4	228.5	32.0	0.35	60 1	0.04	1 13	0 09	0.43	0 15	84.2	50 6	0	1.2
	30	0.56	12.0	130.6	10.1	0.25	46.9	0.05	1.21	0.07	0 42	0.12	51.5	36 9	0	0.6
	21	0.33	9.6	143 8	15.0	0 19	14.1	0 03	0 36	0 05	0 29	0.08	28 7	40.6	0	1.1
	11	0.23	6.4	96.0	7.4	0.20	2.6	0 02	0 01	0.03	0.23	0.07	18.2	28.2	0	0.2
	28	0.93	15.6	247.3	16 4	0.25	30 4	0.08	0 33	0.06	0.47	0.13	46.8	48 4	0	1.2
	20	0.37	14.0	224 8	11.6	0.18	35.7	0 08	0 39	0.08	0.41	0.22	78.3	35 4	0	0.5
	72	0.24	22.5	294.0	12 0	0 30	6 0	0 08	0.20	0.04	0.36	0 16	45.0	56.2	0	0.9
	158	1.76	18.7	630.7	459 0	0 28	360.4	0 04	0.14	0.10	0.72	0 28	69.7	44 2	0	0.7
	144	1.26	27.0	379.5	996 0	0.36	288.0	0 06	0 36	0.10	0 80	0 32	88 5	79.6	0	1.5
	28	0.33	8.4	119.0	12 6	0 12	3 5	0 04	0 10	0.02	0 16	0.08	30.1	25 6	0	0.2
	31	0.56	11.2	170.1	18 9	0.15	39 2	0 04	0.07	0 05	0.29	0 14	12 6	39.9	0	0.4
	24	0.28	19.6	161.0	19.6	0.18	35.0	0 05	0.11	0.02	0 21	0.13	56.0	21 7	0	0.6
	0	0.00	—	—	140	—	0	—	—	—	—	—	—	0	—	—
	26	0.71	8.0	189.6	62 4	0 13	552.0	0.02	—	0.02	0.44	0.08	21.6	2.1	0	0.7
	18	0.16	6.6	176.0	37.9	0.13	459.2	0.03	0.36	0.03	0.54	0.07	10.4	3.2	0	0.1
	28	0.54	16.5	344 6	34.2	0 21	1128 1	0 11	1 37	0 07	0.46	0.26	4 7	10.0	0	0.7
	20	0.18	7.3	195.2	42 1	0.15	509 4	0.04	0.40	0.04	0 60	0 08	11 6	3 6	0	0.1
	23	0.26	7.8	183.3	45 2	0.15	664.6	0 05	0.80	0 03	0.50	0.11	10.9	2.8	0	0.5
	16	0.27	21.6	279.1	14.4	0.35	1.0	0.08	0.19	0.04	0.87	0.09	27.8	21.2	0	0.7
	10	0.19	5.6	88.0	9.3	0.10	0.6	0.02	0.04	0.03	0.25	0.10	27.3	27.5	0	0.4
	15	0.36	8.1	125.1	16.2	0.11	0	0.03	0.05	0.04	0.27	0.07	36.9	28.2	0	0.5
	11	0.22	7.5	151.5	15.0	0.14	0.5	0.03	0.04	0.03	0.26	0.11	28.5	23.2	0	0.3
	20	0.10	5.6	131.3	40.4	0.07	11.1	0.01	0 14	0.03	0.16	0.04	18.2	1.6	0	0.2
	32	0.16	8.8	208.0	64.0	0.10	17.6	0.01	0.21	0.04	0.25	0.05	28.8	2.5	0	0.3
	51	1.98	75.3	480.4	156 6	0.29	267.8	0.03	1.65	0.08	0 32	0.07	7.9	15.8	0	0.8
	18	0.64	29.2	136.4	76.7	0.13	110.2	0.01	0.68	0.03	0.14	0.03	5.0	10.8	0	0.3
	133	1.10	19.0	110.2	15.2	0.21	385.7	0.03	0.83	0.10	0.54	0.12	88.4	17.3	0	0.5
	179	0.95	25.5	213.4	42.5	0.22	488.8	0.04	1.06	0.09	0.54	0.09	64.6	22.4	0	1.3
	2	0.61	32.0	248.0	242.0	0.48	13 0	0.20	0.09	0.07	1.60	0.06	46.0	6.2	0	0.2
	4	0.48	21.8	171.5	364.8	0.67	5.1	0.03	0.09	0.06	1.22	0.08	57.6	5.9	0	0.5
	2	0.36	21.3	173.8	0	0.50	10.7	0.17	0 07	0.05	1.32	0.04	37.7	5.1	0	0.2

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Nut Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	
Vegetables, Legumes—*continued*														
614	Yellow sweet corn, frozen, boiled, drained	½	cup(s)	82	63.2	66	2.1	15.8	2.0	0.5	0.1	0.2	0.3	
618	**Cucumber**	¼	item(s)	75	71.7	11	0.5	2.7	0.4	0.1	0	0	0	
16870	**Cucumber, kim chee**	½	cup(s)	75	68.1	16	0.8	3.6	1.1	0.1	0	0	0	
	Dandelion greens													
620	Chopped, boiled, drained	½	cup(s)	53	47.1	17	1.1	3.4	1.5	0.3	0.1	0	0.1	
2734	Raw	1	cup(s)	55	47.1	25	1.5	5.1	1.9	0.4	0.1	0	0.2	
1066	**Eggplant, boiled, drained**	½	cup(s)	50	44.4	17	0.4	4.3	1.2	0.1	0	0	0	
621	**Endive or escarole, chopped, raw**	1	cup(s)	50	46.9	8	0.6	1.7	1.5	0.1	0	0	0	
8784	**Jicama or yambean**	½	cup(s)	65	116.5	49	0.9	11.4	6.3	0.1	0	0	0.1	
	Kale													
623	Frozen, chopped, boiled, drained	½	cup(s)	65	58.8	20	1.8	3.4	1.3	0.3	0	0	0.2	
29313	Raw	1	cup(s)	67	56.6	33	2.2	6.7	1.3	0.5	0.1	0	0.2	
	Kohlrabi													
1072	Boiled, drained	½	cup(s)	83	74.5	24	1.5	5.5	0.9	0.1	0	0	0	
1071	Raw	1	cup(s)	135	122.9	36	2.3	8.4	4.9	0.1	0	0	0.1	
	Leeks													
1074	Boiled, drained	½	cup(s)	52	47.2	16	0.4	4.0	0.5	0.1	0	0	0	
1073	Raw	1	cup(s)	89	73.9	54	1.3	12.6	1.6	0.3	0	0	0.1	
	Lentils													
522	Boiled	¼	cup(s)	50	34.5	57	4.5	10.0	3.9	0.2	0	0	0.1	
1075	Sprouted	1	cup(s)	77	51.9	82	6.9	17.0	—	0.4	0	0.1	0.2	
	Lettuce													
625	Butterhead leaves	11	piece(s)	83	78.9	11	1.1	1.8	0.9	0.2	0	0	0.1	
624	Butterhead, Boston or Bibb	1	cup(s)	55	52.6	7	0.7	1.2	0.6	0.1	0	0	0.1	
626	Iceberg	1	cup(s)	55	52.6	8	0.5	1.6	0.7	0.1	0	0	0	
628	Iceberg, chopped	1	cup(s)	55	52.6	8	0.5	1.6	0.7	0.1	0	0	0	
629	Looseleaf	1	cup(s)	36	34.2	5	0.5	1.0	0.5	0.1	0	0	0	
1665	Romaine, shredded	1	cup(s)	56	53.0	10	0.7	1.8	1.2	0.2	0	0	0.1	
	Mushrooms													
15585	Crimini (about 6)	3	ounce(s)	85	—	28	3.7	2.8	1.9	0	0	0	0	
8700	Enoki	30	item(s)	90	79.7	40	2.3	6.9	2.4	0.3	0	0	0.1	
1079	Mushrooms, boiled, drained	½	cup(s)	78	71.0	22	1.7	4.1	1.7	0.4	0	0	0.1	
1080	Mushrooms, canned, drained	½	cup(s)	78	71.0	20	1.5	4.0	1.9	0.2	0	0	0.1	
630	Mushrooms, raw	½	cup(s)	48	44.4	11	1.5	1.6	0.5	0.2	0	0	0.1	
15587	Portabella, raw	1	item(s)	84	—	30	3.0	3.9	3.0	0	0	0	0	
2743	Shiitake, cooked	½	cup(s)	73	60.5	41	1.1	10.4	1.5	0.2	0	0.1	0	
	Mustard greens													
2744	Frozen, boiled, drained	½	cup(s)	75	70.4	14	1.7	2.3	2.1	0.2	0	0.1	0	
29319	Raw	1	cup(s)	56	50.8	15	1.5	2.7	1.8	0.1	0	0	0	
	Okra													
16866	Batter coated, fried	11	piece(s)	83	55.6	156	2.1	12.7	2.0	11.2	1.5	3.7	5.5	
32742	Frozen, boiled, drained, no salt added	½	cup(s)	92	83.8	26	1.9	5.3	2.6	0.3	0.1	0	0.1	
632	Sliced, boiled, drained	½	cup(s)	80	74.1	18	1.5	3.6	2.0	0.2	0	0	0	
	Onions													
635	Chopped, boiled, drained	½	cup(s)	105	92.2	46	1.4	10.7	1.5	0.2	0	0	0.1	
2748	Frozen, boiled, drained	½	cup(s)	106	97.8	30	0.8	7.0	1.9	0.1	0	0	0	
1081	Onion rings, breaded and pan fried, frozen, heated	10	piece(s)	71	20.2	289	3.8	27.1	0.9	19.0	6.1	7.7	3.6	
633	Raw, chopped	½	cup(s)	80	71.3	32	0.9	7.5	1.4	0.1	0	0	0	
16850	Red onions, sliced, raw	½	cup(s)	57	50.7	24	0.5	5.8	0.8	0	0	0	0	
636	Scallions, green or spring onions	2	item(s)	30	26.9	10	0.5	2.2	0.8	0.1	0	0	0	
16860	**Palm hearts, cooked**	½	cup(s)	73	50.7	84	2.0	18.7	1.1	0.1	0	0	0.1	
637	**Parsley, chopped**	1	tablespoon(s)	4	3.3	1	0.1	0.2	0.1	0	0	0	0	
638	**Parsnips, sliced, boiled, drained**	½	cup(s)	78	62.6	55	1.0	13.3	2.8	0.2	0	0.1	0	
	Peas													
639	Green peas, canned, drained	½	cup(s)	85	69.4	59	3.8	10.7	3.5	0.3	0.1	0	0.1	
641	Green peas, frozen, boiled, drained	½	cup(s)	80	63.6	62	4.1	11.4	4.4	0.2	0	0	0.1	
35694	Pea pods, boiled with salt, drained	½	cup(s)	80	71.1	32	2.6	5.2	2.2	0.2	0	0	0.1	

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
2	0.38	23.0	191.1	0.8	0.51	8.2	0.02	0.05	0.05	1.07	0.08	28.7	2.9	0	0.6
12	0.20	9.8	110.6	1.5	0.14	3.8	0 01	0.01	0.01	0.07	0.03	5.3	2.1	0	0.2
7	3.61	6.0	87.8	765.8	0.38	—	0.02	—	0.02	0 34	0 08	17.3	2.6	0	—
74	0.95	12.6	121 8	23 1	0.15	179.6	0.07	1.28	0.09	0.27	0.08	6.8	9.5	0	0.2
103	1.70	19.8	218.3	41 8	0 22	279.4	0 10	1 89	0.14	0 44	0 13	14 8	19.2	0	0.3
3	0.12	5.4	60.9	0.5	0.06	1.0	0 04	0.20	0.01	0.30	0 04	6.9	0.6	0	0
26	0.41	7.5	157.0	11.0	0.39	54.0	0.04	0.22	0.03	0.20	0.01	71.0	3.2	0	0.1
16	0.78	15.5	194.0	5.2	0.20	1.3	0.02	0 59	0 04	0 25	0 05	15 5	26.1	0	0.9
90	0.61	11.7	208.7	9.8	0.11	477.8	0.02	0.59	0.07	0.43	0.05	9 1	16.4	0	0.6
90	1.14	22.8	299.5	28 8	0.29	515.2	0 07	—	0 08	0.66	0.18	19.4	80.4	0	0.6
21	0.33	15.7	280.5	17.3	0.26	1 7	0 03	0.43	0 02	0.32	0 13	9.9	44.6	0	0.7
32	0.54	25.7	472.5	27.0	0.04	2.7	0.06	0.64	0.02	0.54	0.20	21.6	83.7	0	0.9
16	0.56	7.3	45.2	5 2	0.02	1.0	0 01	—	0 01	0.10	0.04	12 5	2.2	0	0.3
53	1.86	24.9	160.2	17.8	0.10	73.9	0.05	0.81	0.02	0.35	0.20	57.0	10.7	0	0.9
9	1.65	17.8	182.7	1.0	0.63	0	0.08	0.05	0.04	0.52	0.09	89 6	0.7	0	1.4
19	2.47	28.5	247.9	8.5	1.16	1.5	0.17	—	0.09	0.86	0.14	77.0	12.7	0	0.5
29	1.02	10.7	196.4	4.1	0 16	137 0	0.04	0.14	0.05	0.29	0.06	60.2	3.1	0	0.5
19	0.68	7.1	130 9	2.7	0.11	91.3	0.03	0.09	0.03	0.19	0.04	40.1	2.0	0	0.3
10	0.22	3.8	77.5	5 5	0 08	13 7	0.02	0.09	0.01	0.07	0.02	15.9	1 5	0	0.1
10	0 22	3.8	77.5	5.5	0 08	13 7	0 02	0.09	0.01	0.07	0 02	15 9	1.5	0	0.1
13	0.31	4.7	69 8	10 1	0 06	133.2	0.02	0.10	0.02	0.13	0.03	13.7	6.5	0	0.2
18	0.54	7.8	138.3	4.5	0.13	162.4	0.04	0.07	0.03	0.17	0.04	76.2	13.4	0	0.2
0	0.67	—	—	32 6	—	0	—	—	—	—	—	—	0	0	—
1	0 98	14 4	331 2	2.7	0 54	0	0 16	0 01	0.14	5.31	0 07	46.8	0	0	2.0
5	1.35	9.4	277 7	1.6	0 67	0	0 05	0.01	0.23	3.47	0.07	14 0	3.1	0	9.3
9	0.61	11.7	100.6	331.5	0.56	0	0.06	0.01	0.01	1 24	0.04	9.4	0	0	3.2
1	0.24	4.3	152.6	2.4	0.25	0	0.04	0.01	0.19	1.73	0.05	7.7	1.0	0	4.5
39	0.35	—	—	9 9	—	0	—	—	—	—	—	—	0	0	—
2	0.31	10.2	84.8	2 9	0.96	0	0.02	0.02	0.12	1.08	0.11	15.2	0.2	0	18.0
76	0.84	9.8	104 3	18 8	0.15	265.5	0 03	1.01	0 04	0 19	0.08	52.5	10.4	0	0.5
58	0.81	17.9	198.2	14.0	0.11	294.0	0 04	1.12	0.06	0.45	0.10	104.7	39.2	0	0.5
54	1.13	32.2	170.8	109.7	0.44	14 0	0.16	1.50	0.12	1.29	0.11	39.6	9.2	0	3.6
88	0.61	46.9	215.3	2.8	0.57	15.6	0.09	0.29	0.11	0.72	0.04	134.3	11.2	0	0.6
62	0.22	28.8	108 0	4 8	0.34	11.2	0 10	0.21	0 04	0.69	0.15	36.8	13 0	0	0.3
23	0.24	11.5	174.3	3.1	0.21	0	0.03	0.02	0.02	0.17	0 12	15 7	5.5	0	0.6
17	0.32	6.4	114.5	12.7	0.06	0	0.02	0.01	0.02	0.14	0.06	13 8	2.8	0	0.4
22	1.20	13.5	91.6	266.3	0.29	7.8	0.19	—	0.09	2.56	0.05	46.9	1.0	0	2.5
18	0.16	8.0	116.8	3.2	0.13	0	0 03	0.01	0.02	0.09	0 09	15.2	5.9	0	0.4
13	0.10	5.7	82.4	1.7	0.09	0	0.02	0.01	0 01	0.04	0.08	10.9	3.7	0	0.3
22	0.44	6.0	82.8	4.8	0.11	15.0	0.01	0.16	0.02	0.15	0.01	19.2	5.6	0	0.2
13	1.23	7.3	1318.4	10.2	2.72	2.2	0.03	0.36	0.12	0.62	0 53	14.6	5.0	0	0.5
5	0.23	1.9	21.1	2.1	0.04	16.0	0.00	0 02	0.00	0 05	0.00	5.8	5.1	0	0
29	0.45	22.6	286.3	7.8	0.20	0	0.06	0.78	0.04	0.56	0.07	45.2	10.1	0	1.3
17	0.80	14.5	147.1	214.2	0.60	23.0	0.10	0.02	0.06	0.62	0.05	37.4	8.2	0	1.4
19	1.21	17.6	88.0	57.6	0.53	84.0	0.22	0.02	0.08	1.18	0.09	47.2	7.9	0	0.8
34	1.57	20.8	192.0	192.0	0.29	41.6	0.10	0.31	0.06	0.43	0.11	23.2	38.3	0	0.6

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA1 Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Vegetables, Legumes—*continued*													
1082	Peas and carrots, canned with liquid	½	cup(s)	128	112.4	48	2.8	10.8	2.6	0.3	0.1	0	0.2
1083	Peas and carrots, frozen, boiled, drained	½	cup(s)	80	68.6	38	2.5	8.1	2.5	0.3	0.1	0	0.2
2750	Snow or sugar peas, frozen, boiled, drained	½	cup(s)	80	69.3	42	2.8	7.2	2.5	0.3	0.1	0	0.1
640	Snow or sugar peas, raw	½	cup(s)	32	28.0	13	0.9	2.4	0.8	0.1	0	0	0
29324	Split peas, sprouted	½	cup(s)	60	37.4	77	5.3	16.9	—	0.4	0.1	0	0.2
	Peppers												
644	Green bell or sweet, boiled, drained	½	cup(s)	68	62.5	19	0.6	4.6	0.8	0.1	0	0	0.1
643	Green bell or sweet, raw	½	cup(s)	75	69.9	15	0.6	3.5	1.3	0.1	0	0	0
1664	Green hot chili	1	item(s)	45	39.5	18	0.9	4.3	0.7	0.1	0	0	0
1663	Green hot chili, canned with liquid	½	cup(s)	68	62.9	14	0.6	3.5	0.9	0.1	0	0	0
1086	Jalapeno, canned with liquid	½	cup(s)	68	60.4	18	0.6	3.2	1.8	0.6	0.1	0	0.3
8703	Yellow bell or sweet	1	item(s)	186	171.2	50	1.9	11.8	1.7	0.4	0.1	0	0.2
1087	**Poi**	½	cup(s)	120	86.0	134	0.5	32.7	0.5	0.2	0	0	0.1
	Potatoes												
1090	Au gratin mix, prepared with water, whole milk and butter	½	cup(s)	124	97.7	115	2.8	15.9	1.1	5.1	3.2	1.5	0.2
1089	Au gratin, prepared with butter	½	cup(s)	123	90.7	162	6.2	13.8	2.2	9.3	5.8	2.6	0.3
5791	Baked, flesh and skin	1	item(s)	202	151.3	188	5.1	42.7	4.4	0.3	0.1	0	0.1
645	Baked, flesh only	½	cup(s)	61	46.0	57	1.2	13.1	0.9	0.1	0	0	0
1088	Baked, skin only	1	item(s)	58	27.4	115	2.5	26.7	4.6	0.1	0	0	0
5795	Boiled in skin, flesh only, drained	1	item(s)	136	104.7	118	2.5	27.4	2.1	0.1	0	0	0.1
5794	Boiled, drained, skin and flesh	1	item(s)	150	115.9	129	2.9	29.8	2.5	0.2	0	0	0.1
647	Boiled, flesh only	½	cup(s)	78	60.4	67	1.3	15.6	1.4	0.1	0	0	0
648	French fried, deep fried, prepared from raw	14	item(s)	70	32.8	187	2.7	23.5	2.9	9.5	1.9	4.2	3.0
649	French fried, frozen, heated	14	item(s)	70	43.7	94	1.9	19.4	2.0	3.7	0.7	2.3	0.2
1091	Hashed brown	½	cup(s)	78	36.9	207	2.3	27.4	2.5	9.8	1.5	4.1	3.7
652	Mashed with margarine and whole milk	½	cup(s)	105	79.0	119	2.1	17.7	1.6	4.4	1.0	2.0	1.2
653	Mashed, prepared from dehydrated granules with milk, water, and margarine	½	cup(s)	105	79.8	122	2.3	16.9	1.4	5.0	1.3	2.1	1.4
2759	Microwaved	1	item(s)	202	145.5	212	4.9	49.0	4.6	0.2	0.1	0	0.1
2760	Microwaved in skin, flesh only	½	cup(s)	78	57.1	78	1.6	18.1	1.2	0.1	0	0	0
5804	Microwaved, skin only	1	item(s)	58	36.8	77	2.5	17.2	4.2	0.1	0	0	0
1097	Potato puffs, frozen, heated	½	cup(s)	64	38.2	122	1.3	17.8	1.6	5.5	1.2	3.9	0.3
1094	Scalloped mix, prepared with water, whole milk and butter	½	cup(s)	124	98.4	116	2.6	15.9	1.4	5.3	3.3	1.5	0.2
1093	Scalloped, prepared with butter	½	cup(s)	123	99.2	108	3.5	13.2	2.3	4.5	2.8	1.3	0.2
	Pumpkin												
1773	Boiled, drained	½	cup(s)	123	114.8	25	0.9	6.0	1.3	0.1	0	0	0
656	Canned	½	cup(s)	123	110.2	42	1.3	9.9	3.6	0.3	0.2	0	0
	Radicchio												
8731	Leaves, raw	1	cup(s)	40	37.3	9	0.6	1.8	0.4	0.1	0	0	0
2498	Raw	1	cup(s)	40	37.3	9	0.6	1.8	0.4	0.1	0	0	0
657	**Radishes**	6	item(s)	27	25.7	4	0.2	0.9	0.4	0	0	0	0
1099	**Rutabaga, boiled, drained**	½	cup(s)	85	75.5	33	1.1	7.4	1.5	0.2	0	0	0.1
658	**Sauerkraut, canned**	½	cup(s)	118	109.2	22	1.1	5.1	3.4	0.2	0	0	0.1
	Seaweed												
1102	Kelp	½	cup(s)	40	32.6	17	0.6	3.8	0.5	0.2	0.1	0	0
1104	Spirulina, dried	½	cup(s)	8	0.4	22	4.3	1.8	0.3	0.6	0.2	0.1	0.2
1106	**Shallots**	3	tablespoon(s)	30	23.9	22	0.8	5.0	—	0	0	0	0
	Soybeans												
1670	Boiled	½	cup(s)	86	53.8	149	14.3	8.5	5.2	7.7	1.1	1.7	4.4
2825	Dry roasted	½	cup(s)	86	0.7	388	34.0	28.1	7.0	18.6	2.7	4.1	10.5
2824	Roasted, salted	½	cup(s)	86	1.7	405	30.3	28.9	15.2	21.8	3.2	4.8	12.3
8739	Sprouted, stir fried	½	cup(s)	63	42.3	79	8.2	5.9	0.5	4.5	0.6	1.0	2.5
	Soy products												
1813	Soy milk	1	cup(s)	240	211.3	130	7.8	15.1	1.4	4.2	0.5	1.0	2.3
2838	Tofu, dried, frozen (koyadofu)	3	ounce(s)	85	4.9	408	40.8	12.4	6.1	25.8	3.7	5.7	14.6

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	29	0.96	17.9	127.5	331.5	0.74	368.5	0.09	—	0.07	0.74	0.11	23.0	8.4	0	1.1
	18	0.75	12.8	126.4	54.4	0.36	380.8	0.18	0.41	0.05	0.92	0.07	20.8	6.5	0	0.9
	47	1.92	22.4	173.6	4.0	0.39	52.8	0.05	0.37	0.09	0.45	0.13	28.0	17.6	0	0.6
	14	0.65	7.6	63.0	1.3	0.08	17.0	0 04	0.12	0.02	0.19	0.05	13.2	18.9	0	0.2
	22	1.34	33.6	228.6	12.0	0.62	4.8	0.12	—	0.08	1.84	0 14	86.4	6.2	0	0.4
	6	0.31	6.8	112.9	1.4	0.08	15.6	0.04	0.34	0.02	0.32	0.15	10.9	50.6	0	0.2
	7	0.25	7.5	130.4	2.2	0.09	13 4	0.04	0 27	0 02	0.35	0 16	7.5	59.9	0	0
	8	0.54	11.3	153.0	3.2	0.13	26.6	0.04	0.31	0.04	0.42	0.12	10.4	109.1	0	0.2
	5	0.34	9.5	127.2	797.6	0.10	24.5	0.01	0.46	0.02	0.54	0.10	6.8	46.2	0	0.2
	16	1.28	10.2	131.2	1136.3	0.23	57.8	0.03	0.47	0.03	0.27	0.13	9.5	6.8	0	0 3
	20	0.85	22.3	394.3	3.7	0.31	18.6	0 05	—	0.04	1.65	0.31	48.4	341.3	0	0.6
	19	1.06	28.8	219.6	14.4	0.26	3.6	0.16	2.76	0.05	1.32	0.33	25.2	4.8	0	0.8
	103	0.39	18.6	271.0	543.3	0.29	64.4	0.02	—	0.10	1.16	0.05	8.7	3.8	0	3.3
	146	0.78	24.5	485 1	530.4	0.85	78.4	0 08	—	0 14	1.22	0 21	13.5	12.1	0	3.3
	30	2.18	56.6	1080 7	20.2	0.72	2.0	0 12	0 08	0 09	2 84	0 62	56.6	19.4	0	0.8
	3	0.21	15.3	238.5	3.1	0.18	0	0.06	0 02	0.01	0 85	0 18	5 5	7.8	0	0.2
	20	4.08	24.9	332.3	12.2	0.28	0.6	0 07	0.02	0.06	1.77	0.35	12 8	7.8	0	0.4
	7	0.42	29.9	515.4	5.4	0.40	0	0.14	0.01	0.02	1.95	0.40	13.6	17.7	0	0.4
	13	1.27	34.1	572.0	7.4	0.46	0	0.14	0.01	0.03	2.13	0.44	15.0	18.4	0	—
	6	0.24	15.6	255.8	3.9	0.21	0	0.07	0.01	0 01	1.02	0.21	7.0	5.8	0	0.2
	16	1.05	30.8	567.0	8.4	0.39	0	0.08	0.09	0.03	1.34	0.37	16.1	21.2	0	0.4
	8	0.51	18.2	315 7	271.6	0.26	0	0.09	0.07	0 02	1 55	0 12	19.6	9.3	0	0.1
	11	0.43	27.3	449.3	266.8	0.37	0	0.13	0.01	0.03	1.80	0.37	12.5	10.1	0	0.4
	23	0.27	19.9	344.4	349.6	0.31	43.0	0.09	0.44	0.04	1.23	0.25	9.4	11.0	0.1	0.8
	36	0.21	21.0	164.8	179.5	0.26	49.3	0.09	0.53	0.09	0.90	0.16	8.4	6.8	0.1	5.9
	22	2.50	54.5	902.9	16.2	0.72	0	0.24	—	0.06	3.46	0.69	24.2	30.5	0	0.8
	4	0.31	19.4	319.0	5.4	0.25	0	0.10	—	0.01	1.26	0.25	9.3	11.7	0	0.3
	27	3.44	21.5	377.0	9 3	0.29	0	0.04	0.01	0.04	1.28	0.28	9.9	8.9	0	0.3
	9	0.41	10.9	199.7	307.2	0.21	0	0 08	0.15	0.02	0.97	0.08	9.0	4.0	0	0.4
	45	0.47	17.4	252.2	423.7	0.31	43.5	0.02	—	0.06	1.28	0.05	12.4	4.1	0	2.0
	70	0.70	23.3	463.1	410.4	0.49	0	0.08	—	0.11	1.29	0.22	13.5	13.0	0	2.0
	18	0.69	11.0	281.8	1.2	0 28	306.3	0 03	0 98	0.09	0 50	0 05	11.0	5.8	0	0.2
	32	1.70	28.2	252.4	6.1	0.20	953.1	0.02	1.29	0.06	0.45	0.06	14.7	5.1	0	0.5
	8	0.23	5.2	120.8	8.8	0.25	0.4	0.01	0.90	0.01	0.10	0.02	24.0	3.2	0	0.4
	8	0.23	5.2	120.8	8.8	0.25	0.4	0.01	0 90	0.01	0 10	0.02	24.0	3.2	0	0.4
	7	0.09	2.7	62.9	10.5	0.07	0	0.00	0.00	0.01	0.06	0.01	6.8	4.0	0	0.2
	41	0.45	19.6	277.1	17.0	0.30	0	0.07	0.27	0.04	0.61	0.09	12.8	16.0	0	0.6
	35	1.73	15.3	200.6	780.0	0.22	1.2	0.03	0.17	0.03	0.17	0.15	28.3	17.3	0	0.7
	67	1.12	48.4	35.6	93.2	0.48	2.4	0.02	0.32	0.04	0.16	0.00	72.0	1.2	0	0.3
	9	2.14	14.6	102.2	78.6	0.15	2.2	0.18	0.38	0.28	0.96	0.03	7.1	0.8	0	0.5
	11	0.36	6.3	100.2	3.6	0.12	18.0	0.02	—	0.01	0.06	0.09	10.2	2.4	—	0.4
	88	4.42	74.0	442.9	0.9	0.98	0	0.13	0.30	0.24	0.34	0.20	46.4	1.5	0	6.3
	120	3.39	196.1	1173.0	1.7	4.10	0	0.36	—	0.64	0.90	0.19	176.3	4.0	0	16.6
	119	3.35	124.7	1264.2	140.2	2.70	8.6	0.08	0.78	0.12	1.21	0.17	181.5	1.9	0	16.4
	52	0.25	60.4	356.6	8.8	1.32	0.6	0.26	—	0.12	0.69	0.10	79.9	7.5	0	0.4
	60	1.53	60.0	283.2	122.4	0.28	0	0.14	0.26	0.16	1.23	0.18	43.2	0	0	11.5
	310	8.27	50.2	17.0	5.1	4.16	22.1	0.42	—	0.27	1.01	0.24	78.2	0.6	0	46.2

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

NDA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Vegetables, Legumes—*continued*													
13844	Tofu, extra firm	3	ounce(s)	85	—	86	8.6	2.2	1.1	4.3	0.5	0.9	2.8
13843	Tofu, firm	3	ounce(s)	85	—	75	7.5	2.2	0.5	3.2	0	0.9	2.3
1816	Tofu, firm, with calcium sulfate and magnesium chloride (nigari)	3	ounce(s)	85	72.2	60	7.0	1.4	0.8	3.5	0.7	1.0	1.5
1817	Tofu, fried	3	ounce(s)	85	43.0	230	14.6	8.9	3.3	17.2	2.5	3.8	9.7
13841	Tofu, silken	3	ounce(s)	85	—	42	3.7	1.9	0	2.3	0.5	—	—
13842	Tofu, soft	3	ounce(s)	85	—	65	6.5	1.1	0.5	3.2	0.5	1.1	2.2
1671	Tofu, soft, with calcium sulfate and magnesium chloride (nigari)	3	ounce(s)	85	74.2	52	5.6	1.5	0.2	3.1	0.5	0.7	1.8
	Spinach												
663	Canned, drained	½	cup(s)	107	98.2	25	3.0	3.6	2.6	0.5	0.1	0	0.2
660	Chopped, boiled, drained	½	cup(s)	90	82.1	21	2.7	3.4	2.2	0.2	0	0	0.1
661	Chopped, frozen, boiled, drained	½	cup(s)	95	84.5	32	3.8	4.6	3.5	0.8	0.1	0	0.4
662	Leaf, frozen, boiled, drained	½	cup(s)	95	84.5	32	3.8	4.6	3.5	0.8	0.1	0	0.4
659	Raw, chopped	1	cup(s)	30	27.4	7	0.9	1.1	0.7	0.1	0	0	0
8470	Trimmed leaves	1	cup(s)	32	27.5	3	0.9	0	2.8	0.1	—	—	—
	Squash												
1662	Acorn winter, baked	½	cup(s)	103	85.0	57	1.1	14.9	4.5	0.1	0	0	0.1
29702	Acorn winter, boiled, mashed	½	cup(s)	123	109.9	42	0.8	10.8	3.2	0.1	0	0	0
29451	Butternut, frozen, boiled	½	cup(s)	122	106.9	47	1.5	12.2	1.8	0.1	0	0	0
1661	Butternut winter, baked	½	cup(s)	102	89.5	41	0.9	10.7	3.4	0.1	0	0	0
32773	Butternut winter, frozen, boiled, mashed, no salt added	½	cup(s)	121	106.4	47	1.5	12.2	—	0.1	0	0	0
29700	Crookneck and straightneck summer, boiled, drained	½	cup(s)	65	60.9	12	0.6	2.6	1.2	0.1	0	0	0.1
29703	Hubbard winter, baked	½	cup(s)	102	86.8	51	2.5	11.0	—	0.6	0.1	0	0.3
1660	Hubbard winter, boiled, mashed	½	cup(s)	118	107.5	35	1.7	7.6	3.4	0.4	0.1	0	0.2
29704	Spaghetti winter, boiled, drained, or baked	½	cup(s)	78	71.5	21	0.5	5.0	1.1	0.2	0	0	0.1
664	Summer, all varieties, sliced, boiled, drained	½	cup(s)	90	84.3	18	0.8	3.9	1.3	0.3	0.1	0	0.1
665	Winter, all varieties, baked, mashed	½	cup(s)	103	91.4	38	0.9	9.1	2.9	0.4	0.1	0	0.2
1112	Zucchini summer, boiled, drained	½	cup(s)	90	85.3	14	0.6	3.5	1.3	0	0	0	0
1113	Zucchini summer, frozen, boiled, drained	½	cup(s)	112	105.6	19	1.3	4.0	1.4	0.1	0	0	0.1
	Sweet potatoes												
666	Baked, peeled	½	cup(s)	100	75.8	90	2.0	20.7	3.3	0.2	0	0	0.1
667	Boiled, mashed	½	cup(s)	164	131.4	125	2.2	29.1	4.1	0.2	0.1	0	0.1
668	Candied, home recipe	½	cup(s)	91	61.1	132	0.8	25.4	2.2	3.0	1.2	0.6	0.1
670	Canned, vacuum pack	½	cup(s)	100	76.0	91	1.7	21.1	1.8	0.2	0	0	0.1
2765	Frozen, baked	½	cup(s)	88	64.5	88	1.5	20.5	1.6	0.1	0	0	0
1136	Yams, baked or boiled, drained	½	cup(s)	68	47.7	79	1.0	18.7	2.7	0.1	0	0	0
32785	**Taro shoots, cooked, no salt added**	½	cup(s)	70	66.7	10	0.5	2.2	—	0.1	0	0	0
	Tomatillo												
8774	Raw	2	item(s)	68	62.3	22	0.7	4.0	1.3	0.7	0.1	0.1	0.3
8777	Raw, chopped	½	cup(s)	66	60.5	21	0.6	3.9	1.3	0.7	0.1	0.1	0.3
	Tomato												
16846	Cherry, fresh	5	item(s)	85	80.3	15	0.7	3.3	1.0	0.2	0	0	0.1
671	Fresh, ripe, red	1	item(s)	123	116.2	22	1.1	4.8	1.5	0.2	0	0	0.1
675	Juice, canned	½	cup(s)	122	114.1	21	0.9	5.2	0.5	0.1	0	0	0
75	Juice, no salt added	½	cup(s)	122	114.1	21	0.9	5.2	0.5	0.1	0	0	0
1699	Paste, canned	2	tablespoon(s)	33	24.1	27	1.4	6.2	1.3	0.2	0	0	0.1
1700	Puree, canned	¼	cup(s)	63	54.9	24	1.0	5.6	1.2	0.1	0	0	0.1
1118	Red, boiled	½	cup(s)	120	113.2	22	1.1	4.8	0.8	0.1	0	0	0.1
3952	Red, diced	½	cup(s)	90	85.1	16	0.8	3.5	1.1	0.2	0	0	0.1
1120	Red, stewed, canned	½	cup(s)	128	116.7	33	1.2	7.9	1.3	0.2	0	0	0.1
1125	Sauce, canned	¼	cup(s)	61	55.6	15	0.8	3.3	0.9	0.1	0	0	0
8778	Sun dried	½	cup(s)	27	3.9	70	3.8	15.1	3.3	0.8	0.1	0.1	0.3
8783	Sun dried in oil, drained	¼	cup(s)	28	14.8	59	1.4	6.4	1.6	3.9	0.5	2.4	0.6
	Turnips												
678	Turnip greens, chopped, boiled, drained	½	cup(s)	72	67.1	14	0.8	3.1	2.5	0.2	0	0	0.1

= Breads/Baked Goods H-10 = Cereal/Rice/Pasta H-14 = Fruit H-18 = Vegetables/Legumes H-28 = Nuts/Seeds H-30 = Vegetarian H-32 = Dairy H-40 = Eggs H-40 = Seafood H-42 = Meats H-46 = Poultry
sed Meats H-48 = Beverages H-52 = Fats/Oils H-54 = Sweets H-56 = Spices/Condiments/Sauces H-60 = Mixed Foods/Soups/Sandwiches H-64 = Fast Food H-84 = Convenience H-86 = Baby Foods

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
65	1.16	84.1	—	0	—	0	—	—	—	—	—	—	0	0	—
108	1.16	56.1	—	0	—	0	—	—	—	—	—	—	0	0	—
171	1.36	31.5	125.9	10.2	0.70	0	0.05	0.01	0.05	0.08	0.06	16.2	0.2	0	8.4
316	4.14	51.0	124.2	13.6	1.69	0.9	0.14	0.03	0.04	0.08	0.08	23.0	0	0	24.2
56	0.34	33.1	—	4.7	—	0	—	—	—	—	—	—	0	1.7	—
108	1.16	35.5	—	0	—	0	—	—	—	—	—	—	0	1.9	—
94	0.94	23.0	102.1	6.8	0.54	0	0.04	0.01	0.03	0.45	0.04	37.4	0.2	0	7.6
136	2.45	81.3	370 2	28.9	0 48	524.3	0.02	2.08	0 14	0 41	0 11	104.8	15 3	0	1.5
122	3.21	78.3	419.4	63.0	0.68	471.6	0.08	1.87	0.21	0.44	0.21	131.4	8.8	0	1.4
145	1.86	77.9	286.9	92.2	0.46	572.9	0.07	3.36	0.16	0.41	0.12	115.0	2.1	0	5.2
145	1.86	77.9	286.9	92.2	0.46	572.9	0 07	3.36	0.16	0.41	0.12	115.0	2.1	0	5.2
30	0.81	23.7	167.4	23.7	0.16	140.7	0.02	0.61	0.06	0.22	0.06	58.2	8.4	0	0.3
25	2.13	25.5	134.1	38.0	0.18	—	0.03	—	0.05	0.18	0.07	0	7.5	0	—
45	0 95	44.1	447.9	4 1	0 17	21.5	0 17	—	0 01	0 90	0.19	19 5	11.1	0	0.7
32	0.68	31.9	322.2	3.7	0.13	50.2	0 12	—	0.01	0.65	0 14	13.5	8.0	0	0.5
23	0.70	10.9	161.9	2.4	0.14	203.3	0 06	0.14	0 05	0 56	0 08	19.5	4.3	0	0.6
42	0.61	29.6	289.6	4.1	0 13	569 1	0 07	1.31	0.01	0.99	0.12	19.4	15.4	0	0.5
23	0.70	10.9	161.2	2.4	0.14	202.4	0.06	—	0.05	0.56	0.08	19.4	4.2	0	0.6
14	0.31	13.6	137.1	1.3	0.19	5.2	0.03	—	0.02	0.29	0.07	14.9	5.4	0	0.1
17	0.48	22.4	365.1	8.2	0.15	308.0	0 07	—	0.04	0 57	0 17	16.3	9.7	0	0.6
12	0.33	15.3	252.5	5.9	0.11	236.0	0.05	0 14	0.03	0 39	0.12	11.8	7.7	0	0.4
16	0.26	8.5	90.7	14.0	0.15	4.7	0.02	0.09	0.01	0.62	0.07	6.2	2.7	0	0.2
24	0.32	21.6	172.8	0.9	0.35	9.9	0.04	0.12	0.03	0.46	0.05	18.0	5.0	0	0.2
23	0.45	13.3	247.0	1.0	0.23	267 5	0.02	0.12	0.07	0 51	0.17	20.5	9.8	0	0.4
12	0.32	19.8	227.7	2.7	0.16	50.4	0.04	0.11	0.04	0.39	0.07	15.3	4.1	0	0.2
19	0.54	14.5	216.3	2.2	0.22	10	0.05	0.13	0 04	0.43	0.05	8.9	4.1	0	0.2
38	0.69	27.0	475.0	36.0	0.32	961.0	0.10	0.71	0 10	1.48	0.28	6.0	19.6	0	0.2
44	1.18	29.5	377.2	44.3	0.33	1290.7	0.09	1.54	0.08	0 88	0.27	9.8	21.0	0	0.3
24	1.03	10.0	172.6	63.9	0.13	0	0.01	—	0.03	0.36	0.03	10.0	6.1	0	0.7
22	0.89	22.0	312.0	53.0	0 18	399 0	0.04	1.00	0.06	0.74	0 19	17.0	26.4	0	0.7
31	0.47	18.4	330 1	7.0	0.26	913.3	0.05	0.67	0.04	0.49	0 16	19.3	8.0	0	0.5
10	0.35	12.2	455 6	5.4	0 13	4.1	0.06	0.23	0.01	0 37	0.15	10.9	8.2	0	0.5
10	0.28	5.6	240.8	1.4	0.37	2.1	0.02	—	0.03	0.56	0.07	2.1	13.2	0	0.7
5	0.42	13.6	182.2	0.7	0.15	4.1	0.03	0.25	0.02	1.25	0.03	4 8	8.0	0	0.3
5	0.41	13.2	176.9	0.7	0 15	4.0	0.03	0.25	0.02	1.22	0 04	4.6	7.7	0	0.3
9	0.22	9.4	201.5	4.3	0.14	35.7	0.03	0.45	0.01	0.50	0.06	12.8	10.8	0	0
12	0.33	13.5	291.5	6.2	0.20	51.7	0.04	0.66	0.02	0.73	0.09	18.5	15.6	0	0
12	0.52	13.4	278.2	326.8	0.18	27.9	0.06	0.39	0.04	0.82	0.14	24.3	22.2	0	0.4
12	0.52	13.4	278.2	12.2	0.18	27.9	0.06	0.39	0.04	0.82	0.14	24.3	22.2	0	0.4
12	0.97	13.8	332.6	259.1	0.20	24.9	0.02	1.41	0.05	1.00	0.07	3.9	7.2	0	1.7
11	1.11	14.4	274.4	249.4	0.22	16.3	0.01	1.23	0.05	0.91	0.07	6.9	6.6	0	0.4
13	0.82	10.8	261.6	13.2	0.17	28.8	0.04	0.67	0.03	0.64	0.10	15.6	27.4	0	0.6
9	0.24	9.9	213.3	4.5	0.15	37.8	0.03	0.48	0.01	0.53	0.07	13.5	11.4	0	0
43	1.70	15.3	263.9	281.8	0.22	11.5	0.06	1.06	0.04	0.91	0.02	6.4	10.1	0	0.8
8	0.62	9.8	201.9	319.6	0.12	10.4	0.01	0.87	0.04	0.59	0.06	6.7	4.3	0	0.1
30	2.45	52.4	925.3	565.7	0.53	11.9	0.14	0.00	0.13	2.44	0.09	18.4	10.6	0	1.5
13	0.73	22.3	430.4	73.2	0.21	17.6	0.05	—	0.10	0.99	0.08	6.3	28.0	0	0.8
99	0.58	15.8	146.2	20.9	0.10	274.3	0.03	1.35	0.05	0.30	0.13	85.0	19.7	0	0.6

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA's Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Vegetables, Legumes—*continued*													
679	Turnip greens, frozen, chopped, boiled, drained	½	cup(s)	82	74.1	24	2.7	4.1	2.8	0.3	0.1	0	0.1
677	Turnips, cubed, boiled, drained	½	cup(s)	78	73.0	17	0.6	3.9	1.6	0.1	0	0	0
	Vegetables, mixed												
1132	Canned, drained	½	cup(s)	82	70.9	40	2.1	7.5	2.4	0.2	0	0	0.1
680	Frozen, boiled, drained	½	cup(s)	91	75.7	59	2.6	11.9	4.0	0.1	0	0	0.1
7489	V8 100% vegetable juice	½	cup(s)	120	—	25	1.0	5.0	1.0	0	0	0	0
7490	V8 low sodium vegetable juice	½	cup(s)	120	—	25	0	6.5	1.0	0	0	0	0
7491	V8 spicy hot vegetable juice	½	cup(s)	120	—	25	1.0	5.0	0.5	0	0	0	0
	Water chestnuts												
31073	Sliced, drained	½	cup(s)	75	70.0	20	0	5.0	1.0	0	0	0	0
31087	Whole	½	cup(s)	75	70.0	20	0	5.0	1.0	0	0	0	0
1135	**Watercress**	1	cup(s)	34	32.3	4	0.8	0.4	0.2	0	0	0	0
Nuts, Seeds, and Products													
	Almonds												
32940	Almond butter with salt added	1	tablespoon(s)	16	0.2	101	2.4	3.4	0.6	9.5	0.9	6.1	2.0
1137	Almond butter, no salt added	1	tablespoon(s)	16	0.2	101	2.4	3.4	0.6	9.5	0.9	6.1	2.0
32886	Blanched	¼	cup(s)	36	1.6	211	8.0	7.2	3.8	18.3	1.4	11.7	4.4
32887	Dry roasted, no salt added	¼	cup(s)	35	0.9	206	7.6	6.7	4.1	18.2	1.4	11.6	4.4
29724	Dry roasted, salted	¼	cup(s)	35	0.9	206	7.6	6.7	4.1	18.2	1.4	11.6	4.4
29725	Oil roasted, salted	¼	cup(s)	39	1.1	238	8.3	6.9	4.1	21.7	1.7	13.7	5.3
508	Slivered	¼	cup(s)	27	1.3	155	5.7	5.9	3.3	13.3	1.0	8.3	3.3
1138	**Beechnuts, dried**	¼	cup(s)	57	3.8	328	3.5	19.1	5.3	28.5	3.3	12.5	11.4
517	**Brazil nuts, dried, unblanched**	¼	cup(s)	35	1.2	230	5.0	4.3	2.6	23.3	5.3	8.6	7.2
1166	**Breadfruit seeds, roasted**	¼	cup(s)	57	28.3	118	3.5	22.8	3.4	1.5	0.4	0.2	0.8
1139	**Butternuts, dried**	¼	cup(s)	30	1.0	184	7.5	3.6	1.4	17.1	0.4	3.1	12.8
	Cashews												
32931	Cashew butter with salt added	1	tablespoon(s)	16	0.5	94	2.8	4.4	0.3	7.9	1.6	4.7	1.3
32889	Cashew butter, no salt added	1	tablespoon(s)	16	0.5	94	2.8	4.4	0.3	7.9	1.6	4.7	1.3
1140	Dry roasted	¼	cup(s)	34	0.6	197	5.2	11.2	1.0	15.9	3.1	9.4	2.7
518	Oil roasted	¼	cup(s)	32	1.1	187	5.4	9.6	1.1	15.4	2.7	8.4	2.8
	Coconut, shredded												
32896	Dried, not sweetened	¼	cup(s)	23	0.7	152	1.6	5.4	3.8	14.9	13.2	0.6	0.2
1153	Dried, shredded, sweetened	¼	cup(s)	23	2.9	116	0.7	11.1	1.0	8.3	7.3	0.4	0.1
520	Shredded	¼	cup(s)	20	9.4	71	0.7	3.0	1.8	6.7	5.9	0.3	0.1
	Chestnuts												
1152	Chinese, roasted	¼	cup(s)	36	14.6	87	1.6	19.0	—	0.4	0.1	0.2	0.1
32895	European, boiled and steamed	¼	cup(s)	46	31.3	60	0.9	12.8	—	0.6	0.1	0.2	0.2
32911	European, roasted	¼	cup(s)	36	14.5	88	1.1	18.9	1.8	0.8	0.1	0.3	0.3
32922	Japanese, boiled and steamed	¼	cup(s)	36	31.0	20	0.3	4.5	—	0.1	0	0	0
32923	Japanese, roasted	¼	cup(s)	36	18.1	73	1.1	16.4	—	0.3	0	0.1	0.1
4958	**Flax seeds or linseeds**	¼	cup(s)	43	3.3	225	8.4	12.3	11.9	17.7	1.7	3.2	12.6
32904	**Ginkgo nuts, dried**	¼	cup(s)	39	4.8	136	4.0	28.3	—	0.8	0.1	0.3	0.3
	Hazelnuts or filberts												
32901	Blanched	¼	cup(s)	30	1.7	189	4.1	5.1	3.3	18.3	1.4	14.5	1.7
32902	Dry roasted, no salt added	¼	cup(s)	30	0.8	194	4.5	5.3	2.8	18.7	1.3	14.0	2.5
1156	**Hickory nuts, dried**	¼	cup(s)	30	0.8	197	3.8	5.5	1.9	19.3	2.1	9.8	6.6
	Macadamias												
32905	Dry roasted, no salt added	¼	cup(s)	34	0.5	241	2.6	4.5	2.7	25.5	4.0	19.9	0.5
32932	Dry roasted, with salt added	¼	cup(s)	34	0.5	240	2.6	4.3	2.7	25.5	4.0	19.9	0.5
1157	Raw	¼	cup(s)	34	0.5	241	2.6	4.6	2.9	25.4	4.0	19.7	0.5
	Mixed nuts												
1159	With peanuts, dry roasted	¼	cup(s)	34	0.6	203	5.9	8.7	3.1	17.6	2.4	10.8	3.7
32933	With peanuts, dry roasted, with salt added	¼	cup(s)	34	0.6	203	5.9	8.7	3.1	17.6	2.4	10.8	3.7
32906	Without peanuts, oil roasted, no salt added	¼	cup(s)	36	1.1	221	5.6	8.0	2.0	20.2	3.3	11.9	4.1
	Peanuts												
2807	Dry roasted	¼	cup(s)	37	0.6	214	8.6	7.9	2.9	18.1	2.5	9.0	5.7
2806	Dry roasted, salted	¼	cup(s)	37	0.6	214	8.6	7.9	2.9	18.1	2.5	9.0	5.7
1763	Oil roasted, salted	¼	cup(s)	36	0.5	216	10.1	5.5	3.4	18.9	3.1	9.4	5.5
1884	Peanut butter, chunky	1	tablespoon(s)	16	0.2	94	3.8	3.5	1.3	8.0	1.3	3.9	2.4
30303	Peanut butter, low sodium	1	tablespoon(s)	16	0.2	95	4.0	3.1	0.9	8.2	1.8	3.9	2.2
30305	Peanut butter, reduced fat	1	tablespoon(s)	18	0.2	94	4.7	6.4	0.9	6.1	1.3	2.9	1.8

ol (g)	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	125	1.59	21.3	183.7	12.3	0.34	441.2	0.04	2.18	0.06	0.38	0.06	32 0	17.9	0	1.0
	26	0.14	7.0	138.1	12.5	0.09	0	0.02	0.02	0.02	0.23	0.05	7.0	9.0	0	0.2
	22	0.86	13.0	237.2	121.4	0.33	475.1	0.04	0.24	0.04	0.47	0.06	19.6	4.1	0	0.2
	23	0.74	20.0	153.8	31.9	0.44	194.7	0.06	0.34	0.10	0 77	0.06	17.3	2.9	0	0.3
	20	0.36	12.9	260.0	310.0	0.24	100.0	0 05	—	0.03	0.87	0 17	—	30.0	0	—
	20	0.36	—	450.0	70.0	—	100.0	0.02	—	0.02	0.75	—	—	30.0	0	—
	20	0.36	12.9	240.0	360.0	0.24	50.0	0.05	—	0.03	0.88	0.17	—	15.0	0	—
	7	0.00	—	—	5.0	—	0	—	—	—	—	—	—	2.0	—	—
	7	0.00	—	—	5.0	—	0	—	—	—	—	—	—	2.0	—	—
	41	0.06	7.1	112.2	13.9	0.03	54.4	0.03	0.34	0.04	0.06	0.04	3.1	14.6	0	0.3
	43	0.59	48.5	121.3	72.0	0.49	0	0.02	4.16	0 10	0.46	0.01	10.4	0.1	0	0.8
	43	0.59	48.5	121.3	1.8	0 48	0	0.02	—	0.09	0.46	0.01	10.4	0.1	0	—
	78	1.34	99.7	249.0	10.2	1.13	0	0.07	8.95	0.20	1.32	0 04	10 9	0	0	1.0
	92	1.55	98.7	257.4	0.3	1.22	0	0.02	8.97	0.29	1 32	0.04	11.4	0	0	1.0
	92	1.55	98.7	257.4	117.0	1.22	0	0.02	8.97	0.29	1.32	0.04	11.4	0	0	1.0
	114	1.44	107.5	274.4	133.1	1.20	0	0.03	10.19	0.30	1.43	0.04	10.6	0	0	1.1
	71	1.00	72.4	190 4	0.3	0.83	0	0.05	7.07	0.27	0.91	0.03	13.5	0	0	0.7
	1	1.39	0	579.7	21.7	0.20	0	0.16	—	0.20	0.48	0.38	64.4	8.8	0	4.0
	56	0.85	131.6	230.7	1.1	1.42	0	0.21	2.00	0 01	0.10	0.03	7.7	0.2	0	671.0
	49	0.50	35.3	616.7	15.9	0.58	8.5	0 22	—	0 12	4.20	0 22	33.6	4.3	0	8.0
	16	1.21	71.1	126.3	0.3	0.94	1.8	0.12	—	0.04	0.31	0.17	19 8	1.0	0	5.2
	7	0.81	41.3	87.4	98.2	0.83	0	0.05	0.15	0.03	0.26	0.04	10.9	0	0	1.8
	7	0.81	41.3	87.4	2.4	0.83	0	0.05	—	0.03	0.26	0.04	10.9	0	0	1.8
	15	2.06	89.1	193.5	5.5	1.92	0	0.07	0.32	0.07	0.48	0.09	23.6	0	0	4.0
	14	1.95	88.0	203.8	4.2	1.73	0	0.12	0.30	0.07	0.56	0.10	8.1	0.1	0	6.5
	6	0.76	20.7	125.2	8.5	0.46	0	0.01	0.10	0.02	0.13	0.07	2.1	0.3	0	4.3
	3	0.45	11.6	78.4	60.9	0.42	0	0 01	0.09	0.00	0.11	0 06	1.9	0.2	0	3.9
	3	0.48	6.4	71.2	4.0	0.21	0	0.01	0.04	0.00	0.11	0.01	5.2	0.7	0	2.0
	7	0.54	32.6	173.0	1.4	0.33	0	0.05	—	0.03	0.54	0.15	26.1	13.9	0	2.6
	21	0.80	24.8	328.9	12.4	0.11	0.5	0.06	—	0.03	0.32	0.10	17.5	12.3	0	—
	10	0.32	11.8	211.6	0.7	0.20	0.4	0.08	0.18	0.05	0.48	0.18	25.0	9.3	0	0.4
	4	0.19	6.5	42.8	1.8	0.14	0.4	0.04	—	0.01	0.19	0.03	6.1	3.4	0	—
	13	0.75	23.2	154.8	6.9	0.51	1.4	0.15	—	—	0.24	0.14	21.4	10.1	0	—
	142	2.13	156.1	354.0	11.9	1.83	0	0.06	0.14	0.06	0.59	0.39	118.4	0.5	0	2.3
	8	0.62	20.7	390.2	5.1	0.26	21.5	0.17	—	0.07	4.58	0.25	41.4	11.4	0	—
	45	0.98	48.0	197.4	0	0.66	0.6	0.14	5.25	0.03	0.46	0.17	23.4	0.6	0	1.2
	37	1.31	51.9	226.5	0	0.74	0.9	0.10	4.58	0.03	0.61	0.18	26.4	1.1	0	1.2
	18	0.64	51.9	130.8	0.3	1.29	2.1	0.26	—	0.04	0.27	0.06	12.0	0.6	0	2.4
	23	0.88	39.5	121.6	1.3	0.43	0	0.23	0.19	0.02	0.76	0.12	3.4	0.2	0	3.9
	23	0.88	39.5	121.6	88.8	0.43	0	0.23	0.19	0.02	0.76	0.12	3.4	0.2	0	3.9
	28	1.24	43.6	123.3	1.7	0.44	0	0.40	0.18	0.05	0.83	0.09	3.7	0.4	0	1.2
	24	1.27	77.1	204.5	4.1	1.30	0.3	0.07	—	0.07	1.61	0.10	17.1	0.1	0	1.0
	24	1.26	77.1	204.5	229.1	1.30	0	0.06	3.74	0.06	1.61	0.10	17.1	0.1	0	2.6
	38	0.92	90.4	195.8	4.0	1.67	0.4	0.18	—	0.17	0.70	0.06	20.2	0.2	0	—
	20	0.82	64.2	240.2	2.2	1.20	0	0.16	2.52	0.03	4.93	0.09	52.9	0	0	2.7
	20	0.82	64.2	240.2	296.7	1.20	0	0.16	2.84	0.03	4.93	0.09	52.9	0	0	2.7
	22	0.54	63.4	261.4	115.2	1.18	0	0.03	2.49	0.03	4.97	0.16	43.2	0.3	0	1.2
	7	0.30	25.6	119.2	77.8	0.45	0	0.02	1.01	0.02	2.19	0.07	14.7	0	0	1.3
	6	0.29	25.4	107.0	2.7	0.47	0	0.01	1.23	0.02	2.14	0.07	11.8	0	0	1.2
	6	0.34	30.6	120.4	97.2	0.50	0	0.05	1.20	0.01	2.63	0.06	10.8	0	0	1.4

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

NLEA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	
Nuts, Seeds, and Products—*continued*														
524	Peanut butter, smooth	1	tablespoon(s)	16	0.3	94	4.0	3.1	1.0	8.1	1.7	3.9	2.3	
2804	Raw	¼	cup(s)	37	2.4	207	9.4	5.9	3.1	18.0	2.5	8.9	5.7	
	Pecans													
32907	Dry roasted, no salt added	¼	cup(s)	28	0.3	198	2.6	3.8	2.6	20.7	1.8	12.3	5.7	
32936	Dry roasted, with salt added	¼	cup(s)	27	0.3	192	2.6	3.7	2.5	20.0	1.7	11.9	5.6	
1162	Oil roasted	¼	cup(s)	28	0.3	197	2.5	3.6	2.6	20.7	2.0	11.3	6.5	
526	Raw	¼	cup(s)	27	1.0	188	2.5	3.8	2.6	19.6	1.7	11.1	5.9	
12973	**Pine nuts or pignolia, dried**	1	tablespoon(s)	9	0.2	58	1.2	1.1	0.3	5.9	0.4	1.6	2.9	
	Pistachios													
1164	Dry roasted	¼	cup(s)	31	0.6	176	6.6	8.5	3.2	14.1	1.7	7.4	4.3	
32938	Dry roasted, with salt added	¼	cup(s)	32	0.6	182	6.8	8.6	3.3	14.7	1.8	7.7	4.4	
1167	**Pumpkin or squash seeds, roasted**	¼	cup(s)	57	4.0	296	18.7	7.6	2.2	23.9	4.5	7.4	10.9	
	Sesame													
32912	Sesame butter paste	1	tablespoon(s)	16	0.3	94	2.9	3.8	0.9	8.1	1.1	3.1	3.6	
32941	Tahini or sesame butter	1	tablespoon(s)	15	0.5	89	2.6	3.2	0.7	8.0	1.1	3.0	3.5	
1169	Whole, roasted, toasted	3	tablespoon(s)	10	0.3	54	1.6	2.4	1.3	4.6	0.6	1.7	2.0	
	Soy nuts													
34173	Deep sea salted	¼	cup(s)	28	—	119	11.9	8.9	4.9	4.0	1.0	—	—	
34174	Unsalted	¼	cup(s)	28	—	119	11.9	8.9	4.9	4.0	0	—	—	
	Sunflower seeds													
528	Kernels, dried	1	tablespoon(s)	9	0.4	53	1.9	1.8	0.8	4.6	0.4	1.7	2.1	
29721	Kernels, dry roasted, salted	1	tablespoon(s)	8	0.1	47	1.5	1.9	0.7	4.0	0.4	0.8	2.6	
29723	Kernels, toasted, salted	1	tablespoon(s)	8	0.1	52	1.4	1.7	1.0	4.8	0.5	0.9	3.1	
32928	Sunflower seed butter with salt added	1	tablespoon(s)	16	0.2	93	3.1	4.4	—	7.6	0.8	1.5	5.0	
	Trail mix													
4646	Trail mix	¼	cup(s)	38	3.5	173	5.2	16.8	2.0	11.0	2.1	4.7	3.6	
4647	Trail mix with chocolate chips	¼	cup(s)	38	2.5	182	5.3	16.8	—	12.0	2.3	5.1	4.2	
4648	Tropical trail mix	¼	cup(s)	35	3.2	142	2.2	23.0	—	6.0	3.0	0.9	1.8	
	Walnuts													
529	Dried black, chopped	¼	cup(s)	31	1.4	193	7.5	3.1	2.1	18.4	1.1	4.7	11.0	
531	English or Persian	¼	cup(s)	29	1.2	191	4.5	4.0	2.0	19.1	1.8	2.6	13.8	
Vegetarian Foods														
	Prepared													
34222	Brown rice and tofu stir-fry (vegan)	8	ounce(s)	227	244.4	302	16.5	18.0	3.2	21.0	1.7	4.7	13.4	0
34368	Cheese enchilada casserole (lacto)	8	ounce(s)	227	80.3	385	16.6	38.4	4.1	17.8	9.5	6.1	1.1	—
34247	Five bean casserole (vegan)	8	ounce(s)	227	175.8	178	5.9	26.6	6.0	5.8	1.1	2.5	1.9	0
34261	Lentil stew (vegan)	8	ounce(s)	227	227.9	188	11.5	35.9	11.0	0.7	0.1	0.1	0.3	0
34397	Macaroni and cheese (lacto)	8	ounce(s)	227	352.1	391	18.1	37.1	1.0	18.7	9.8	6.0	1.8	0
34238	Steamed rice and vegetables (vegan)	8	ounce(s)	227	222.9	587	11.2	87.9	5.8	23.1	4.1	8.7	9.1	0
34308	Tofu rice burgers (ovo-lacto)	1	piece(s)	218	77.6	435	22.4	68.6	5.6	8.4	1.7	2.4	3.5	—
34276	Vegan spinach enchiladas (vegan)	1	piece(s)	82	59.2	93	4.9	14.5	1.8	2.4	0.3	0.6	1.3	—
34243	Vegetable chow mein (vegan)	8	ounce(s)	227	163.3	166	6.5	22.1	2.0	6.4	0.7	2.7	2.5	0
34454	Vegetable lasagna (lacto)	8	ounce(s)	227	178.9	208	13.7	29.9	2.6	4.1	2.3	1.1	0.3	—
34339	Vegetable marinara (vegan)	8	ounce(s)	252	200.7	104	3.0	16.7	1.4	3.1	0.4	1.4	1.0	0
34356	Vegetable rice casserole (lacto)	8	ounce(s)	227	178.9	238	9.7	24.4	4.0	12.5	4.9	3.5	3.1	—
34311	Vegetable strudel (ovo-lacto)	8	ounce(s)	227	63.1	478	12.0	32.4	2.5	33.8	11.5	16.7	3.9	0
34371	Vegetable taco (lacto)	1	item(s)	85	46.5	117	4.2	13.6	2.9	5.6	2.1	1.9	1.3	—
34282	Vegetarian chili (vegan)	8	ounce(s)	227	191.4	115	5.6	21.4	7.1	1.5	0.2	0.3	0.7	0
34367	Vegetarian vegetable soup (vegan)	8	ounce(s)	227	257.9	111	3.2	16.0	3.2	5.0	1.0	2.1	1.6	0
	Boca burger													
32067	All American flamed grilled patty	1	item(s)	71	—	90	14.0	4.0	3.0	3.0	1.0	—	—	0
32074	Boca chik'n nuggets	4	item(s)	87	—	180	14.0	17.0	3.0	7.0	1.0	—	—	0
32075	Boca meatless ground burger	½	cup(s)	57	—	60	13.0	6.0	3.0	0.5	0	—	—	0
32072	Breakfast links	2	item(s)	45	—	70	8.0	5.0	2.0	3.0	0.5	—	—	0
32071	Breakfast patties	1	item(s)	38	—	60	7.0	5.0	2.0	2.5	0	—	—	0
35780	Cheeseburger meatless burger patty	1	item(s)	71	—	100	12.0	5.0	3.0	5.0	1.5	—	—	0
33958	Original meatless chik'n patties	1	item(s)	71	—	160	11.0	15.0	2.0	6.0	1.0	—	—	0

	Calc (mg)	Iron (mg)	[illegible] (mg)	[illegible] (mg)	[illegible] (mg)	[illegible] (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	[illegible] (mg)	Vit B_6 (mg)	[illegible] (µg)	Vit C (mg)	Vit B_{12} (µg)	[illegible] (µg)
	7	0.30	24.6	103.8	73.4	0.47	0	0.01	1.44	0.02	2.14	0.09	11.8	0	0	0.9
	34	1.67	61.3	257.3	6.6	1.19	0	0.23	3.04	0.04	4.40	0.12	87.6	0	0	2.6
	20	0.78	36.8	118.3	0.3	1.41	1.9	0.12	0.35	0.03	0.32	0.05	4.5	0.2	0	1.1
	19	0.75	35.6	114.5	103.4	1.36	1.9	0.11	0.34	0.03	0.31	0 05	4.3	0.2	0	1.1
	18	0.68	33.3	107.8	0.3	1.23	1.4	0.13	0.70	0.03	0.33	0 05	4.1	0.2	0	1.7
	19	0.69	33.0	111.7	0	1.23	0.8	0 18	0.38	0.04	0.32	0.06	6.0	0.3	0	1.0
	1	0.47	21.6	51.3	0.2	0.55	0.1	0.03	0.80	0.02	0.37	0.01	2.9	0.1	0	0.1
	34	1.29	36.9	320.4	3.1	0.71	4.0	0.26	0 59	0.05	0.44	0.39	15.4	0.7	0	2.9
	35	1.34	38.4	333.4	129 6	0.73	4.2	0 26	0 61	0.05	0.45	0.40	16.0	0 7	0	3.0
	24	8.48	303.0	457.4	10.2	4.22	10.8	0.12	0.00	0.18	0.99	0.05	32.3	1.0	0	3.2
	154	3.07	57.9	93.1	1.9	1.17	0.5	0.04	—	0.03	1.07	0.13	16.0	0	0	0.9
	21	0.66	14.3	68.9	5.3	0 69	0.5	0.24	—	0.02	0.85	0.02	14.7	0.6	0	0.3
	94	1.40	33.8	45.1	1.0	0.68	0	0.07	—	0.02	0.43	0.07	9.3	0	0	0.5
	59	1.07	—	—	148.1	—	0	—	—	—	—	—	—	0	—	—
	59	1.07	—	—	9.9	—	0	—	—	—	—	—	—	0	—	—
	7	0.47	29.3	58.1	0.8	0.45	0.3	0.13	2 99	0 03	0.75	0.12	20 4	0.1	0	4.8
	6	0.30	10.3	68.0	32.8	0.42	0	0.01	2.09	0 02	0 56	0.06	19.0	0 1	0	6.3
	5	0.57	10.8	41.1	51.3	0.44	0	0 03	—	0.02	0.35	0.07	19.9	0.1	0	5.2
	20	0.76	59.0	11.5	83.2	0.85	0.5	0.05	—	0.05	0.85	0.13	37.9	0.4	0	—
	29	1.14	59.3	256.9	85.9	1.20	0 4	0.17	—	0 07	1 76	0.11	26.6	0.5	0	—
2	41	1.27	60.4	243.0	45.4	1.17	0.8	0.15	—	0.08	1.65	0.09	24.4	0.5	0	—
	20	0.92	33.6	248 2	3.5	0.41	0 7	0.15	—	0.04	0.51	0.11	14.7	2.7	0	—
	19	0.97	62.8	163 4	0.6	1 05	0.6	0 01	0 56	0 04	0 14	0.18	9.7	0 5	0	5.3
	29	0 85	46 2	129 0	0.6	0.90	0.3	0.10	0.20	0.04	0.32	0.15	28.7	0.4	0	1.4
	353	6 34	118.3	501.4	142.2	2 03	—	0.23	0.07	0.14	1 49	0.36	51.8	24.8	0	14.8
39	441	2.44	34.6	191.2	1139.7	1.84	—	0.31	0 05	0.35	2.23	0.11	87.1	20.4	0.4	20.0
	48	1 78	40.8	364.1	613.6	0.61	—	0.10	0.52	0.07	0.93	0.11	39 4	8 3	0	3.3
	34	3.23	50.0	548.8	436.5	1.42	—	0 24	0 14	0 16	2.31	0.29	91.4	26.4	[illegible]	12.1
13	415	1.71	45.4	267.8	1641.0	2.32	—	0.32	0.27	0.48	2.18	0.13	74.2	0.9	0.8	33.3
	91	3.31	153 1	810.1	3117.8	2.04	—	0 37	3.03	0.21	6 16	0 64	61 7	35.2	0	18.8
52	467	9.01	89.7	455.6	2449.5	2 06	—	0.27	0 12	0 26	3 43	0.29	106 6	2.0	0 1	43.0
	117	1.13	40.4	170.5	134.2	0.68	—	0.07	—	0.07	0.53	0.10	52.1	1.8	0	5.1
	189	3.70	28.0	310.3	372.7	0.76	—	0.13	0 05	0.11	1 43	0.14	45.6	8.0	0	6.5
10	176	1 86	41.9	470.0	759.4	1 14	—	0 26	0 05	0 25	2 49	0.22	64.7	19.0	0.4	21.8
	17	0.94	19.1	189.9	439.6	0.42	—	0 15	0.55	0.08	1.36	0 12	40.6	23 5	0	10.8
17	190	1.28	29.3	414.2	626.0	1.24	—	0 16	0.35	0 29	2 00	0.19	72.6	56.0	0.2	5.8
29	200	2.15	24.5	181.0	512.1	1.24	—	0.28	0 20	0.31	2 88	0.11	88.3	17.4	0.2	19.7
7	77	0.88	26.3	174.1	280.7	0.59	—	0 08	0.04	0.06	0.49	0.08	38 7	4.6	0	3.0
	65	1.98	41.0	543.1	390.7	0.74	—	0 14	0.15	0.10	1.31	0.18	59.3	20.3	0	4.4
	46	1.87	34.9	550.3	729.5	0.56	—	0.13	0.55	0.09	1.99	0.27	47.8	29 9	0	1.4
5	150	1.80	—	—	280.0	—	0	—	—	—	—	—	—	0	—	—
	40	1.44	—	—	500.0	—	—	—	—	—	—	—	—	0	—	—
	60	1.80	—	—	270.0	—	0	—	—	—	—	—	—	0	—	—
	20	1.44	—	—	330.0	—	0	—	—	—	—	—	—	0	—	—
	20	1.08	—	—	280.0	—	0	—	—	—	—	—	—	0	—	—
5	80	1.80	—	—	360.0	—	—	—	—	—	—	—	—	0	—	—
	40	1.80	—	—	430.0	—	—	—	—	—	—	—	—	0	—	—

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	T
Vegetarian Foods—*continued*														
32066	Original patty	1	item(s)	71	—	70	13.0	6.0	4.0	0.5	0	—	—	
32068	Roasted garlic patty	1	item(s)	71	—	70	12.0	6.0	4.0	1.5	0	—	—	
37814	Roasted onion meatless burger patty	1	item(s)	71	—	70	11.0	7.0	4.0	1.0	0	—	—	
	Gardenburger													
37810	BBQ chik'n with sauce	1	item(s)	142	—	250	14.0	30.0	5.0	8.0	1.0	—	—	
39661	Black bean burger	1	item(s)	71	—	80	8.0	11.0	4.0	2.0	0	—	—	
39666	Buffalo chik'n wing	3	item(s)	95	—	180	9.0	8.0	5.0	12.0	1.5	—	—	
39665	Country fried chicken with creamy pepper gravy	1	item(s)	142	—	190	9.0	16.0	2.0	9.0	1.0	—	—	
37808	Flamed grilled chik'n	1	item(s)	71	—	100	13.0	5.0	3.0	2.5	0	—	—	
37803	Garden vegan	1	item(s)	71	—	100	10.0	12.0	2.0	1.0	—	—	—	
39663	Homestyle classic burger	1	item(s)	71	—	110	12.0	6.0	4.0	5.0	0.5	—	—	
37807	Meatless breakfast sausage	1	item(s)	43	—	50	5.0	2.0	2.0	3.5	0	—	—	
37809	Meatless meatballs	6	item(s)	85	—	110	12.0	8.0	4.0	4.5	1.0	—	—	
37806	Meatless riblets with sauce	1	item(s)	142	—	160	17.0	11.0	4.0	5.0	0	—	—	
29913	Original	1	item(s)	71	—	90	10.0	8.0	3.0	2.0	0.5	—	—	
39662	Sun-dried tomato basil burger	1	item(s)	71	—	80	10.0	11.0	3.0	1.5	0.5	—	—	
29915	Veggie medley	1	item(s)	71	—	90	9.0	11.0	4.0	2.0	0	—	—	
	Loma Linda													
9311	Big franks, canned	1	item(s)	51	—	110	11.0	3.0	2.0	6.0	1.0	1.5	3.5	
9323	Fried chik'n with gravy	2	piece(s)	80	45.9	150	12.0	5.0	2.0	10	1.5	2.5	5.0	
9326	Linketts, canned	1	item(s)	35	21.0	70	7.0	1.0	1.0	4.0	0.5	1.0	2.5	
9336	Redi-Burger patties, canned	1	slice(s)	85	50.5	120	18.0	7.0	4.0	2.5	0.5	0.5	1.5	
9350	Swiss Stake pattie with gravy, frozen	1	piece(s)	92	65.7	130	9.0	9.0	3.0	6.0	1.0	1.5	3.5	
9354	Tender Rounds meatball substitute, canned in gravy	6	piece(s)	80	53.9	120	13.0	6.0	1.0	4.5	0.5	1.5	2.5	
	Morningstar Farms													
33707	America's Original Veggie Dog links	1	item(s)	57	—	80	11.0	6.0	1.0	0.5	0	—	—	
9362	Better'n Eggs egg substitute	¼	cup(s)	57	50.3	20	5.0	0	0	0	0	0	0	
9371	Breakfast bacon strips	2	item(s)	16	6.8	60	2.0	2.0	0.5	4.5	0.5	1.0	3.0	
9368	Breakfast sausage links	2	item(s)	45	26.8	80	9.0	3.0	2.0	3.0	0.5	1.5	1.0	
33705	Chik'n nuggets	4	piece(s)	86	—	190	12.0	18.0	2.0	7.0	1.0	2.0	4.0	
11587	Chik patties	1	item(s)	71	36.3	150	9.0	16.0	2.0	6.0	1.0	1.5	2.5	
2531	Garden veggie patties	1	item(s)	67	40.1	100	10.0	9.0	4.0	2.5	0.5	0.5	1.5	
33702	Spicy black bean veggie burger	1	item(s)	78	—	140	12.0	15.0	3.0	4.0	0.5	1.0	2.5	
9412	Vegetarian chili, canned	1	cup(s)	230	172.6	180	16.0	25.0	10.0	1.5	0.5	0.5	0.5	
	Worthington													
9424	Chili, canned	1	cup(s)	230	167.0	280	24.0	25.0	8.0	10.0	1.5	1.5	7.0	
9436	Diced chik, canned	¼	cup(s)	55	42.7	50	9.0	2.0	1.0	0	0	0	0	
9440	Dinner roast, frozen	1	slice(s)	85	53.2	180	14.0	6.0	3.0	11.0	1.5	4.5	5.0	
9420	Meatless chicken slices, frozen	3	slice(s)	57	38.9	90	9.0	2.0	0.5	4.5	1.0	1.0	2.5	
36702	Meatless chicken style roll, frozen	1	slice(s)	55	—	90	9.0	2.0	1.0	4.5	1.0	1.0	2.5	
9428	Meatless corned beef, sliced, frozen	3	slice(s)	57	31.2	140	10.0	5.0	0	9.0	1.0	2.0	5.0	
9470	Meatless salami, sliced, frozen	3	slice(s)	57	32.4	120	12.0	3.0	2.0	7.0	1.0	1.0	5.0	
9480	Meatless smoked turkey, sliced	3	slice(s)	57	—	140	10.0	4.0	0	9.0	1.5	2.0	5.0	
9462	Prosage links	2	item(s)	45	26.8	80	9.0	3.0	2.0	3.0	0.5	0.5	2.0	
9484	Stakelets patty beef steak substitute, frozen	1	piece(s)	71	41.5	150	14.0	7.0	2.0	7.0	1.0	2.5	3.5	
9486	Stripples bacon substitute	2	item(s)	16	6.8	60	2.0	2.0	0.5	4.5	0.5	1.0	3.0	
9496	Vegetable Skallops meat substitute, canned	½	cup(s)	85	—	90	17.0	4.0	3.0	1.0	0	0	0.5	
Dairy														
	Cheese													
1433	Blue, crumbled	1	ounce(s)	28	12.0	100	6.1	0.7	0	8.1	5.3	2.2	0.2	
884	Brick	1	ounce(s)	28	11.7	105	6.6	0.8	0	8.4	5.3	2.4	0.2	
885	Brie	1	ounce(s)	28	13.7	95	5.9	0.1	0	7.8	4.9	2.3	0.2	
34821	Camembert	1	ounce(s)	28	14.7	85	5.6	0.1	0	6.9	4.3	2.0	0.2	
5	Cheddar, shredded	¼	cup(s)	28	10.4	114	7.0	0.4	0	9.4	6.0	2.7	0.3	
888	Cheddar or colby	1	ounce(s)	28	10.8	112	6.7	0.7	0	9.1	5.7	2.6	0.3	
32096	Cheddar or colby, low fat	1	ounce(s)	28	17.9	49	6.9	0.5	0	2.0	1.2	0.6	0.1	
889	Edam	1	ounce(s)	28	11.8	101	7.1	0.4	0	7.9	5.0	2.3	0.2	

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	60	1.80	—	—	280.0	—	0	—	—	—	—	—	—	0	—	—
	60	1.80	—	—	370.0	—	0	—	—	—	—	—	—	0	—	—
	100	2.70	—	—	300.0	—	—	—	—	—	—	—	—	0	—	—
	150	1.08	—	—	890.0	—	—	—	—	—	—	—	—	0	—	—
	40	1.44	—	—	330.0	—	—	—	—	—	—	—	—	0	—	—
	40	0.72	—	—	1000.0	—	—	—	—	—	—	—	—	0	—	—
	40	1.44	—	—	550.0	—	—	—	—	—	—	—	—	0	—	—
	60	3.60	—	—	360.0	—	—	—	—	—	—	—	—	0	—	—
	40	4.50	—	—	230.0	—	—	—	—	—	—	—	—	0	—	—
	80	1.44	—	—	380.0	—	—	—	—	—	—	—	—	0	—	—
	20	0.72	—	—	120.0	—	—	—	—	—	—	—	—	0	—	—
	60	1.80	—	—	400.0	—	—	—	—	—	—	—	—	0	—	—
	60	1.80	—	—	720.0	—	—	—	—	—	—	—	—	3.6	—	—
	80	1.08	30.4	193.4	490.0	0.89	—	0.10	—	0.15	1.08	0.08	10.1	1.2	0.1	7.0
	60	1.44	—	—	260.0	—	—	—	—	—	—	—	—	3.6	—	—
	40	1.44	27.0	182.0	290.0	0.46	—	0.07	—	0.08	0.90	0.09	10.6	3.0	0	4.0
	0	0.77	—	50.0	220.0	—	0	0.22	—	0.10	2.00	0.70	—	0	2.4	—
	20	1.80	—	70.0	430.0	0.33	0	1.05	—	0.34	4.00	0.30	—	0	2.4	—
	0	0.36	—	20.0	160.0	0.46	0	0.12	—	0.20	0.80	0.16	—	0	0.9	—
	0	1.06	—	140.0	450.0	—	0	0.15	—	0.25	4.00	0.40	—	0	1.2	—
	0	0.72	—	200.0	430.0	—	0	0.45	—	0.25	10.00	1.00	—	0	5.4	—
	20	1.08	—	80.0	340.0	0.66	0	0.75	—	0.17	2.00	0.16	—	0	1.2	—
	0	0.72	—	60.0	580.0	—	0	—	—	—	—	—	—	0	—	—
	20	0.72	—	75.0	90.0	0.60	37.5	0.03	—	0.34	0.00	0.08	24.0	—	0.6	—
	0	0.36	—	15.0	220.0	0.05	0	0.75	—	0.04	0.40	0.07	—	0	0.2	—
	0	1.80	—	50.0	300.0	—	0	0.37	—	0.17	7.00	0.50	—	0	3.0	—
	20	2.70	—	320.0	490.0	—	0	0.52	—	0.25	5.00	0.30	—	0	1.5	—
	0	1.80	—	210.0	540.0	—	0	1.80	—	0.17	2.00	0.20	—	0	1.2	—
	40	0.72	—	180.0	350.0	—	—	—	—	—	—	—	—	0	—	—
	40	1.80	—	320.0	470.0	—	0	—	—	—	0.00	—	—	0	—	—
	40	3.60	—	660.0	900.0	—	—	—	—	—	—	—	—	0	—	—
	40	3.60	—	330.0	1130.0	—	0	0.30	—	0.13	2.00	0.70	—	0	1.5	—
	0	1.08	—	100.0	220.0	0.24	0	0.06	—	0.10	4.00	0.08	—	0	0.2	—
	20	1.80	—	120.0	580.0	0.64	0	1.80	—	0.25	6.00	0.60	—	0	1.5	—
	250	1.80	—	250.0	250.0	0.26	0	0.37	—	0.13	4.00	0.30	—	0	1.8	—
	100	1.08	—	240.0	240.0	—	0	0.37	—	0.13	4.00	0.30	—	0	1.8	—
	0	1.80	—	130.0	460.0	0.26	0	0.45	—	0.17	5.00	0.30	—	0	1.8	—
	0	1.08	—	95.0	800.0	0.30	0	0.75	—	0.17	4.00	0.20	—	0	0.6	—
	60	2.70	—	60.0	450.0	0.23	0	1.80	—	0.17	6.00	0.40	—	0	3.0	—
	0	1.44	—	50.0	320.0	0.36	0	1.80	—	0.17	2.00	0.30	—	0	3.0	—
	40	1.08	—	130.0	480.0	0.50	0	1.20	—	0.13	3.00	0.30	—	0	1.5	—
	0	0.36	—	15.0	220.0	0.05	0	0.75	—	0.03	0.40	0.08	—	0	0.2	—
	0	0.36	—	10.0	390.0	0.67	0	0.03	—	0.03	0.00	0.01	—	0	0	—
21	150	0.08	6.5	72.6	395.5	0.75	56.1	0.01	0.07	0.10	0.28	0.04	10.2	0	0.3	4.1
27	191	0.12	6.8	38.6	158.8	0.73	82.8	0.00	0.07	0.10	0.03	0.01	5.7	0	0.4	4.1
28	52	0.14	5.7	43.1	178.3	0.67	49.3	0.02	0.06	0.14	0.10	0.06	18.4	0	0.5	4.1
20	110	0.09	5.7	53.0	238.7	0.67	68.3	0.01	0.06	0.14	0.18	0.06	17.6	0	0.4	4.1
30	204	0.19	7.9	27.7	175.4	0.87	74.9	0.01	0.08	0.10	0.02	0.02	5.1	0	0.2	3.9
27	194	0.21	7.4	36.0	171.2	0.87	74.8	0.00	0.07	0.10	0.02	0.02	5.1	0	0.2	4.1
6	118	0.11	4.5	18.7	173.5	0.51	17.0	0.00	0.01	0.06	0.01	0.01	3.1	0	0.1	4.1
25	207	0.12	8.5	53.3	273.6	1.06	68.9	0.01	0.06	0.11	0.02	0.02	4.5	0	0.4	4.1

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	T
Dairy—*continued*														
890	Feta	1	ounce(s)	28	15.7	75	4.0	1.2	0	6.0	4.2	1.3	0.2	
891	Fontina	1	ounce(s)	28	10.8	110	7.3	0.4	0	8.8	5.4	2.5	0.5	
8527	Goat cheese, soft	1	ounce(s)	28	17.2	76	5.3	0.3	0	6.0	4.1	1.4	0.1	
893	Gouda	1	ounce(s)	28	11.8	101	7.1	0.6	0	7.8	5.0	2.2	0.2	
894	Gruyere	1	ounce(s)	28	9.4	117	8.5	0.1	0	9.2	5.4	2.8	0.5	
895	Limburger	1	ounce(s)	28	13.7	93	5.7	0.1	0	7.7	4.7	2.4	0.1	
896	Monterey jack	1	ounce(s)	28	11.6	106	6.9	0.2	0	8.6	5.4	2.5	0.3	
13	Mozzarella, part skim milk	1	ounce(s)	28	15.2	72	6.9	0.8	0	4.5	2.9	1.3	0.1	
12	Mozzarella, whole milk	1	ounce(s)	28	14.2	85	6.3	0.6	0	6.3	3.7	1.9	0.2	
897	Muenster	1	ounce(s)	28	11.8	104	6.6	0.3	0	8.5	5.4	2.5	0.2	
898	Neufchatel	1	ounce(s)	28	17.6	74	2.8	0.8	0	6.6	4.2	1.9	0.2	
14	Parmesan, grated	1	tablespoon(s)	5	1.0	22	1.9	0.2	0	1.4	0.9	0.4	0.1	
17	Provolone	1	ounce(s)	28	11.6	100	7.3	0.6	0	7.5	4.8	2.1	0.2	
19	Ricotta, part skim milk	¼	cup(s)	62	45.8	85	7.0	3.2	0	4.9	3.0	1.4	0.2	
18	Ricotta, whole milk	¼	cup(s)	62	44.1	107	6.9	1.9	0	8.0	5.1	2.2	0.2	
20	Romano	1	tablespoon(s)	5	1.5	19	1.6	0.2	0	1.3	0.9	0.4	0	
900	Roquefort	1	ounce(s)	28	11.2	105	6.1	0.6	0	8.7	5.5	2.4	0.4	
21	Swiss	1	ounce(s)	28	10.5	108	7.6	1.5	0	7.9	5.0	2.1	0.3	
	Imitation cheese													
42245	Imitation American cheddar cheese	1	ounce(s)	28	15.1	68	4.7	3.3	0	4.0	2.5	1.2	0.1	
53914	Imitation cheddar	1	ounce(s)	28	15.1	68	4.7	3.3	0	4.0	2.5	1.2	0.1	
	Cottage cheese													
9	Low fat, 1% fat	½	cup(s)	113	93.2	81	14.0	3.1	0	1.2	0.7	0.3	0	
8	Low fat, 2% fat	½	cup(s)	113	89.6	102	15.5	4.1	0	2.2	1.4	0.6	0.1	
	Cream cheese													
11	Cream cheese	2	tablespoon(s)	29	15.6	101	2.2	0.8	0	10.1	6.4	2.9	0.4	
17366	Fat-free cream cheese	2	tablespoon(s)	30	22.7	29	4.3	1.7	0	0.4	0.3	0.1	0	
10438	Tofutti Better than Cream Cheese	2	tablespoon(s)	30	—	80	1.0	1.0	0	8.0	2.0	—	6.0	
	Processed cheese													
24	American cheese food, processed	1	ounce(s)	28	12.3	94	5.2	2.2	0	7.1	4.2	2.0	0.3	
25	American cheese spread, processed	1	ounce(s)	28	13.5	82	4.7	2.5	0	6.0	3.8	1.8	0.2	
22	American cheese, processed	1	ounce(s)	28	11.1	106	6.3	0.5	0	8.9	5.6	2.5	0.3	
9110	Kraft deluxe singles pasteurized process American cheese	1	ounce(s)	28	—	108	5.4	0	0	9.5	5.4	—	—	
23	Swiss cheese, processed	1	ounce(s)	28	12.0	95	7.0	0.6	0	7.1	4.5	2.0	0.2	
	Soy cheese													
10437	Galaxy Foods vegan grated parmesan cheese alternative	1	tablespoon(s)	8	—	23	3.0	1.5	0	0	0	0	0	
10430	Nu Tofu cheddar flavored cheese alternative	1	ounce(s)	28	—	70	6.0	1.0	0	4.0	0.5	2.5	1.0	
	Cream													
26	Half and half cream	1	tablespoon(s)	15	12.1	20	0.4	0.6	0	1.7	1.1	0.5	0.1	
32	Heavy whipping cream, liquid	1	tablespoon(s)	15	8.7	52	0.3	0.4	0	5.6	3.5	1.6	0.2	
28	Light coffee or table cream, liquid	1	tablespoon(s)	15	11.1	29	0.4	0.5	0	2.9	1.8	0.8	0.1	
30	Light whipping cream, liquid	1	tablespoon(s)	15	9.5	44	0.3	0.4	0	4.6	2.9	1.4	0.1	
34	Whipped cream topping, pressurized	1	tablespoon(s)	3	1.8	8	0.1	0.4	0	0.7	0.4	0.2	0	
	Sour cream													
30556	Fat-free sour cream	2	tablespoon(s)	32	25.8	24	1.0	5.0	0	0	0	0	0	0
36	Sour cream	2	tablespoon(s)	24	17.0	51	0.8	1.0	0	5.0	3.1	1.5	0.2	
	Imitation cream													
3659	Coffeemate nondairy creamer, liquid	1	tablespoon(s)	15	—	20	0	2.0	0	1.0	0	0.5	0	
40	Cream substitute, powder	1	teaspoon(s)	2	0	11	0.1	1.1	0	0.7	0.7	0	0	
904	Imitation sour cream	2	tablespoon(s)	29	20.5	60	0.7	1.9	0	5.6	5.1	0.2	0	
35972	Nondairy coffee whitener, liquid, frozen	1	tablespoon(s)	15	11.7	21	0.2	1.7	0	1.5	0.3	1.1	0	
35976	Nondairy dessert topping, frozen	1	tablespoon(s)	5	2.4	15	0.1	1.1	0	1.2	1.0	0.1	0	
35975	Nondairy dessert topping, pressurized	1	tablespoon(s)	4	2.7	12	0	0.7	0	1.0	0.8	0.1	0	

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	(µg)
	140	0.18	5.4	17.6	316.4	0.81	35.4	0.04	0.05	0.23	0.28	0.12	9.1	0	0.5	4.3
	156	0.06	4.0	18.1	226.8	0.99	74.0	0.01	0.07	0.05	0.04	0.02	1.7	0	0.5	4.1
	40	0.53	4.5	7.4	104.3	0.26	81.6	0.02	0.05	0.10	0.12	0.07	3.4	0	0.1	0.8
	198	0.06	8.2	34.3	232.2	1.10	46.8	0.01	0.06	0.09	0.01	0.02	6.0	0	0.4	4.1
	287	0.04	10.2	23.0	95.3	1.10	76.8	0.01	0.07	0.07	0.03	0.02	2.8	0	0.5	4.1
	141	0.03	6.0	36.3	226.8	0.59	96.4	0.02	0.06	0.14	0.04	0.02	16.4	0	0.3	4.1
	211	0.20	7.7	23.0	152.0	0.85	56.1	0.00	0.07	0.11	0.02	0.02	5.1	0	0.2	4.1
	222	0.06	6.5	23.8	175.5	0.78	36.0	0.01	0.04	0.08	0.03	0.02	2.6	0	0.2	4.1
	143	0.12	5.7	21.5	177.8	0.82	50.7	0.01	0.05	0.08	0.02	0.01	2.0	0	0.6	4.8
	203	0.11	7.7	38.0	178.0	0.79	84.5	0.00	0.07	0.09	0.02	0.01	3.4	0	0.4	4.1
	21	0.07	2.3	32.3	113.1	0.14	84.5	0.00	—	0.05	0.03	0.01	3.1	0	0.1	0.9
	55	0.04	1.9	6.3	76.5	0.19	6.0	0.00	0.01	0.02	0.01	0.00	0.5	0	0.1	0.9
	214	0.14	7.9	39.1	248.3	0.91	66.9	0.01	0.06	0.09	0.04	0.02	2.8	0	0.4	4.1
	167	0.27	9.2	76.9	76.9	0.82	65.8	0.01	0.04	0.11	0.04	0.01	8.0	0	0.2	10.3
	127	0.23	6.8	64.6	51.7	0.71	73.8	0.01	0.06	0.12	0.06	0.02	7.4	0	0.2	8.9
	53	0.03	2.1	4.3	60	0.12	4.8	0.00	0.01	0.01	0.00	0.00	0.4	0	0.1	0.7
	188	0.15	8.5	25.8	512.9	0.59	83.3	0.01	—	0.16	0.20	0.03	13.9	0	0.2	4.1
	224	0.05	10.8	21.8	54.4	1.23	62.4	0.01	0.10	0.08	0.02	0.02	1.7	0	0.9	5.2
	159	0.08	8.2	68.6	381.3	0.73	32.3	0.01	0.07	0.12	0.03	0.03	2.0	0	0.1	4.3
	159	0.09	8.2	68.6	381.3	0.73	32.3	0.01	0.07	0.12	0.04	0.03	2.0	0	0.1	4.3
	69	0.15	5.7	97.2	458.8	0.42	12.4	0.02	0.01	0.18	0.14	0.07	13.6	0	0.7	10.2
	78	0.18	6.8	108.5	458.8	0.47	23.7	0.02	0.02	0.20	0.16	0.08	14.7	0	0.8	11.5
	23	0.34	1.7	34.5	85.8	0.15	106.1	0.01	0.08	0.05	0.02	0.01	3.8	0	0.1	0.7
	56	0.05	4.2	48.9	163.5	0.26	83.7	0.01	0.00	0.05	0.04	0.01	11.1	0	0.2	1.5
	0	0.00	—	—	135.0	—	0	—	—	—	—	—	—	0	—	—
	162	0.16	8.8	82.5	358.6	0.90	57.0	0.01	0.06	0.14	0.04	0.02	2.0	0	0.4	4.6
	159	0.09	8.2	68.6	381.3	0.73	49.0	0.01	0.05	0.12	0.03	0.03	2.0	0	0.1	3.2
	156	0.05	7.7	47.9	422.1	0.80	72.0	0.01	0.07	0.10	0.02	0.02	2.3	0	0.2	4.1
	338	0.00	0	33.8	459.0	1.22	114.0	—	—	0.14	—	—	—	0	0.2	—
	219	0.17	8.2	61.2	388.4	1.02	56.1	0.00	0.09	0.07	0.01	0.01	1.7	0	0.3	4.5
	60	0.00	—	75.0	97.5	—	—	—	—	—	—	—	—	—	—	—
	200	0.36	—	—	190.0	—	—	—	—	—	—	—	—	0	—	—
	16	0.01	1.5	19.5	6.2	0.08	14.6	0.01	0.05	0.02	0.01	0.01	0.5	0.1	0	0.3
	10	0.00	1.1	11.3	5.7	0.03	61.7	0.00	0.15	0.01	0.01	0.00	0.6	0.1	0	0.1
	14	0.01	1.4	18.3	6.0	0.04	27.2	0.01	0.08	0.02	0.01	0.01	0.3	0.1	0	0.1
	10	0.00	1.1	14.6	5.1	0.03	41.9	0.00	0.13	0.01	0.01	0.00	0.6	0.1	0	0.1
	3	0.00	0.3	4.4	3.9	0.01	5.6	0.00	0.01	0.00	0.00	0.00	0.1	0	0	0
	40	0.00	3.2	41.3	45.1	0.16	23.4	0.01	0.00	0.04	0.02	0.01	3.5	0	0.1	1.7
	28	0.01	2.6	34.6	12.7	0.06	42.5	0.01	0.14	0.03	0.01	0.00	2.6	0.2	0.1	0.5
	0	0.00	—	30.0	0	—	0	0.01	—	0.01	0.20	—	—	0	—	—
	0	0.02	0.1	16.2	3.6	0.01	0	0.00	0.01	0.00	0.00	0.00	0	0	0	0
	1	0.11	1.7	46.3	29.3	0.34	0	0.00	0.21	0.00	0.00	0.00	0	0	0	0.7
	1	0.00	0	28.9	12.0	0.00	0.2	0.00	0.12	0.00	0.00	0.00	0	0	0	0.2
	0	0.00	0.1	0.9	1.2	0.00	0.3	0.00	0.05	0.00	0.00	0.00	0	0	0	0.1
	0	0.00	0	0.8	2.8	0.00	0.2	0.00	0.04	0.00	0.00	0.00	0	0	0	0.1

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DAI Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tr
Dairy—*continued*														
	Fluid milk													
60	Buttermilk, low fat	1	cup(s)	245	220.8	98	8.1	11.7	0	2.2	1.3	0.6	0.1	
54	Low fat, 1%	1	cup(s)	244	219.4	102	8.2	12.2	0	2.4	1.5	0.7	0.1	
55	Low fat, 1%, with nonfat milk solids	1	cup(s)	245	220.0	105	8.5	12.2	0	2.4	1.5	0.7	0.1	
57	Nonfat, skim or fat free	1	cup(s)	245	222.6	83	8.3	12.2	0	0.2	0.1	0.1	0	
58	Nonfat, skim or fat free with nonfat milk solids	1	cup(s)	245	221.4	91	8.7	12.3	0	0.6	0.4	0.2	0	
51	Reduced fat, 2%	1	cup(s)	244	218.0	122	8.1	11.4	0	4.8	3.1	1.4	0.2	
52	Reduced fat, 2%, with nonfat milk solids	1	cup(s)	245	217.7	125	8.5	12.2	0	4.7	2.9	1.4	0.2	
50	Whole, 3.3%	1	cup(s)	244	215.5	146	7.9	11.0	0	7.9	4.6	2.0	0.5	
	Canned milk													
62	Nonfat or skim evaporated	2	tablespoon(s)	32	25.3	25	2.4	3.6	0	0.1	0	0	0	
63	Sweetened condensed	2	tablespoon(s)	38	10.4	123	3.0	20.8	0	3.3	2.1	0.9	0.1	
61	Whole evaporated	2	tablespoon(s)	32	23.3	42	2.1	3.2	0	2.4	1.4	0.7	0.1	
	Dried milk													
64	Buttermilk	¼	cup(s)	30	0.9	117	10.4	14.9	0	1.8	1.1	0.5	0.1	
65	Instant nonfat with added vitamin A	¼	cup(s)	17	0.7	61	6.0	8.9	0	0.1	0.1	0	0	
5234	Skim milk powder	¼	cup(s)	17	0.7	62	6.1	9.1	0	0.1	0.1	0	0	
907	Whole dry milk	¼	cup(s)	32	0.8	159	8.4	12.3	0	8.5	5.4	2.5	0.2	
909	**Goat milk**	1	cup(s)	244	212.4	168	8.7	10.9	0	10.1	6.5	2.7	0.4	
	Chocolate milk													
33155	Chocolate syrup, prepared with milk	1	cup(s)	282	227.0	254	8.7	36.0	0.8	8.3	4.7	2.1	0.5	
33184	Cocoa mix with aspartame, added sodium and vitamin A, no added calcium or phosphorus, prepared with water	1	cup(s)	192	177.4	56	2.3	10.8	1.2	0.4	0.3	0.1	0	
908	Hot cocoa, prepared with milk	1	cup(s)	250	206.4	193	8.8	26.6	2.5	5.8	3.6	1.7	0.1	0
69	Low fat	1	cup(s)	250	211.3	158	8.1	26.1	1.3	2.5	1.5	0.8	0.1	
68	Reduced fat	1	cup(s)	250	205.4	190	7.5	30.3	1.8	4.8	2.9	1.1	0.2	
67	Whole	1	cup(s)	250	205.8	208	7.9	25.9	2.0	8.5	5.3	2.5	0.3	
70	**Eggnog**	1	cup(s)	254	188.9	343	9.7	34.4	0	19.0	11.3	5.7	0.9	
	Breakfast drinks													
10093	Carnation Instant Breakfast classic chocolate malt, prepared with skim milk, no sugar added	1	cup(s)	243	—	142	11.1	21.3	0.7	1.3	0.7	—	—	
10092	Carnation Instant Breakfast classic French vanilla, prepared with skim milk, no sugar added	1	cup(s)	273	—	150	12.9	24.0	0	0.4	0.4	—	—	
10094	Carnation Instant Breakfast stawberry sensation, prepared with skim milk, no sugar added	1	cup(s)	243	—	142	11.1	21.3	0	0.4	0.4	—	—	
10091	Carnation Instant Breakfast strawberry sensation, prepared with skim milk	1	cup(s)	273	—	220	12.5	38.8	0	0.4	0.4	—	—	
1417	Ovaltine rich chocolate flavor, prepared with skim milk	1	cup(s)	258	—	170	8.5	31.0	0	0	0	0	0	0
8539	**Malted milk, chocolate mix, fortified, prepared with milk**	1	cup(s)	265	215.8	223	8.9	28.9	1.1	8.6	5.0	2.2	0.5	
	Milkshakes													
73	Chocolate	1	cup(s)	227	164.0	270	6.9	48.1	0.7	6.1	3.8	1.8	0.2	
3163	Strawberry	1	cup(s)	226	167.8	256	7.7	42.8	0.9	6.3	3.9	—	—	
74	Vanilla	1	cup(s)	227	169.2	254	8.8	40.3	0	6.9	4.3	2.0	0.3	
	Ice cream													
4776	Chocolate	½	cup(s)	66	36.8	143	2.5	18.6	0.8	7.3	4.5	2.1	0.3	
12137	Chocolate fudge, no sugar added	½	cup(s)	71	—	100	3.0	16.0	2.0	3.0	1.5	—	—	0
16514	Chocolate, soft serve	½	cup(s)	87	49.9	177	3.2	24.1	0.7	8.4	5.2	2.4	0.3	
16523	Sherbet, all flavors	½	cup(s)	97	63.8	139	1.1	29.3	3.2	1.9	1.1	0.5	0.1	
4778	Strawberry	½	cup(s)	66	39.6	127	2.1	18.2	0.6	5.5	3.4	—	—	
76	Vanilla	½	cup(s)	72	43.9	145	2.5	17.0	0.5	7.9	4.9	2.1	0.3	
12146	Vanilla chocolate swirl, fat-free, no sugar added	½	cup(s)	71	—	100	3.0	14.0	2.0	3.0	2.0	—	—	0
82	Vanilla, light	½	cup(s)	76	48.3	125	3.6	19.6	0.2	3.7	2.2	1.0	0.2	
78	Vanilla, light, soft serve	½	cup(s)	88	61.2	111	4.3	19.2	0	2.3	1.4	0.7	0.1	

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	284	0.12	27.0	370.0	257.3	1.02	17.2	0.08	0.12	0.37	0.14	0.08	12.3	2.5	0.5	4.9
	290	0 07	26.8	366.0	107.4	1.02	141.5	0.04	0.02	0.45	0.22	0.09	12.2	0	1.1	8.1
	314	0.12	34.3	396.9	127.4	0.98	144.6	0.09	—	0.42	0.22	0.11	12.3	2.5	0.9	5.6
	306	0.07	27.0	382.2	102.9	1.02	149.5	0.11	0.02	0.44	0.23	0.09	12.3	0	1.3	7.6
	316	0.12	36.8	419.0	129.9	1.00	149.5	0.10	0.00	0.42	0.22	0.11	12.3	2.5	1.0	5.4
	285	0.07	26.8	366.0	100.0	1.04	134.2	0.09	0.07	0 45	0.22	0.09	12.2	0.5	1.1	6.1
	314	0.12	34.3	396.9	127.4	0.98	137.2	0.09	—	0.42	0.22	0.11	12.3	2.5	0.9	5.6
	276	0.07	24.4	348.9	97.6	0.97	68.3	0.10	0.14	0.44	0.26	0.08	12.2	0	1.1	9.0
	93	0.09	8.6	105.9	36.7	0.28	37.6	0.01	0.00	0.09	0.05	0.01	2.9	0.4	0.1	0.8
	109	0.07	9.9	141.9	48.6	0 36	28.3	0.03	0.06	0.16	0.08	0 02	4.2	1.0	0.2	5.7
	82	0.06	7.6	95.4	33.4	0.24	20.5	0.01	0.04	0.10	0.06	0.01	2.5	0.6	0.1	0.7
	359	0.09	33.3	482.5	156.7	1.21	14.9	0 11	0.03	0.48	0.27	0.10	14.2	1.7	1.2	6.2
	209	0.05	19.9	289.9	93.3	0.75	120.5	0.07	0.00	0.30	0.15	0.06	8.5	1.0	0.7	4.6
	214	0.05	20.3	296.0	95.3	0.76	123.1	0 07	0.00	0.30	0.15	0.06	8.7	1.0	0.7	4.7
	292	0.15	27.2	425.6	118.7	1.06	82.2	0.09	0.15	0 38	0.20	0 09	11.8	2.8	1.0	5.2
	327	0.12	34.2	497.8	122.0	0.73	139.1	0.11	0.17	0.33	0.67	0.11	2.4	3.2	0.2	3.4
	251	0.90	50.8	408.9	132.5	1.21	70.5	0.11	0.14	0.46	0.38	0.09	14.1	0	1 1	9.6
	92	0.74	32.6	405.1	138.2	0.51	0	0.04	0.00	0.20	0.16	0.04	1.9	0	0.2	2.5
	263	1.20	57.5	492.5	110.0	1.57	127.5	0.09	0.07	0.45	0.33	0.10	12.5	0.5	1.1	6.8
	288	0.60	32.5	425.0	152.5	1 02	145 0	0.09	0.05	0.41	0.31	0.10	12.5	2.3	0.9	4 8
	273	0.60	35.0	422.5	165.0	0.97	160.0	0.11	0 10	0 45	0.41	0.06	5.0	0	0.8	8.5
	280	0.60	32.5	417.5	150.0	1.02	65 0	0.09	0 15	0.40	0 31	0 10	12.5	2 3	0.8	4.8
	330	0.50	48.3	419.1	137.2	1.16	116.8	0.08	0.50	0.48	0 26	0.12	2.5	3.8	1.1	10.7
	444	4.00	88.9	631.1	195.6	3.38	—	0.33	—	0.45	4.44	0.44	4.0	26.7	1.3	8.0
	500	4.50	100.0	665.0	192.0	3.75	—	0.37	—	0.51	5.00	0.49	100.0	30.0	1.5	9.0
	444	4.00	88.9	568.9	186.7	3.38	—	0.33	—	0.45	4.44	0.44	88.9	26.7	1.3	8.0
	500	4.47	100.0	665.0	288.0	3.75	—	0.37	—	0.51	5.07	0.50	100.0	30 0	1.5	8.8
	350	3.60	100.0	—	270.0	3.75	—	0.37	—	—	4.00	0.40	—	12.0	1.2	—
	339	3.76	45.1	577.7	230.6	1.16	903.7	0.75	0.15	1.31	11.08	1.01	18.6	31.8	1.1	12.5
	300	0.70	36.4	508.9	252.2	1.09	40.9	0.10	0.11	0.50	0.28	0.05	11.4	0	0.7	4.3
	256	0.24	29.4	412.0	187.9	0.81	58.9	0.10	—	0.44	0.39	0.10	6.8	1.8	0.7	4.8
	332	0.22	27.3	415.8	215.8	0.88	56.8	0.06	0.11	0.44	0.33	0.09	15.9	0	1.2	5.2
	72	0.61	19.1	164.3	50.2	0.38	77.9	0.02	0.19	0.12	0.14	0.03	10.6	0.5	0.2	1.7
	100	0.36	—	—	65.0	—	—	—	—	—	—	—	—	0	—	—
	103	0.32	19.0	192.0	43.3	0.45	66.6	0.03	0.22	0.13	0.11	0.03	4.3	0.5	0.3	2.5
	52	0.13	7.7	92.6	44.4	0.46	9.7	0.02	0.02	0.08	0.07	0.02	6.8	5.6	0.1	1.3
	79	0.13	9.2	124.1	39.6	0.22	63.4	0.03	—	0.16	0.11	0.03	7.9	5.1	0.2	1.3
	92	0.06	10.1	143.3	57.6	0.49	85.0	0.03	0.21	0.17	0.08	0.03	3.6	0.4	0.3	1.3
	100	0.00	—	—	65.0	—	—	—	—	—	—	—	—	0	—	—
	122	0.14	10.6	158.1	56.2	0.55	97.3	0.04	0.09	0.19	0.10	0.03	4.6	0.9	0.4	1.5
	138	0.05	12.3	194.5	61.6	0.46	25.5	0.04	0.05	0.17	0.10	0.04	4.4	0.8	0.4	3.2

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

CBA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g) Sat	Mono	Poly	
Dairy—*continued*														
	Soy desserts													
10694	Tofutti low fat vanilla fudge nondairy frozen dessert	½	cup(s)	70	—	140	2.0	24.0	0	4.0	1.0	—	—	
15721	Tofutti premium chocolate supreme nondairy frozen dessert	½	cup(s)	70	—	180	3.0	18.0	0	11.0	2.0	—	—	
15720	Tofutti premium vanilla non-dairy frozen dessert	½	cup(s)	70	—	190	2.0	20.0	0	11.0	2.0	—	—	
	Ice milk													
16517	Chocolate	½	cup(s)	66	42.9	94	2.8	16.9	0.3	2.1	1.3	0.6	0.1	
16516	Flavored, not chocolate	½	cup(s)	66	41.4	108	3.5	17.5	0.2	2.6	1.7	0.6	0.1	
	Pudding													
25032	Chocolate	½	cup(s)	144	109.7	155	5.1	22.7	0.7	5.4	3.1	1.7	0.2	
1923	Chocolate, sugar free, prepared with 2% milk	½	cup(s)	133	—	100	5.0	14.0	0.3	3.0	1.5	—	—	
1722	Rice	½	cup(s)	113	75.6	151	4.1	29.9	0.5	1.9	1.1	0.5	0.1	
4747	Tapioca, ready to eat	1	item(s)	142	102.0	185	2.8	30.8	0	5.5	1.4	3.6	0.1	
25031	Vanilla	½	cup(s)	136	109.7	116	4.7	17.6	0	2.8	1.6	0.9	0.2	
1924	Vanilla, sugar free, prepared with 2% milk	½	cup(s)	133	—	90	4.0	12.0	0.2	2.0	1.5	—	—	
	Frozen yogurt													
4785	Chocolate, soft serve	½	cup(s)	72	45.9	115	2.9	17.9	1.6	4.3	2.6	1.3	0.2	
1747	Fruit varieties	½	cup(s)	113	80.5	144	3.4	24.4	0	4.1	2.6	1.1	0.1	
4786	Vanilla, soft serve	½	cup(s)	72	47.0	117	2.9	17.4	0	4.0	2.5	1.1	0.2	
	Milk substitutes													
	Lactose free													
16081	Fat-free, calcium fortified [milk]	1	cup(s)	240	—	80	8.0	13.0	0	0	0	0	0	
36486	Low fat milk	1	cup(s)	240	—	110	8.0	13.0	0	2.5	1.5	—	—	
36487	Reduced fat milk	1	cup(s)	240	—	130	8.0	12.0	0	5.0	3.0	—	—	
36488	Whole milk	1	cup(s)	240	—	150	8.0	12.0	0	8.0	5.0	—	—	
	Rice													
10083	Rice Dream carob rice beverage	1	cup(s)	240	—	150	1.0	32.0	0	2.5	0	—	—	
17089	Rice Dream original rice beverage, enriched	1	cup(s)	240	—	120	1.0	25.0	0	2.0	0	—	—	
10087	Rice Dream vanilla enriched rice beverage	1	cup(s)	240	—	130	1.0	28.0	0	2.0	0	—	—	
	Soy													
34750	Soy Dream chocolate enriched soy beverage	1	cup(s)	240	—	210	7.0	37.0	1.0	3.5	0.5	—	—	
34749	Soy Dream vanilla enriched soy beverage	1	cup(s)	240	—	150	7.0	22.0	0	4.0	0.5	—	—	
13840	Vitasoy light chocolate soymilk	1	cup(s)	240	—	100	4.0	17.0	0	2.0	0.5	0.5	1.0	
13839	Vitasoy light vanilla soymilk	1	cup(s)	240	—	70	4.0	10.0	0	2.0	0.5	0.5	1.0	
13836	Vitasoy rich chocolate soymilk	1	cup(s)	240	—	160	7.0	24.0	1.0	4.0	0.5	1.0	2.5	
13835	Vitasoy vanilla delite soymilk	1	cup(s)	240	—	120	7.0	13.0	1.0	4.0	0.5	1.0	2.5	
	Yogurt													
3615	Custard style, fruit flavors	6	ounce(s)	170	127.1	190	7.0	32.0	0	3.5	2.0	—	—	
3617	Custard style, vanilla	6	ounce(s)	170	134.1	190	7.0	32.0	0	3.5	2.0	0.9	0.1	
32101	Fruit, low fat	1	cup(s)	245	184.5	243	9.8	45.7	0	2.8	1.8	0.8	0.1	
29638	Fruit, nonfat, sweetened with low-calorie sweetener	1	cup(s)	241	208.3	123	10.6	19.4	1.2	0.4	0.2	0.1	0	
93	Plain, low fat	1	cup(s)	245	208.4	154	12.9	17.2	0	3.8	2.5	1.0	0.1	
94	Plain, nonfat	1	cup(s)	245	208.8	137	14.0	18.8	0	0.4	0.3	0.1	0	
32100	Vanilla, low fat	1	cup(s)	245	193.6	208	12.1	33.8	0	3.1	2.0	0.8	0.1	
5242	Yogurt beverage	1	cup(s)	245	199.8	172	6.2	32.8	0	2.2	1.4	0.6	0.1	
38202	Yogurt smoothie, nonfat, all flavors	1	item(s)	325	—	290	10.0	60.0	6.0	0	0	0	0	0
	Soy yogurt													
34617	Stonyfield Farm O'Soy strawberry-peach pack organic cultured soy yogurt	1	item(s)	113	—	100	5.0	16.0	3.0	2.0	0	—	—	0
34616	Stonyfield Farm O'Soy vanilla organic cultured soy yogurt	1	item(s)	170	—	150	7.0	26.0	4.0	2.0	0	—	—	0
10453	White Wave plain silk cultured soy yogurt	8	ounce(s)	227	—	140	5.0	22.0	1.0	3.0	0.5	—	—	0

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	0	0.00	—	8.0	90.0	—	0	—	—	—	—	—	—	0	—	—
	0	0.00	—	7.0	180.0	—	0	—	—	—	—	—	—	0	—	—
	0	0.00	—	2.0	210.0	—	0	—	—	—	—	—	—	0	—	—
	94	0.15	13.1	155.2	40.6	0.36	15.7	0.03	0 05	0.11	0.08	0 02	3.9	0.5	0.3	2.2
	76	0.05	9.2	136.2	48.5	0.47	90.4	0.02	0.05	0.11	0.06	0.01	3.3	0.1	0.2	1.3
	149	0.46	31.3	226.7	137.0	0.71	—	0 05	0.00	0.22	0.15	0.06	8.3	1.2	0.5	4.9
	150	0.72	—	330.0	310.0	—	—	0.06	—	0.26	—	—	—	0	—	—
	113	0.28	15.8	201.4	66.4	0.52	41.6	0.03	0.05	0.17	0.34	0 06	4.5	0.2	0.2	4.8
	101	0.15	8.5	130.6	205.9	0.31	0	0.03	0.21	0 13	0.09	0.03	4.3	0.4	0.3	0
	146	0.17	17.2	188.9	136 4	0.52	—	0 04	0 00	0.22	0.10	0.05	8.0	1.2	0.5	4.6
	150	0.00	—	190.0	380.0	—	—	0.03	—	0.17	—	—	—	0	—	—
	106	0.90	19.4	187.9	70.6	0.35	31.7	0.02	—	0.15	0.22	0 05	7.9	0 2	0.2	1.7
	113	0.52	11.3	176.3	71.2	0.31	55.4	0.04	0.10	0.20	0.07	0.04	4.5	0.8	0.1	2.1
	103	0.21	10.1	151.9	62.6	0.30	42.5	0.02	0 07	0.16	0.20	0.05	4.3	0 6	0.2	2.4
	500	0.00	—	—	125.0	—	100.0	—	—	—	—	—	—	0	0	—
	300	0.00	—	—	125.0	—	100.0	—	—	—	—	—	—	0	—	—
	300	0.00	—	—	125.0	—	98.2	—	—	—	—	—	—	0	—	—
	300	0.00	—	—	125.0	—	58.1	—	—	—	—	—	—	0	—	—
	20	0.72	—	82.5	100.0	—	—	—	—	—	—	—	—	1.2	—	—
	300	0.00	13.3	60.0	90.0	0.24	—	0.06	—	0.00	0.84	0.07	—	0	1.5	—
	300	0.00	—	53.0	90.0	—	—	—	—	—	—	—	—	0	1.5	—
	300	1.80	60.0	350.0	160.0	0.60	33.3	0.15	—	0 06	0.80	0.12	60.0	0	3.0	—
	300	1.80	40.0	260.0	140.0	0.60	33.3	0.15	—	0.06	0.80	0.12	60.0	0	3.0	—
	300	0.72	24.0	200.0	140.0	0.90	—	0.09	—	0.34	—	—	24.0	0	0.9	—
	300	0.72	24.0	200 0	120.0	0.90	—	0.09	—	0.34	—	—	24.0	0	0.9	—
	300	1.08	40.0	320.0	150.0	0.90	—	0.15	—	0.34	—	—	60.0	0	0.9	—
	40	0.72	—	320.0	115.0	—	0	—	—	—	—	—	—	0	—	—
	300	0.00	16.0	310.0	100.0	—	—	—	—	0.25	—	—	—	0	—	—
	300	0.00	16.0	310.0	100.0	—	—	—	—	0.25	—	—	—	0	—	—
	338	0.14	31.9	433.7	129.9	1.64	27.0	0.08	0.04	0.39	0.21	0.09	22.1	1.5	1.1	6.9
	369	0.62	41.0	549.5	139.8	1.83	4.8	0.10	0.16	0.44	0.49	0.10	31.3	26.5	1.1	7.0
	448	0.19	41.7	573.3	171.5	2.18	34.3	0.10	0.07	0.52	0.27	0.12	27.0	2.0	1.4	8.1
	488	0.22	46.6	624.8	188.7	2.37	4.9	0.11	0.00	0.57	0.30	0.13	29.4	2.2	1.5	8.8
	419	0.17	39.2	536.6	161.7	2.03	29.4	0.10	0.04	0.49	0.26	0.11	27.0	2.0	1.3	12.0
	260	0.22	39.2	399.4	98.0	1.10	14.7	0.11	0.00	0.51	0.30	0.14	29.4	2.1	1.5	—
	300	2.70	100.0	580.0	290.0	2.25	—	0.37	—	0.42	5.00	0.50	100.0	15.0	1.5	—
	100	1.08	24.0	5.0	20.0	—	0	0.22	—	0.10	—	0.04	—	0	0	—
	150	1.44	40.0	15.0	40.0	—	—	0.30	—	0.13	—	0.08	—	0	0	—
	400	1.44	—	0	30.0	—	0	—	—	—	—	—	—	0	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DAT Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	T
Eggs														
	Eggs													
99	Fried	1	item(s)	46	31.8	90	6.3	0.4	0	7.0	2.0	2.9	1.2	
100	Hard boiled	1	item(s)	50	37.3	78	6.3	0.6	0	5.3	1.6	2.0	0.7	
101	Poached	1	item(s)	50	37.8	71	6.3	0.4	0	5.0	1.5	1.9	0.7	
97	Raw, white	1	item(s)	33	28.9	16	3.6	0.2	0	0.1	0	0	0	
96	Raw, whole	1	item(s)	50	37.9	72	6.3	0.4	0	5.0	1.5	1.9	0.7	
98	Raw, yolk	1	item(s)	17	8.9	54	2.7	0.6	0	4.5	1.6	2.0	0.7	
102	Scrambled, prepared with milk and butter	2	item(s)	122	89.2	204	13.5	2.7	0	14.9	4.5	5.8	2.6	
	Egg substitute													
4028	Egg Beaters	¼	cup(s)	61	—	30	6.0	1.0	0	0	0	0	0	
920	Frozen	¼	cup(s)	60	43.9	96	6.8	1.9	0	6.7	1.2	1.5	3.7	
918	Liquid	¼	cup(s)	63	51.9	53	7.5	0.4	0	2.1	0.4	0.6	1.0	
Seafood														
	Cod													
6040	Atlantic cod or scrod, baked or broiled	3	ounce(s)	85	64.6	89	19.4	0	0	0.7	0.1	0.1	0.2	
1573	Atlantic cod, cooked, dry heat	3	ounce(s)	85	64.6	89	19.4	0	0	0.7	0.1	0.1	0.2	
2905	**Eel, raw**	3	ounce(s)	85	58.0	156	15.7	0	0	9.9	2.0	6.1	0.8	
	Fish fillets													
25079	Baked	3	ounce(s)	84	79.9	99	21.7	0	0	0.7	0.1	0.1	0.3	
8615	Batter coated or breaded, fried	3	ounce(s)	85	45.6	197	12.5	14.4	0.4	10.5	2.4	2.2	5.3	
25082	Broiled fish steaks	3	ounce(s)	85	68.1	128	24.2	0	0	2.6	0.4	0.9	0.8	
25083	Poached fish steaks	3	ounce(s)	85	67.1	111	21.1	0	0	2.3	0.3	0.8	0.7	
25084	Steamed	3	ounce(s)	85	72.2	79	17.2	0	0	0.6	0.1	0.1	0.2	
25089	**Flounder, baked**	3	ounce(s)	85	64.4	113	14.8	0.4	0.1	5.5	1.1	2.2	1.4	
1825	**Grouper, cooked, dry heat**	3	ounce(s)	85	62.4	100	21.1	0	0	1.1	0.3	0.2	0.3	
	Haddock													
6049	Baked or broiled	3	ounce(s)	85	63.2	95	20.6	0	0	0.8	0.1	0.1	0.3	
1578	Cooked, dry heat	3	ounce(s)	85	63.1	95	20.6	0	0	0.8	0.1	0.1	0.3	
1886	**Halibut, Atlantic and Pacific, cooked, dry heat**	3	ounce(s)	85	61.0	119	22.7	0	0	2.5	0.4	0.8	0.8	
1582	**Herring, Atlantic, pickled**	4	piece(s)	60	33.1	157	8.5	5.8	0	10.8	1.4	7.2	1.0	
1587	**Jack mackerel, solids, canned, drained**	2	ounce(s)	57	39.2	88	13.1	0	0	3.6	1.1	1.3	0.9	
8580	**Octopus, common, cooked, moist heat**	3	ounce(s)	85	51.5	139	25.4	3.7	0	1.8	0.4	0.3	0.4	
1831	**Perch, mixed species, cooked, dry heat**	3	ounce(s)	85	62.3	100	21.1	0	0	1.0	0.2	0.2	0.4	
1592	**Pacific rockfish, cooked, dry heat**	3	ounce(s)	85	62.4	103	20.4	0	0	1.7	0.4	0.4	0.5	
	Salmon													
2938	Coho, farmed, raw	3	ounce(s)	85	59.9	136	18.1	0	0	6.5	1.5	2.8	1.6	
1594	Broiled or baked with butter	3	ounce(s)	85	53.9	155	23.0	0	0	6.3	1.2	2.3	2.3	
29727	Smoked chinook (lox)	2	ounce(s)	57	40.8	66	10.4	0	0	2.4	0.5	1.1	0.6	
154	**Sardine, Atlantic with bones, canned in oil**	3	ounce(s)	85	50.7	177	20.9	0	0	9.7	1.3	3.3	4.4	
	Scallops													
155	Mixed species, breaded, fried	3	item(s)	47	27.2	100	8.4	4.7	—	5.1	1.2	2.1	1.3	
1599	Steamed	3	ounce(s)	85	64.8	90	13.8	2.0	0	2.6	0.4	1.0	0.8	
1839	**Snapper, mixed species, cooked, dry heat**	3	ounce(s)	85	59.8	109	22.4	0	0	1.5	0.3	0.3	0.5	
	Squid													
1868	Mixed species, fried	3	ounce(s)	85	54.9	149	15.3	6.6	0	6.4	1.6	2.3	1.8	
16617	Steamed or boiled	3	ounce(s)	85	63.3	89	15.2	3.0	0	1.3	0.4	0.1	0.5	
1570	**Striped bass, cooked, dry heat**	3	ounce(s)	85	62.4	105	19.3	0	0	2.5	0.6	0.7	0.9	
1601	**Sturgeon, steamed**	3	ounce(s)	85	59.4	111	17.0	0	0	4.3	1.0	2.0	0.7	
1840	**Surimi, formed**	3	ounce(s)	85	64.9	84	12.9	5.8	0	0.8	0.2	0.1	0.4	
1842	**Swordfish, cooked, dry heat**	3	ounce(s)	85	58.5	132	21.6	0	0	4.4	1.2	1.7	1.0	
1846	**Tuna, yellowfin or ahi, raw**	3	ounce(s)	85	60.4	92	19.9	0	0	0.8	0.2	0.1	0.2	
	Tuna, canned													
159	Light, canned in oil, drained	2	ounce(s)	57	33.9	112	16.5	0	0	4.6	0.9	1.7	1.6	
355	Light, canned in water, drained	2	ounce(s)	57	42.2	66	14.5	0	0	0.5	0.1	0.1	0.2	
33211	Light, no salt, canned in oil, drained	2	ounce(s)	57	33.9	112	16.5	0	0	4.7	0.9	1.7	1.6	
33212	Light, no salt, canned in water, drained	2	ounce(s)	57	42.6	66	14.5	0	0	0.5	0.1	0.1	0.2	

ol (g)	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
0	27	0.91	6.0	67.6	93.8	0.55	91.1	0.03	0 56	0.23	0.03	0.07	23.5	0	0.6	15.7
2	25	0.59	5.0	63.0	62.0	0.52	84.5	0.03	0.51	0.25	0.03	0.06	22.0	0	0.6	15.4
1	27	0.91	6.0	66.5	147.0	0.55	69.5	0.02	0.48	0.20	0.03	0 06	17.5	0	0.6	15.8
	2	0.02	3.6	53.8	54.8	0 01	0	0.00	0.00	0.14	0.03	0.00	1.3	0	0	6.6
2	27	0.91	6.0	67.0	70.0	0.55	70.0	0.03	0.48	0.23	0.03	0.07	23.5	0	0.6	15.9
0	22	0.46	0.9	18.5	8.2	0.39	64.8	0.03	0.43	0.09	0.00	0.06	24.8	0	0.3	9.5
9	87	1.46	14.6	168.4	341.6	1.22	174.5	0.06	1.33	0.53	0.09	0.14	36.6	0.2	0.9	27.5
	20	1.08	4.0	85.0	115 0	0.60	112.5	0 15	—	0.85	0.20	0.08	60 0	0	1.2	—
	44	1.18	9.0	127.8	119.4	0.58	6.6	0.07	0.95	0.23	0.08	0.08	9 6	0.3	0.2	24.8
	33	1.32	5.6	207.1	111.1	0.82	11.3	0.07	0.17	0.19	0.07	0.00	9.4	0	0.2	15.6
7	12	0.41	35.7	207.5	66.3	0.49	11.9	0.07	0.68	0.06	2.13	0.24	6.8	0.8	0.9	32.0
7	12	0.41	35.7	207.5	66 3	0 49	11 9	0 07	0 68	0.06	2 13	0.24	6 8	0.9	0.9	32 0
07	17	0.42	17.0	231.3	43.4	1.37	887 0	0 13	3 40	0.03	2 97	0 05	12 8	1.5	2.6	5 5
4	8	0.31	29.1	489.0	86.1	0.48	—	0.02	—	0.05	2 47	0.46	8 1	3.0	1.0	44 3
9	15	1.79	20.4	272.2	452.5	0 37	9.4	0 09	—	0 09	1 78	0.08	14 5	0	0.9	7.7
7	55	0.97	96.7	524 3	62 9	0.49	—	0 05	—	0.08	6 47	0 36	12 6	0	1.2	42.5
2	48	0.85	84 0	455.6	54 7	0 42	—	0 05	—	0 07	5 92	0.33	11.5	0	1.1	37.0
1	12	0.29	24.7	319.3	41 7	0 34	—	0.06	—	0 06	1 89	0 21	6.1	0.8	0.8	32.0
4	19	0 34	47.3	224 7	280 2	0 20	—	0 06	0 40	0 07	2 02	0 18	7.4	2.8	1.6	33.5
0	18	0.96	31 5	404.0	45.1	0 43	42.5	0 06	—	0 01	0 32	0.29	8.5	0	0.6	39.8
3	36	1.15	42 5	339.4	74.0	0 40	16 2	0 03	0 42	0 03	3 94	0 29	6.8	0	1.2	34.4
3	36	1 14	42 5	339.3	74.0	0 40	16 2	0 03	—	0 03	3 93	0 29	11.1	0	1.2	34.4
5	51	0.91	91.0	489.9	58.7	0.45	45 9	0.05	—	0.07	6 05	0.33	11.9	0	1.2	39.8
8	46	0.73	4.8	41 4	522 0	0 31	154 8	0 02	1 02	0 08	1 98	0 10	1.2	0	2.6	35.1
5	137	1.15	21.0	110.0	214.9	0.57	73 7	0.02	0 58	0.12	3.50	0.11	2.8	0.5	3.9	21.4
2	90	8.11	51.0	535.8	391.2	2.85	76.5	0.04	1.02	0.06	3.21	0.55	20.4	6.8	30.6	76.2
8	87	0.98	32.3	292.6	67.2	1.21	8.5	0.06	—	0 10	1.61	0.11	5.1	1.4	1.9	13.7
7	10	0.45	28.9	442.3	65.5	0 45	60.4	0.03	1.32	0.07	3.33	0.22	8.5	0	1.0	39.8
3	10	0.29	26.4	382 7	40 0	0 36	47.6	0 08	—	0.09	5.79	0.56	11.1	0.9	2.3	10.7
0	15	1.02	26 9	376.6	98 6	0.56	—	0 13	1 14	0 05	8 33	0.18	4.2	1.8	2.3	41.0
3	6	0.48	10.2	99.2	1134.0	0.17	14 7	0.01	—	0.05	2 67	0.15	1.1	0	1.8	21.6
21	325	2.48	33.2	337.6	429.5	1.10	27.2	0.04	1.70	0.18	4.43	0.14	10.2	0	7.6	44.8
28	20	0.38	27.4	154.8	215 8	0.49	10.7	0.02	—	0.05	0 70	0.06	17.2	1.1	0.6	12.5
27	20	0.22	45 9	238.0	358.7	0.78	32.3	0.01	0.16	0.05	0.84	0.11	10.2	2.0	1.1	18.2
40	34	0.20	31.5	444.0	48.5	0.37	29.8	0.04	—	0.00	0.29	0.39	5.1	1.4	3.0	41.7
21	33	0.85	32.3	237.3	260.3	1.48	9.4	0.04	—	0.39	2 21	0.04	11.9	3.6	1.0	44.1
27	31	0.62	28.9	192.1	356.2	1.49	8.5	0.01	1.17	0.32	1.69	0.04	3.4	3.2	1.0	43.7
88	16	0.91	43.4	279.0	74.8	0.43	26.4	0.09	—	0.03	2.17	0.29	8.5	0	3.8	39.8
63	11	0.59	29.8	239.7	388.5	0 35	198 9	0 06	0.52	0.07	8.30	0.19	14.5	0	2.2	13.3
26	8	0.22	36.6	95.3	121.6	0.28	17.0	0.01	0.53	0.01	0.18	0.02	1.7	0	1.4	23.9
43	5	0.88	28.9	313.8	97.8	1.25	34.9	0.03	—	0.09	10.02	0.32	1.7	0.9	1.7	52.5
38	14	0.62	42.5	377.6	31.5	0.44	15.3	0.37	0.42	0.04	8.33	0.77	1.7	0.8	0.4	31.0
10	7	0.79	17.6	117.3	200.6	0.51	13.0	0.02	0.49	0.07	7.03	0.06	2.8	0	1.2	43.1
17	6	0.87	15.3	134.3	191.5	0.43	9.6	0.01	0.19	0.04	7.52	0.19	2.3	0	1.7	45.6
10	7	0.78	17.6	117.4	28.3	0.51	0	0.02	—	0.06	7.03	0.06	2.8	0	1.2	43.1
17	6	0.86	15.3	134.4	28.3	0.43	0	0.01	—	0.04	7.52	0.19	2.3	0	1.7	45.6

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Seafood—*continued*													
2961	White, canned in oil, drained	2	ounce(s)	57	36.3	105	15.0	0	0	4.6	0.7	1.8	1.7
351	White, canned in water, drained	2	ounce(s)	57	41.5	73	13.4	0	0	1.7	0.4	0.4	0.6
33213	White, no salt, canned in oil, drained	2	ounce(s)	57	36.3	105	15.0	0	0	4.6	0.9	1.4	1.9
33214	White, no salt, canned in water, drained	2	ounce(s)	57	42.0	73	13.4	0	0	1.7	0.4	0.4	0.6
	Yellowtail												
8548	Mixed species, cooked, dry heat	3	ounce(s)	85	57.3	159	25.2	0	0	5.7	1.4	2.2	1.5
2970	Mixed species, raw	2	ounce(s)	57	42.2	83	13.1	0	0	3.0	0.7	1.1	0.8
	Shellfish, meat only												
1857	Abalone, mixed species, fried	3	ounce(s)	85	51.1	161	16.7	9.4	0	5.8	1.4	2.3	1.4
16618	Abalone, steamed or poached	3	ounce(s)	85	40.7	177	28.8	10.1	0	1.3	0.3	0.2	0.2
	Crab												
1851	Blue crab, canned	2	ounce(s)	57	43.2	56	11.6	0	0	0.7	0.1	0.1	0.2
1852	Blue crab, cooked, moist heat	3	ounce(s)	85	65.9	87	17.2	0	0	1.5	0.2	0.2	0.6
8562	Dungeness crab, cooked, moist heat	3	ounce(s)	85	62.3	94	19.0	0.8	0	1.1	0.1	0.2	0.3
1860	**Clams, cooked, moist heat**	3	ounce(s)	85	54.1	126	21.7	4.4	0	1.7	0.2	0.1	0.5
1853	**Crayfish, farmed, cooked, moist heat**	3	ounce(s)	85	68.7	74	14.9	0	0	1.1	0.2	0.2	0.4
	Oysters												
8720	Baked or broiled	3	ounce(s)	85	68.6	89	5.6	3.2	0	5.8	1.3	2.1	1.9
152	Eastern, farmed, raw	3	ounce(s)	85	73.3	50	4.4	4.7	0	1.3	0.4	0.1	0.5
8715	Eastern, wild, cooked, moist heat	3	ounce(s)	85	59.8	117	12.0	6.7	0	4.2	1.3	0.5	1.6
8584	Pacific, cooked, moist heat	3	ounce(s)	85	54.5	139	16.1	8.4	0	3.9	0.9	0.7	1.5
1865	Pacific, raw	3	ounce(s)	85	69.8	69	8.0	4.2	0	2.0	0.4	0.3	0.8
1854	**Lobster, northern, cooked, moist heat**	3	ounce(s)	85	64.7	83	17.4	1.1	0	0.5	0.1	0.1	0.1
1862	**Mussel, blue, cooked, moist heat**	3	ounce(s)	85	52.0	146	20.2	6.3	0	3.8	0.7	0.9	1.0
	Shrimp												
158	Mixed species, breaded, fried	3	ounce(s)	85	44.9	206	18.2	9.8	0.3	10.4	1.8	3.2	4.3
1855	Mixed species, cooked, moist heat	3	ounce(s)	85	65.7	84	17.8	0	0	0.9	0.2	0.2	0.4
Beef, Lamb, Pork													
	Beef												
4450	Breakfast strips, cooked	2	slice(s)	23	5.9	101	7.1	0.3	0	7.8	3.2	3.8	0.4
174	Corned beef, canned	3	ounce(s)	85	49.1	213	23.0	0	0	12.7	5.3	5.1	0.5
33147	Cured, thin sliced	2	ounce(s)	57	32.9	100	15.9	3.2	0	2.2	0.9	1.0	0.1
4581	Jerky	1	ounce(s)	28	6.6	116	9.4	3.1	0.5	7.3	3.1	3.2	0.3
	Ground beef												
5898	Lean, broiled, medium	3	ounce(s)	85	50.4	202	21.6	0	0	12.2	4.8	5.3	0.4
5899	Lean, broiled, well done	3	ounce(s)	85	48.4	214	23.8	0	0	12.5	5.0	5.7	0.3
5914	Regular, broiled, medium	3	ounce(s)	85	46.1	246	20.5	0	0	17.6	6.9	7.7	0.6
5915	Regular, broiled, well done	3	ounce(s)	85	43.8	259	21.6	0	0	18.4	7.5	8.5	0.5
	Beef rib												
4241	Rib, small end, separable lean, 0" fat, broiled	3	ounce(s)	85	53.2	164	25.0	0	0	6.4	2.4	2.6	0.2
4183	Rib, whole, lean and fat, ¼" fat, roasted	3	ounce(s)	85	39.0	320	18.9	0	0	26.6	10.7	11.4	0.9
	Beef roast												
16981	Bottom round, choice, separable lean and fat, ⅛" fat, braised	3	ounce(s)	85	46.2	216	27.9	0	0	10.7	4.1	4.6	0.4
16979	Bottom round, separable lean and fat, ⅛" fat, roasted	3	ounce(s)	85	52.4	185	22.5	0	0	9.9	3.8	4.2	0.4
16924	Chuck, arm pot roast, separable lean and fat, ⅛" fat, braised	3	ounce(s)	85	42.9	257	25.6	0	0	16.3	6.5	7.0	0.6
16930	Chuck, blade roast, separable lean and fat, ⅛" fat, braised	3	ounce(s)	85	40.5	290	22.8	0	0	21.4	8.5	9.2	0.8
5853	Chuck, blade roast, separable lean, 0" trim, pot roasted	3	ounce(s)	85	47.4	202	26.4	0	0	9.9	3.9	4.3	0.3
4296	Eye of round, choice, separable lean, 0" fat, roasted	3	ounce(s)	85	56.5	138	24.4	0	0	3.7	1.3	1.5	0.1
16989	Eye of round, separable lean and fat, ⅛" fat, roasted	3	ounce(s)	85	52.2	180	24.2	0	0	8.5	3.2	3.6	0.3

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	2	0.36	19.3	188.8	224.5	0.26	2.8	0.01	1.30	0.04	6.63	0.24	2.8	0	1.2	34.1
	8	0.55	18.7	134.3	213.6	0.27	3.4	0.00	0 48	0.02	3.28	0.12	1.1	0	0.7	37.2
	2	0.36	19.3	188.8	28.3	0.26	0	0.01	—	0 04	6.63	0.24	2.8	0	1.2	34.1
	8	0.54	18.7	134.4	28.3	0.27	3.4	0.00	—	0 02	3.28	0.12	1.1	0	0.7	37.3
	25	0.53	32.3	457.6	42.5	0.56	26 4	0.14	—	0 04	7.41	0 15	3.4	2.5	1.1	39 8
	13	0.28	17.0	238.1	22.1	0.29	16.4	0 08	—	0.02	3.86	0 09	2.3	1.6	0.7	20.7
	31	3.23	47.6	241 5	502.6	0.80	1.7	0.18	—	0.11	1.61	0 12	11.9	1.5	0.6	44.1
4	50	4.84	68.9	295.0	980.1	1.38	3.4	0.28	6.74	0 12	1.89	0 21	6.0	2.6	0.7	75.6
	57	0.47	22.1	212.1	188.8	2.27	1.1	0 04	1.04	0 04	0.77	0.08	24.4	1.5	0.3	18.0
5	88	0.77	28 1	275 6	237.3	3.58	1.7	0 08	1.56	0 04	2 80	0 15	43.4	2.8	6.2	34.2
5	50	0.36	49.3	347.0	321.5	4 65	26.4	0.04	—	0 17	3 08	0.14	55 7	3.1	8 8	40 5
7	78	23.78	15.3	534 1	95 3	2.32	145 4	0 12	—	0 36	2 85	0 09	24.7	16 8	84 1	54 4
7	43	0.94	28.1	202.4	82 5	1.25	12.8	0 03	—	0.06	1.41	0.11	9.4	0.4	2 6	29.1
3	36	5.30	37.4	125 0	403 8	72 22	60.4	0 07	0 98	0 06	1 04	0 04	7 7	2.8	14 7	50 7
1	37	4.91	28 1	105.4	151 3	32.23	6 8	0.08	—	0 05	1.07	0 05	15.3	4.0	13.8	54.1
9	77	10.19	80.8	239.0	358.9	154.45	45.9	0 16	—	0 15	2 11	0.10	11.9	5.1	29.8	60.9
5	14	7.82	37.4	256 8	180 3	28 27	124 2	0 10	0.72	0 37	3 07	0 07	12.8	10.9	24.5	131.0
3	7	4.34	18.7	142 9	90.1	14 13	68 9	0 05	—	0.20	1 70	0.04	8.5	6.8	13.6	65.5
1	52	0.33	29.8	299 4	323.2	2 48	22 1	0 01	0.85	0.05	0.91	0.06	9.4	0	2.6	36.3
8	28	5.71	31.5	227.9	313.8	2.27	77.4	0 25	—	0.35	2 55	0 08	64.6	11.6	20.4	76.2
50	57	1 07	34 0	191 3	292 4	1 17	0	0.11	—	0 11	2 60	0 08	15.3	1.3	1.6	35.4
66	33	2.62	28.9	154.8	190.5	1.32	57.8	0.02	1 17	0 02	2.20	0.10	3.4	1.9	1.3	33.7
7	2	0.71	6.1	93.1	509.2	1.44	0	0 02	0.06	0 05	1 46	0.07	1.8	0	0.8	6.1
3	10	1.76	11.9	115.7	855 6	3.03	0	0 01	0.12	0.12	2 06	0 11	7.7	0	1.4	36 5
3	6	1.53	10.8	243.2	815.9	2 25	0	0 04	0.00	0 10	2 98	0 19	6.2	0	1.5	16.0
4	6	1.53	14.5	169.2	627.4	2 29	0	0 04	0.13	0.04	0.49	0.05	38.0	0	0.3	3.0
58	6	2.00	17.9	266.2	59.5	4 63	0	0.05	—	0.23	4.21	0 23	7.6	0	1.8	16.0
59	12	2.21	18.4	250.0	62.4	5.86	0	0 08	—	0.23	5.10	0.16	9.4	0	1.7	19.0
52	9	2.07	17.0	248 3	70 6	4.40	0	0.02	—	0 16	4 90	0 23	7.6	0	2.5	16.2
71	12	2.30	18.5	242.4	72.4	5.18	0	0 08	—	0.23	4.93	0.17	8.5	0	1.6	18.0
55	16	1.59	21.3	319.8	51.9	4.64	0	0.06	0.34	0.12	7.15	0.53	8.5	0	1.4	29.2
72	9	1.96	16.2	251.7	53.6	4.45	0	0.06	—	0.14	2.85	0.19	6.0	0	2.1	18.7
68	6	2.29	17.9	223.7	35.7	4.59	0	0.05	0.41	0.15	5.05	0.36	8.5	0	1.7	29.3
64	5	1.83	14.5	182.0	29.8	3.76	0	0.05	0.34	0.12	3.92	0 29	6.8	0	1.3	23.0
67	14	2.15	17.0	205.8	42.5	5.93	0	0.05	0.45	0.15	3.63	0.25	7.7	0	1.9	24.1
88	11	2.66	16.2	198.2	55.3	7.15	0	0.06	0.17	0.20	2.06	0.22	4.3	0	1.9	20.9
73	11	3.12	19.6	223.7	60.4	8.73	0	0.06	—	0.23	2.27	0.24	5.1	0	2.1	22.7
49	5	2.16	16.2	200.7	32.3	4.28	0	0.05	0.30	0.15	4.69	0.34	8.5	0	1.4	28.0
54	5	1.98	15.3	193.1	31.5	3.95	0	0.05	0 34	0 13	4.37	0 31	7.7	0	1.5	25.2

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Beef, Lamb, Pork—*continued*													
	Beef steak												
4348	Short loin, t-bone steak, lean and fat, ¼" fat, broiled	3	ounce(s)	85	43.2	274	19.4	0	0	21.2	8.3	9.6	0.8
4349	Short loin, t-bone steak, lean, ¼" fat, broiled	3	ounce(s)	85	52.3	174	22.8	0	0	8.5	3.1	4.2	0.3
4360	Top loin, prime, lean and fat, ¼" fat, broiled	3	ounce(s)	85	42.7	275	21.6	0	0	20.3	8.2	8.6	0.7
	Beef variety												
188	Liver, pan fried	3	ounce(s)	85	52.7	149	22.6	4.4	0	4.0	1.3	0.5	0.5
4447	Tongue, simmered	3	ounce(s)	85	49.2	242	16.4	0	0	19.0	6.9	8.6	0.6
	Lamb chop												
3275	Loin, domestic, lean and fat, ¼" fat, broiled	3	ounce(s)	85	43.9	269	21.4	0	0	19.6	8.4	8.3	1.4
	Lamb leg												
3264	Domestic, lean and fat, ¼" fat, cooked	3	ounce(s)	85	45.7	250	20.9	0	0	17.8	7.5	7.5	1.3
	Lamb rib												
182	Domestic, lean and fat, ¼" fat, broiled	3	ounce(s)	85	40.0	307	18.8	0	0	25.2	10.8	10.3	2.0
183	Domestic, lean, ¼" fat, broiled	3	ounce(s)	85	50.0	200	23.6	0	0	11.0	4.0	4.4	1.0
	Lamb shoulder												
186	Shoulder, arm and blade, domestic, choice, lean and fat, ¼" fat, roasted	3	ounce(s)	85	47.8	235	19.1	0	0	17.0	7.2	6.9	1.4
187	Shoulder, arm and blade, domestic, choice, lean, ¼" fat, roasted	3	ounce(s)	85	53.8	173	21.2	0	0	9.2	3.5	3.7	0.8
3287	Shoulder, arm, domestic, lean and fat, ¼" fat, braised	3	ounce(s)	85	37.6	294	25.8	0	0	20.4	8.4	8.7	1.5
3290	Shoulder, arm, domestic, lean, ¼" fat, braised	3	ounce(s)	85	41.9	237	30.2	0	0	12.0	4.3	5.2	0.8
	Lamb variety												
3375	Brain, pan fried	3	ounce(s)	85	51.6	232	14.4	0	0	18.9	4.8	3.4	1.9
3406	Tongue, braised	3	ounce(s)	85	49.2	234	18.3	0	0	17.2	6.7	8.5	1.1
	Pork, cured												
29229	Bacon, Canadian style, cured	2	ounce(s)	57	37.9	89	11.7	1.0	0	4.0	1.3	1.8	0.4
161	Bacon, cured, broiled, pan fried or roasted	2	slice(s)	16	2.0	87	5.9	0.2	0	6.7	2.2	3.0	0.7
35422	Breakfast strips, cured, cooked	3	slice(s)	34	9.2	156	9.8	0.4	0	12.5	4.3	5.6	1.9
189	Ham, cured, boneless, 11% fat, roasted	3	ounce(s)	85	54.9	151	19.2	0	0	7.7	2.7	3.8	1.2
29215	Ham, cured, extra lean, 4% fat, canned	2	2 ounce(s)	57	41.7	68	10.5	0	0	2.6	0.9	1.3	0.2
1316	Ham, cured, extra lean, 5% fat, roasted	3	ounce(s)	85	57.6	123	17.8	1.3	0	4.7	1.5	2.2	0.5
16561	Ham, smoked or cured, lean, cooked	1	slice(s)	42	27.6	66	10.5	0	0	2.3	0.8	1.1	0.3
	Pork chop												
32671	Loin, blade, chops, lean and fat, pan fried	3	ounce(s)	85	42.5	291	18.3	0	0	23.6	8.6	10	2.6
32672	Loin, center cut, chops, lean and fat, pan fried	3	ounce(s)	85	45.1	236	25.4	0	0	14.1	5.1	6.0	1.6
32682	Loin, center rib, chops, boneless, lean and fat, braised	3	ounce(s)	85	49.5	217	22.4	0	0	13.4	5.2	6.1	1.1
32603	Loin, center rib, chops, lean, broiled	3	ounce(s)	85	55.4	158	21.9	0	0	7.1	2.4	3.0	0.8
32478	Loin, whole, lean and fat, braised	3	ounce(s)	85	49.6	203	23.2	0	0	11.6	4.3	5.2	1.0
32481	Loin, whole, lean, braised	3	ounce(s)	85	52.2	174	24.3	0	0	7.8	2.9	3.5	0.6
	Pork leg or ham												
32471	Pork leg or ham, rump portion, lean and fat, roasted	3	ounce(s)	85	48.3	214	24.6	0	0	12.1	4.5	5.4	1.2
32468	Pork leg or ham, whole, lean and fat, roasted	3	ounce(s)	85	46.8	232	22.8	0	0	15.0	5.5	6.7	1.4
	Pork ribs												
32693	Loin, country style, lean and fat, roasted	3	ounce(s)	85	43.3	279	19.9	0	0	21.6	7.8	9.4	1.7
32696	Loin, country style, lean, roasted	3	ounce(s)	85	49.5	210	22.6	0	0	12.6	4.5	5.5	0.9

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Selc (µg)
7	2.56	17.9	233.9	57.8	3.56	0	0.07	0.18	0.17	3.29	0.27	6.0	0	1.8	10.0
5	3.11	22.1	278.1	65.5	4.34	0	0.09	0.11	0.21	3.93	0 33	6.8	0	1.9	8.5
8	1.88	19.6	294.3	53.6	3.85	0	0 06	—	0.15	3.96	0.31	6.0	0	1.6	19.5
5	5.24	18.7	298.5	65.5	4.44	6586.3	0.15	0 39	2.91	14 86	0 87	221.1	0.6	70.7	27.9
4	2.22	12.8	156.5	55.3	3.47	0	0.01	0.25	0.25	2.96	0.13	6.0	1.1	2.7	11.2
17	1.53	20.4	278.1	65.5	2.96	0	0.08	0.11	0.21	6.03	0.11	15.3	0	2.1	23.3
14	1.59	19.6	263.7	61.2	3.79	0	0.08	0 11	0.21	5.66	0 11	15.3	0	2.2	22.5
16	1.59	19.6	229.5	64.6	3.40	0	0.07	0.10	0.18	5.95	0.09	11 9	0	2.2	20.3
14	1.87	24.7	266.1	72.3	4.47	0	0.08	0 15	0.21	5.56	0.12	17.9	0	2.2	26.4
17	1.67	19.6	213.4	56.1	4.44	0	0.07	0.11	0.20	5.22	0.11	17.9	0	2.2	22.3
16	1.81	21.3	225.3	57 8	5.13	0	0.07	0.15	0 22	4.89	0 12	21.3	0	2.3	24.2
21	2.03	22.1	260.3	61.2	5.17	0	0.06	0 12	0.21	5.66	0.09	15.3	0	2.2	31.6
22	2.29	24.7	287.5	64.6	6.20	0	0.06	0.15	0.23	5.38	0.11	18.7	0	2.3	32.1
18	1.73	18.7	304.5	133.5	1.70	0	0.14	—	0.31	3 87	0 19	6.0	19.6	20.5	10.2
9	2.23	13.6	134.4	57.0	2 54	0	0.06	—	0 35	3 13	0.14	2.6	6.0	5.4	23.8
5	0.38	9.6	195 0	798.9	0 78	0	0 42	0 11	0.09	3 53	0.22	2.3	0	0.4	14.2
2	0.22	5.3	90 4	369 6	0 56	1.8	0 06	0 04	0 04	1 76	0.04	0.3	0	0.2	9.9
5	0.67	8.8	158.4	713.7	1.25	0	0.25	0.08	0.12	2.58	0.11	1.4	0	0.6	8.4
7	1.13	18.7	347.7	1275.0	2.09	0	0.62	0.26	0.28	5.22	0.26	2.6	0	0.6	16.8
3	0.53	9.6	206.4	711.6	1.09	0	0.47	0.09	0.13	3.00	0.25	3.4	0	0.5	8.2
7	1.25	11.9	244.1	1023.1	2.44	0	0.64	0.21	0.17	3.42	0.34	2.6	0	0.6	16.6
3	0.39	9.2	132.7	557.3	1.07	0	0.28	0.10	0.10	2.10	0.19	1.7	0	0.3	10.7
26	0.74	17.9	282.4	57.0	2.71	1.7	0.52	0.17	0.25	3.35	0.28	3.4	0.5	0.7	29.7
23	0.77	24.7	361.5	68.0	1.96	1.7	0.96	0.21	0.25	4.76	0.39	5.1	0.9	0.6	33.2
4	0.78	14.5	329.1	34.0	1.76	1.7	0.44	—	0.20	3.66	0.26	3.4	0.3	0.4	28.4
22	0.57	21.3	291.7	48.5	1.91	0	0.48	0.08	0.18	6.68	0.57	0	0	0.4	38.6
18	0.91	16.2	318.1	40.8	2.02	1.7	0.53	0.20	0.21	3.75	0.31	2.6	0.5	0.5	38.5
15	0.96	17.0	329.1	42.5	2.10	1.7	0.56	0.17	0.22	3.90	0.32	3.4	0.5	0.5	41.0
10	0.89	23.0	318.1	52.7	2.39	2.6	0.63	0.18	0.28	3.95	0.26	2.6	0.2	0.6	39.8
12	0.85	18.7	299.4	51.0	2.51	2.6	0.54	0.18	0.26	3.89	0.34	8.5	0.3	0.6	38.5
21	0.90	19.6	292.6	44.2	2.00	2.6	0.75	—	0.29	3.67	0.37	4.3	0.3	0.7	31.6
25	1.09	20.4	296.8	24.7	3.24	1.7	0.48	—	0.29	3.96	0.37	4.3	0.3	0.7	36.0

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Beef, Lamb, Pork—*continued*													
	Pork shoulder												
32626	Shoulder, arm picnic, lean and fat, roasted	3	ounce(s)	85	44.3	270	20.0	0	0	20.4	7.5	9.1	2.0
32629	Shoulder, arm picnic, lean, roasted	3	ounce(s)	85	51.3	194	22.7	0	0	10.7	3.7	5.1	1.0
	Rabbit												
3366	Domesticated, roasted	3	ounce(s)	85	51.5	168	24.7	0	0	6.8	2.0	1.8	1.3
3367	Domesticated, stewed	3	ounce(s)	85	50.0	175	25.8	0	0	7.2	2.1	1.9	1.4
	Veal												
3391	Liver, braised	3	ounce(s)	85	50.9	163	24.2	3.2	0	5.3	1.7	1.0	0.9
3319	Rib, lean only, roasted	3	ounce(s)	85	55.0	151	21.9	0	0	6.3	1.8	2.3	0.6
1732	Deer or venison, roasted	3	ounce(s)	85	55.5	134	25.7	0	0	2.7	1.1	0.7	0.5
Poultry													
	Chicken												
29562	Flaked, canned	2	ounce(s)	57	39.3	97	10.3	0.1	0	5.8	1.6	2.3	1.3
	Chicken, fried												
29632	Breast, meat only, breaded, baked or fried	3	ounce(s)	85	44.3	193	25.3	6.9	0.2	6.6	1.6	2.7	1.7
35327	Broiler breast, meat only, fried	3	ounce(s)	85	51.2	159	28.4	0.4	0	4.0	1.1	1.5	0.9
36413	Broiler breast, meat and skin, flour coated, fried	3	ounce(s)	85	48.1	189	27.1	1.4	0.1	7.5	2.1	3.0	1.7
36414	Broiler drumstick, meat and skin, flour coated, fried	3	ounce(s)	85	48.2	208	22.9	1.4	0.1	11.7	3.1	4.6	2.7
35389	Broiler drumstick, meat only, fried	3	ounce(s)	85	52.9	166	24.3	0	0	6.9	1.8	2.5	1.7
35406	Broiler leg, meat only, fried	3	ounce(s)	85	51.5	177	24.1	0.6	0	7.9	2.1	2.9	1.9
35484	Broiler wing, meat only, fried	3	ounce(s)	85	50.9	179	25.6	0	0	7.8	2.1	2.6	1.8
29580	Patty, fillet or tenders, breaded, cooked	3	ounce(s)	85	40.2	256	14.5	12.2	0	16.5	3.7	8.4	3.7
	Chicken, roasted, meat only												
35409	Broiler leg, meat only, roasted	3	ounce(s)	85	55.0	162	23.0	0	0	7.2	1.9	2.6	1.7
35486	Broiler wing, meat only, roasted	3	ounce(s)	85	53.4	173	25.9	0	0	6.9	1.9	2.2	1.5
35138	Roasting chicken, dark meat, meat only, roasted	3	ounce(s)	85	57.0	151	19.8	0	0	7.4	2.1	2.8	1.7
35136	Roasting chicken, light meat, meat only, roasted	3	ounce(s)	85	57.7	130	23.1	0	0	3.5	0.9	1.3	0.8
35132	Roasting chicken, meat only, roasted	3	ounce(s)	85	57.3	142	21.3	0	0	5.6	1.5	2.1	1.3
	Chicken, stewed												
1268	Gizzard, simmered	3	ounce(s)	85	57.8	124	25.8	0	0	2.3	0.6	0.4	0.3
1270	Liver, simmered	3	ounce(s)	85	56.8	142	20.8	0.7	0	5.5	1.8	1.2	1.7
3174	Meat only, stewed	3	ounce(s)	85	56.8	151	23.2	0	0	5.7	1.6	2.0	1.3
	Duck												
1286	Domesticated, meat and skin, roasted	3	ounce(s)	85	44.1	287	16.2	0	0	24.1	8.2	11.0	3.1
1287	Domesticated, meat only, roasted	3	ounce(s)	85	54.6	171	20.0	0	0	9.5	3.5	3.1	1.2
	Goose												
35507	Domesticated, meat and skin, roasted	3	ounce(s)	85	44.2	259	21.4	0	0	18.6	5.8	8.7	2.1
35524	Domesticated, meat only, roasted	3	ounce(s)	85	48.7	202	24.6	0	0	10.8	3.9	3.7	1.3
1297	Liver pate, smoked, canned	4	tablespoon(s)	52	19.3	240	5.9	2.4	0	22.8	7.5	13.3	0.4
	Turkey												
3256	Ground turkey, cooked	3	ounce(s)	85	50.5	200	23.3	0	0	11.2	2.9	4.2	2.7
3263	Patty, batter coated, breaded, fried	1	item(s)	94	46.7	266	13.2	14.8	0.5	16.9	4.4	7.0	4.4
219	Roasted, dark meat, meat only	3	ounce(s)	85	53.7	159	24.3	0	0	6.1	2.1	1.4	1.8
222	Roasted, fryer roaster breast, meat only	3	ounce(s)	85	58.2	115	25.6	0	0	0.6	0.2	0.1	0.2
220	Roasted, light meat, meat only	3	ounce(s)	85	56.4	134	25.4	0	0	2.7	0.9	0.5	0.7
1303	Turkey roll, light and dark meat	2	slice(s)	57	39.8	84	10.3	1.2	0	4.0	1.2	1.3	1.0
1302	Turkey roll, light meat	2	slice(s)	57	42.5	56	8.4	2.9	0	0.9	0.2	0.2	0.1
Processed Meats													
	Beef												
1331	Corned beef loaf, jellied, sliced	2	slice(s)	57	39.2	87	13.0	0	0	3.5	1.5	1.5	0.2

APPENDIX H

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
16	1.00	14.5	276.4	59.5	2.93	1.7	0.44	—	0.25	3.33	0.29	3.4	0.2	0.6	28.6
8	1.20	17.0	298.5	68.0	3.46	1.7	0.49	—	0.30	3.66	0.34	4.3	0.3	0.7	32.7
16	1.93	17.9	325.7	40.0	1.93	0	0 07	—	0.17	7.17	0 40	9.4	0	7.1	32.7
17	2.01	17.0	255.1	31.5	2.01	0	0 05	0.37	0.14	6.09	0.28	7.7	0	5.5	32.7
5	4.34	17.0	279.8	66.3	9.55	8026	0.15	0.57	2.43	11.18	0.78	281.5	0.9	72.0	16.4
10	0.81	20.4	264.5	82.5	3.81	0	0.05	0.30	0.24	6.37	0.23	11.9	0	1.3	9.4
6	3.80	20.4	284.9	45.9	2.33	0	0.15	—	0.51	5.70	—	—	0	—	11.0
8	0.89	6.8	147 4	408.2	0.79	19.3	0 01	—	0.07	3 58	0.19	2 3	0	0.2	—
19	1.05	24.7	222.6	450.2	0.84	—	0.08	—	0.09	10.97	0.46	4.3	0	0.3	—
14	0.96	26 4	234 7	67 2	0.91	6 0	0 06	0 35	0 10	12 57	0.54	3 4	0	0.3	22.3
14	1.01	25.5	220.3	64.6	0.93	12.8	0.06	0.39	0.11	11.68	0.49	5.1	0	0.3	20.3
10	1.13	19.6	194.8	75.7	2.45	21.3	0.06	0.65	0.19	5.13	0.29	8.5	0	0.3	15.6
10	1.12	20.4	211.8	81.6	2.73	15.3	0.06	—	0.20	5.22	0.33	7.7	0	0.3	16.7
11	1 19	21.3	216.0	81 6	2 53	17 0	0 07	0 38	0 21	5 68	0 33	7.7	0	0.3	16.0
13	0 96	17 9	176 9	77 4	1 80	15 3	0 03	0 40	0 10	6 15	0 50	3.4	0	0.3	21.6
11	0.75	19.6	244.8	411.4	0.79	4.3	0.09	1.04	0.12	5.99	0.24	24.7	0	0.2	13.9
10	1.11	20.4	205 8	77 4	2 43	16 2	0 06	0 22	0 19	5 37	0 31	6 8	0	0.3	18.8
14	0.98	17.9	178.6	78.2	1.82	15.3	0.03	0.22	0.10	6.21	0.50	3.4	0	0.3	21.0
9	1.13	17.0	190.5	80.8	1.81	13.6	0.05	—	0.16	4.87	0.26	6.0	0	0.2	16.7
11	0.91	19.6	200.7	43.4	0.66	6.8	0.05	0.22	0.07	8.90	0.45	2.6	0	0.3	21.9
10	1.02	17.9	194.8	63.8	1.29	10.2	0.05	—	0.12	6.70	0.34	4.3	0	0.2	20.9
14	2.71	2 6	152 2	47.6	3.75	0	0.02	0 17	0 17	2.65	0 06	4.3	0	0.9	35.0
9	9 89	21 3	223 7	64 6	3.38	3385 8	0 24	0.69	1.69	9 39	0 64	491 6	23.7	14.3	70.1
12	0.99	17.9	153.1	59.5	1.69	12 8	0.04	0.22	0 13	5 20	0.22	5.1	0	0.2	17.8
9	2.29	13.6	173.5	50.2	1.58	53.6	0.14	0.59	0.22	4.10	0.15	5.1	0	0.3	17.0
10	2.29	17.0	214.3	55.3	2.21	19.6	0.22	0.59	0.39	4.33	0.21	8.5	0	0.3	19.1
11	2.40	18.7	279.8	59.5	2.22	17.9	0 06	1.47	0.27	3.54	0.31	1.7	0	0.3	18.5
12	2.44	21.3	330.0	64 6	2.69	10.2	0.07	—	0.33	3.47	0.39	10.2	0	0.4	21.7
36	2.86	6.8	71.8	362.4	0.47	520 5	0.04	—	0.15	1.30	0.03	31 2	0	4.9	22.9
21	1.64	20.4	229.6	91.0	2.43	0	0.04	0.28	0.14	4.09	0.33	6.0	0	0.3	31.6
13	2.06	14.1	258.5	752.0	1.35	9.4	0.09	0.87	0.17	2.16	0.18	38.5	0	0.2	20.8
27	1.98	20.4	246.6	67.2	3.79	0	0.05	0.54	0.21	3.10	0.30	7.7	0	0.3	34.8
10	1.30	24.7	248.3	44.2	1.48	0	0.03	0.07	0.11	6.37	0.47	5.1	0	0.3	27.3
16	1.14	23.8	259 4	54.4	1.73	0	0.05	0 07	0.11	5.81	0.45	5.1	0	0.3	27.3
18	0.76	10.2	153 1	332.3	1 13	0	0.05	0 19	0.16	2.72	0.15	2.8	0	0.1	16.6
4	0.21	10.8	242.1	590.8	0.50	0	0.01	0.07	0.08	4.05	0.23	2.3	0	0.2	7.4
6	1.15	6.2	57.3	540.4	2.31	0	0.00	—	0.06	0.99	0.06	4.5	0	0.7	9.8

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Processed Meats—*continued*													
	Bologna												
13459	Beef	1	slice(s)	28	15.1	90	3.0	1.0	0	8.0	3.5	4.3	0.3
13461	Light, made with pork and chicken	1	slice(s)	28	18.2	60	3.0	2.0	0	4.0	1.0	2.0	0.4
13458	Made with chicken and pork	1	slice(s)	28	15.0	90	3.0	1.0	0	8.0	3.0	4.1	1.1
13565	Turkey bologna	1	slice(s)	28	19.0	50	3.0	1.0	0	4.0	1.0	1.1	1.0
	Chicken												
7125	Breast, smoked	1	slice(s)	10	—	10	1.8	0.3	0	0.2	0	—	—
	Ham												
7127	Deli-sliced, honey	1	slice(s)	10	—	10	1.7	0.3	0	0.3	0.1	—	—
7126	Deli-sliced, smoked	1	slice(s)	10	—	10	1.7	0.2	0	0.3	0.1	—	—
8614	**Beef and pork mortadella, sliced**	2	slice(s)	46	24.1	143	7.5	1.4	0	11.7	4.4	5.2	1.4
1323	**Pork olive loaf**	2	slice(s)	57	33.1	133	6.7	5.2	0	9.4	3.3	4.5	1.1
1324	**Pork pickle and pimento loaf**	2	slice(s)	57	34.2	128	6.4	4.8	0.9	9.1	3.0	4.0	1.6
	Sausages and frankfurters												
37296	Beerwurst beef, beer salami (bierwurst)	1	slice(s)	29	16.6	74	4.1	1.2	0	5.7	2.5	2.7	0.2
37257	Beerwurst pork, beer salami	1	slice(s)	21	12.9	50	3.0	0.4	0	4.0	1.3	1.9	0.5
35338	Berliner, pork and beef	1	ounce(s)	28	17.3	65	4.3	0.7	0	4.9	1.7	2.3	0.4
37298	Bratwurst pork, cooked	1	piece(s)	74	42.3	181	10.4	1.9	0	14.3	5.1	6.7	1.5
37299	Braunschweiger pork liver sausage	1	slice(s)	15	8.2	51	2.0	0.3	0	4.5	1.5	2.1	0.5
1329	Cheesefurter or cheese smokie, beef and pork	1	item(s)	43	22.6	141	6.1	0.6	0	12.5	4.5	5.9	1.3
1330	Chorizo, beef and pork	2	ounce(s)	57	18.1	258	13.7	1.1	0	21.7	8.2	10.4	2.0
8600	Frankfurter, beef	1	item(s)	45	23.4	149	5.1	1.8	0	13.3	5.3	6.4	0.5
202	Frankfurter, beef and pork	1	item(s)	45	25.2	137	5.2	0.8	0	12.4	4.8	6.2	1.2
1293	Frankfurter, chicken	1	item(s)	45	28.1	100	7.0	1.2	0.2	7.3	1.7	2.7	1.7
3261	Frankfurter, turkey	1	item(s)	45	28.3	100	5.5	1.7	0	7.8	1.8	2.6	1.8
37275	Italian sausage, pork, cooked	1	item(s)	68	32.0	234	13.0	2.9	0.1	18.6	6.5	8.1	2.2
37307	Kielbasa or kolbassa, pork and beef	1	slice(s)	30	18.5	67	5.0	1.0	0	4.7	1.7	2.2	0.5
1333	Knockwurst or knackwurst, beef and pork	2	ounce(s)	57	31.4	174	6.3	1.8	0	15.7	5.8	7.3	1.7
37285	Pepperoni, beef and pork	1	slice(s)	11	3.4	51	2.2	0.4	0.2	4.4	1.8	2.1	0.3
37313	Polish sausage, pork	1	slice(s)	21	11.4	60	2.8	0.7	0	5.0	1.8	2.3	0.5
206	Salami, beef, cooked, sliced	2	slice(s)	52	31.2	136	6.5	1.0	0	11.5	5.1	5.5	0.5
37272	Salami, pork, dry or hard	1	slice(s)	13	4.6	52	2.9	0.2	0	4.3	1.5	2.0	0.5
40987	Sausage, turkey, cooked	2	ounce(s)	57	36.9	111	13.5	0	0	5.9	1.3	1.7	1.5
8620	Smoked sausage, beef and pork	2	ounce(s)	57	30.6	181	6.8	1.4	0	16.3	5.5	6.9	2.2
8619	Smoked sausage, pork	2	ounce(s)	57	32.0	178	6.8	1.2	0	16.0	5.3	6.4	2.1
37273	Smoked sausage, pork link	1	piece(s)	76	29.8	295	16.8	1.6	0	24.0	8.6	11.1	2.8
1336	Summer sausage, thuringer, or cervelat, beef and pork	2	ounce(s)	57	25.6	205	9.9	1.9	0	17.3	6.5	7.4	0.7
37294	Vienna sausage, cocktail, beef and pork, canned	1	piece(s)	16	10.4	37	1.7	0.4	0	3.1	1.1	1.5	0.2
	Spreads												
1318	Ham salad spread	¼	cup(s)	60	37.6	130	5.2	6.4	0	9.3	3.0	4.3	1.6
32419	Pork and beef sandwich spread	4	tablespoon(s)	60	36.2	141	4.6	7.2	0.1	10.4	3.6	4.6	1.5
	Turkey												
13604	Breast, fat free, oven roasted	1	slice(s)	28	—	25	4.0	1.0	0	0	0	0	0
13606	Breast, hickory smoked fat free	1	slice(s)	28	—	25	4.0	1.0	0	0	0	0	0
16049	Breast, hickory smoked slices	1	slice(s)	56	—	50	11.0	1.0	0	0	0	0	0
16047	Breast, honey roasted slices	1	slice(s)	56	—	60	11.0	3.0	0	0	0	0	0
16048	Breast, oven roasted slices	1	slice(s)	56	—	50	11.0	1.0	0	0	0	0	0
7124	Breast, oven roasted	1	slice(s)	10	—	10	1.8	0.3	0	0.1	0	0	0
13567	Turkey ham, 10% water added	2	slice(s)	56	40.9	70	10.0	2.0	0	3.0	0	0.4	0.6
37270	Turkey pastrami	1	slice(s)	28	20.3	35	4.6	1.0	0	1.2	0.3	0.4	0.3
3262	Turkey salami	2	slice(s)	57	39.1	98	10.9	0.9	0.1	5.2	1.6	1.8	1.4
37318	Turkey salami, cooked	1	slice(s)	28	20.4	43	4.3	0.1	0	2.7	0.8	0.9	0.7
Beverages													
	Beer												
866	Ale, mild	12	fluid ounce(s)	360	332.3	148	1.1	13.3	0.4	0	0	0	0
686	Beer	12	fluid ounce(s)	356	327.7	153	1.6	12.7	0	0	0	0	0
16886	Beer, non alcoholic	12	fluid ounce(s)	360	328.1	133	0.8	29.0	0	0.4	0.1	0	0.2

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	[illegible] (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
0	0.36	3.9	47.0	310.0	0.56	0	0.01	—	0.03	0.67	0.04	3.6	0	0.4	—
40	0.36	5.6	45.6	300.0	0.45	0	—	—	—	—	—	—	0	—	—
20	0.36	5.9	43.1	300.0	0.39	0	—	—	—	—	—	—	0	—	—
40	0.36	6.2	42.6	270.0	0.51	0	—	—	—	—	—	—	0	—	—
0	0.00	—	—	100.0	—	0	—	—	—	—	—	—	0	—	—
0	0.12	—	—	100.0	—	0	—	—	—	—	—	—	0.6	—	—
0	0.12	—	—	103.3	—	0	—	—	—	—	—	—	0.6	—	—
8	0.64	5.1	75.0	573.2	0.96	0	0.05	0.10	0.07	1.23	0.06	1.4	0	0.7	10.4
62	0.30	10.8	168.7	842.9	0.78	34.1	0.16	0.14	0.14	1.04	0.13	1.1	0	0.7	9.3
62	0.75	19.3	210.7	740.7	0.95	44.3	0.22	0.22	0.06	1.41	0.23	21.0	4.4	0.3	4.5
3	0.44	3.5	66.5	264.9	0.71	0	0.02	0.05	0.03	0.98	0.04	0.9	0	0.6	4.7
2	0.15	2.7	53.3	261.0	0.36	0	0.11	0.03	0.04	0.68	0.07	0.6	0	0.2	4.4
3	0.32	4.3	80.2	367.7	0.70	0	0.10	—	0.06	0.88	0.05	1.4	0	0.8	4.0
33	0.95	11.1	156.9	412.2	1.70	0	0.37	0.01	0.13	2.36	0.15	1.5	0.7	0.7	15.7
1	1.42	1.7	27.5	131.5	0.42	641.0	0.03	0.05	0.23	1.27	0.05	6.7	0	3.1	8.8
25	0.46	5.6	88.6	465.3	0.96	20.2	0.10	0.10	0.06	1.24	0.05	1.3	0	0.7	6.8
5	0.90	10.2	225.7	700.2	1.93	0	0.35	0.12	0.17	2.90	0.30	1.1	0	1.1	12.0
6	0.67	6.3	70.2	513.0	1.10	0	0.01	0.09	0.06	1.06	0.04	2.3	0	0.8	3.7
5	0.51	4.5	75.2	504.0	0.82	8.1	0.09	0.11	0.05	1.18	0.05	1.8	0	0.6	6.2
33	0.52	9.0	90.9	379.8	0.50	0	0.02	0.09	0.11	2.10	0.14	3.2	0	0.2	10.4
67	0.66	6.3	176.4	485.1	0.82	0	0.01	0.27	0.08	1.65	0.06	4.1	0	0.4	6.8
14	0.97	12.2	206.7	820.8	1.62	6.8	0.42	0.17	0.15	2.83	0.22	3.4	0.1	0.9	15.0
13	0.44	4.9	84.4	283.0	0.61	0	0.06	0.06	0.06	0.87	0.05	1.5	0	0.5	5.4
6	0.37	6.2	112.8	527.3	0.94	0	0.19	0.32	0.07	1.55	0.09	1.1	0	0.7	7.7
2	0.15	2.0	34.7	196.7	0.30	0	0.05	0.00	0.02	0.59	0.04	0.7	0.1	0.2	2.4
2	0.29	2.9	37.3	199.3	0.40	0	0.10	0.04	0.03	0.71	0.03	0.4	0.2	0.2	3.7
3	1.14	6.8	97.8	592.8	0.92	0	0.04	0.08	0.08	1.68	0.08	1.0	0	1.6	7.6
2	0.16	2.8	48.4	289.3	0.53	0	0.11	0.02	0.04	0.71	0.07	0.3	0	0.4	3.3
12	0.84	11.9	169.0	377.1	2.19	7.4	0.04	0.10	0.14	3.24	0.18	3.4	0.4	0.7	0
7	0.42	7.4	101.5	516.5	0.71	7.4	0.10	0.07	0.06	1.66	0.09	1.1	0	0.3	0
6	0.33	6.2	273.9	468.9	0.74	0	0.12	0.14	0.10	1.59	0.10	0.6	0	0.4	10.4
23	0.87	14.4	254.6	1136.6	2.13	0	0.53	0.18	0.19	3.43	0.26	3.8	1.5	1.2	16.4
5	1.15	7.9	147.4	737.1	1.45	0	0.08	0.12	0.18	2.44	0.14	1.1	9.4	3.1	11.5
2	0.14	1.1	16.2	155.0	0.25	0	0.01	0.03	0.01	0.25	0.01	0.6	0	0.2	2.7
5	0.35	6.0	90.0	547.2	0.66	0	0.26	1.04	0.07	1.25	0.09	0.6	0	0.5	10.7
7	0.47	4.8	66.0	607.8	0.61	15.6	0.10	1.04	0.08	1.03	0.07	1.2	0	0.7	5.8
0	0.00	—	—	340.0	—	0	—	—	—	—	—	—	0	—	—
0	0.00	—	—	300.0	—	0	—	—	—	—	—	—	0	—	—
0	0.72	—	—	720.0	—	0	—	—	—	—	—	—	0	—	—
0	0.72	—	—	660.0	—	0	—	—	—	—	—	—	0	—	—
0	0.72	—	—	660.0	—	0	—	—	—	—	—	—	0	—	—
0	0.06	—	—	103.3	—	0	—	—	—	—	—	—	0	—	—
0	0.72	12.3	162.4	700.0	1.44	0	—	—	—	—	—	—	0	—	—
3	1.19	4.0	97.8	278.1	0.61	1.1	0.01	0.06	0.07	1.00	0.07	1.4	4.6	0.1	4.6
23	0.70	12.5	122.5	569.3	1.31	1.1	0.24	0.13	0.17	2.25	0.24	5.7	0	0.6	15.0
11	0.35	6.2	61.2	284.6	0.65	0.6	0.12	0.06	0.08	1.12	0.12	2.8	0	0.3	7.5
18	0.07	21.6	90.0	14.4	0.03	0	0.03	0.00	0.10	1.62	0.18	21.6	0	0.1	2.5
14	0.07	21.4	96.2	14.3	0.03	0	0.01	0.00	0.08	1.82	0.16	21.4	0	0.1	2.1
25	0.21	25.2	28.8	46.8	0.07	—	0.07	0.00	0.18	3.99	0.10	50.4	1.8	0.1	4.3

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Beverages - *continued*													
31609	Bud Light beer	12	fluid ounce(s)	355	335.5	110	0.9	6.6	0	0	0	0	0
31608	Budweiser beer	12	fluid ounce(s)	355	327.7	145	1.3	10.6	0	0	0	0	0
869	Light beer	12	fluid ounce(s)	354	335.9	103	0.9	5.8	0	0	0	0	0
31613	Michelob beer	12	fluid ounce(s)	355	323.4	155	1.3	13.3	0	0	0	0	0
31614	Michelob Light beer	12	fluid ounce(s)	355	329.8	134	1.1	11.7	0	0	0	0	0
	Gin, rum, vodka, whiskey												
857	Distilled alcohol, 100 proof	1	fluid ounce(s)	28	16.0	82	0	0	0	0	0	0	0
687	Distilled alcohol, 80 proof	1	fluid ounce(s)	28	18.5	64	0	0	0	0	0	0	0
688	Distilled alcohol, 86 proof	1	fluid ounce(s)	28	17.8	70	0	0	0	0	0	0	0
689	Distilled alcohol, 90 proof	1	fluid ounce(s)	28	17.3	73	0	0	0	0	0	0	0
856	Distilled alcohol, 94 proof	1	fluid ounce(s)	28	16.8	76	0	0	0	0	0	0	0
	Liqueurs												
33187	Coffee liqueur, 53 proof	1	fluid ounce(s)	35	10.8	113	0	16.3	0	0.1	0	0	0
3142	Coffee liqueur, 63 proof	1	fluid ounce(s)	35	14.4	107	0	11.2	0	0.1	0	0	0
736	Cordials, 54 proof	1	fluid ounce(s)	30	8.9	106	0	13.3	0	0.1	0	0	0
	Wine												
861	California red wine	5	fluid ounce(s)	150	133.4	125	0.3	3.7	0	0	0	0	0
858	Domestic champagne	5	fluid ounce(s)	150	—	105	0.3	3.8	0	0	0	0	0
690	Sweet dessert wine	5	fluid ounce(s)	147	103.7	235	0.3	20.1	0	0	0	0	0
1481	White wine	5	fluid ounce(s)	148	128.1	121	0.1	3.8	0	0	0	0	0
1811	Wine cooler	10	fluid ounce(s)	300	267.4	159	0.3	20.2	0	0.1	0	0	0
	Carbonated												
31898	7 Up	12	fluid ounce(s)	360	321.0	140	0	39.0	0	0	0	0	0
692	Club soda	12	fluid ounce(s)	355	354.8	0	0	0	0	0	0	0	0
12010	Coca-Cola Classic cola soda	12	fluid ounce(s)	360	319.4	146	0	40.5	0	0	0	0	0
693	Cola	12	fluid ounce(s)	368	332.7	136	0.3	35.2	0	0.1	0	0	0
2391	Cola or pepper-type soda, low calorie with saccharin	12	fluid ounce(s)	355	354.5	0	0	0.3	0	0	0	0	0
9522	Cola soda, decaffeinated	12	fluid ounce(s)	372	333.4	153	0	39.3	0	0	0	0	0
9524	Cola, decaffeinated, low calorie with aspartame	12	fluid ounce(s)	355	354.3	4	0.4	0.5	0	0	0	0	0
1415	Cola, low calorie with aspartame	12	fluid ounce(s)	355	353.6	7	0.4	1.0	0	0.1	0	0	0
1412	Cream soda	12	fluid ounce(s)	371	321.5	189	0	49.3	0	0	0	0	0
31899	Diet 7 Up	12	fluid ounce(s)	360	—	0	0	0	0	0	0	0	0
12031	Diet Coke cola soda	12	fluid ounce(s)	360	—	2	0	0.2	0	0	0	0	0
29392	Diet Mountain Dew soda	12	fluid ounce(s)	360	—	0	0	0	0	0	0	0	0
29389	Diet Pepsi cola soda	12	fluid ounce(s)	360	—	0	0	0	0	0	0	0	0
12034	Diet Sprite soda	12	fluid ounce(s)	360	—	4	0	0	0	0	0	0	0
695	Ginger ale	12	fluid ounce(s)	366	333.9	124	0	32.1	0	0	0	0	0
694	Grape soda	12	fluid ounce(s)	372	330.3	160	0	41.7	0	0	0	0	0
1876	Lemon lime soda	12	fluid ounce(s)	368	330.8	147	0.2	37.4	0	0.1	0	0	0
29391	Mountain Dew soda	12	fluid ounce(s)	360	314.0	170	0	46.0	0	0	0	0	0
3145	Orange soda	12	fluid ounce(s)	372	325.9	179	0	45.8	0	0	0	0	0
1414	Pepper-type soda	12	fluid ounce(s)	368	329.3	151	0	38.3	0	0.4	0.3	0	0
29388	Pepsi regular cola soda	12	fluid ounce(s)	360	318.9	150	0	41.0	0	0	0	0	0
696	Root beer	12	fluid ounce(s)	370	330.0	152	0	39.2	0	0	0	0	0
12044	Sprite soda	12	fluid ounce(s)	360	321.0	144	0	39.0	0	0	0	0	0
	Coffee												
731	Brewed	8	fluid ounce(s)	237	235.6	2	0.3	0	0	0	0	0	0
9520	Brewed, decaffeinated	8	fluid ounce(s)	237	234.3	5	0.3	1.0	0	0	0	0	0
16882	Cappuccino	8	fluid ounce(s)	240	224.8	79	4.1	5.8	0.2	4.9	2.3	1.0	0.2
16883	Cappuccino, decaffeinated	8	fluid ounce(s)	240	224.8	79	4.1	5.8	0.2	4.9	2.3	1.0	0.2
16880	Espresso	8	fluid ounce(s)	237	231.8	21	0	3.6	0	0.4	0.2	0	0.2
16881	Espresso, decaffeinated	8	fluid ounce(s)	237	231.8	21	0	3.6	0	0.4	0.2	0	0.2
732	Instant, prepared	8	fluid ounce(s)	239	236.5	5	0.2	0.8	0	0	0	0	0
	Fruit drinks												
29357	Crystal Light sugar-free lemonade drink	8	fluid ounce(s)	240	—	5	0	0	0	0	0	0	0
6012	Fruit punch drink with added vitamin C, canned	8	fluid ounce(s)	248	218.2	117	0	29.7	0.5	0	0	0	0
31143	Gatorade Thirst Quencher, all flavors	8	fluid ounce(s)	240	—	50	0	14.0	0	0	0	0	0
260	Grape drink, canned	8	fluid ounce(s)	250	210.5	153	0	39.4	0	0	0	0	0
17372	Kool-Aid (lemonade/punch/fruit drink)	8	fluid ounce(s)	248	220.0	108	0.1	27.8	0.2	0	0	0	0

Calc (mg)	Iron (mg)	Magn (mg)	Phos (mg)	Pota (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Niac (mg)	Vit B_6 (mg)	Folic (µg)	Vit C (mg)	Vit B_{12} (µg)	Selen (µg)
18	0.14	17.8	63.9	9.0	0.10	0	0.03	—	0.10	1.39	0.12	14.6	0	0	4.0
18	0.10	21.3	88.8	9.0	0 07	0	0.02	—	0.09	1.60	0.17	21.3	0	0.1	4.0
14	0.10	17.7	74.3	14.2	0 03	0	0.01	0.00	0.05	1.38	0.12	21.2	0	0.1	1.4
18	0.10	21.3	88.8	9.0	0 07	0	0 02	—	0.09	1.60	0.17	21.3	0	0.1	4.0
18	0.14	17.8	63 9	9.0	0.10	0	0.03	—	0.10	1.39	0 12	14.6	0	0	4.0
0	0.01	0	0.6	0.3	0.01	0	0.00	—	0.00	0.00	0.00	0	0	0	0
0	0.01	0	0.6	0.3	0.01	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
0	0.01	0	0.6	0.3	0.01	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
0	0.01	0	0.6	0.3	0.01	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
0	0.01	0	0.6	0.3	0.01	0	0.00	—	0.00	0.00	0.00	0	0	0	0
0	0.02	1.0	10 4	2 8	0 01	0	0 00	0.00	0.00	0.05	0.00	0	0	0	0.1
0	0.02	1 0	10 4	2.8	0.01	0	0 00	—	0 00	0 05	0.00	0	0	0	0.1
0	0.02	0.6	4.5	2.1	0.01	0	0.00	0 00	0.00	0.02	0.00	0	0	0	0.1
12	1.43	16 2	170.6	15.0	0.14	0	0.01	0.00	0.04	0.11	0.05	1.5	0	0	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	—
12	0 34	13.2	135 4	13.2	0 10	0	0 01	0 00	0 01	0.30	0.00	0	0	0	0.7
13	0 39	14 8	104.7	7 4	0 18	0	0 01	0 00	0 01	0 15	0 06	1 5	0	0	0.1
18	0.75	15 0	129 0	24 0	0.18	—	0.01	0 03	0.03	0 13	0.03	3.0	5 4	0	0.6
—	—	—	0 6	75 0	—	—	—	—	—	—	—	—	—	—	—
18	0.03	3 5	7.1	74.6	0 35	0	0 00	0 00	0 00	0 00	0.00	0	0	0	0
—	—	—	0	49.5	—	0	—	—	—	—	—	—	0	—	—
7	0 41	0	7.4	14 7	0 06	0	0 00	0 00	0 00	0 00	0.00	0	0	0	0.4
14	0.06	3.5	14.2	56.8	0.11	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0.3
7	0 08	0	11.2	14 9	0.03	0	0 00	0 00	0 00	0 00	0 00	0	0	0	0.4
11	0.06	0	24.9	14.2	0.03	0	0.02	0.00	0.08	0.00	0.00	0	0	0	0.3
11	0.39	3.5	28.4	28.4	0.03	0	0.02	0 00	0.08	0 00	0.00	0	0	0	0
19	0.18	3.7	3.7	44.5	0.26	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
—	—	—	77.0	45.0	—	—	—	—	—	—	—	—	—	—	—
—	—	—	18.0	42.0	—	0	—	—	—	—	—	—	0	—	—
—	—	—	70.0	35.0	—	—	—	—	—	—	—	—	—	—	—
—	—	—	30.0	35.0	—	—	—	—	—	—	—	—	—	—	—
—	—	—	109.5	36.0	—	0	—	—	—	—	—	—	0	—	—
11	0.65	3.7	3.7	25.6	0.18	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0.4
11	0 29	3.7	3.7	55 8	0.26	0	0 00	—	0.00	0.00	0 00	0	0	0	0
7	0.41	3.7	3.7	33.2	0.14	0	0.00	0.00	0.00	0.05	0.00	0	0	0	0
—	—	—	0	70.0	—	—	—	—	—	—	—	—	—	—	—
19	0.21	3.7	7.4	44.6	0.36	0	0.00	—	0.00	0.00	0.00	0	0	0	0
11	0.14	0	3.7	36.8	0.14	0	0.00	—	0.00	0.00	0.00	0	0	0	0.4
—	—	—	0	35.0	—	—	—	—	—	—	—	—	—	—	—
18	0.18	3.7	3.7	48.0	0.26	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0.4
—	—	—	0	70.5	—	0	—	—	—	—	—	—	0	—	—
5	0.02	7.1	116.1	4.7	0.04	0	0.03	0.02	0.18	0.45	0.00	4.7	0	0	0
7	0.14	11.8	108.9	4.7	0.00	0	0.00	0.00	0.03	0.66	0.00	0	0	0	0.5
144	0.19	14.4	232.8	50.4	0.50	33.6	0.04	0.09	0.27	0.13	0.04	7.2	0	0.4	4.6
144	0.19	14 4	232.8	50.4	0.50	33.6	0.04	0.09	0.27	0.13	0.04	7 2	0	0.4	4.6
5	0.30	189.6	272.6	33.2	0.11	0	0.00	0.04	0.42	12.34	0.00	2.4	0.5	0	0
5	0 30	189.6	272.6	33.2	0.11	0	0.00	0.04	0.42	12.34	0.00	2.4	0.5	0	0
10	0.09	9.5	71.6	9.5	0.01	0	0.00	0.00	0.00	0.56	0.00	0	0	0	0.2
0	0.00	—	160.0	40.0	—	0	—	—	—	—	—	—	0	—	—
20	0.22	7.4	62.0	94.2	0.02	5.0	0.05	0.04	0.05	0.05	0.02	9.9	89.3	0	0.5
0	0.00	—	30.0	110.0	—	0	—	—	—	—	—	—	0	—	—
130	0.17	2.5	30.0	40.0	0.30	0	0.00	0.00	0.01	0.02	0.01	0	78.5	0	0.3
14	0.45	5.0	49.6	31.0	0.19	—	0.03	—	0.05	0.04	0.01	4.3	41.6	0	1.0

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Beverages—*continued*													
17225	Kool-Aid sugar free, low calorie tropical punch drink mix, prepared	8	fluid ounce(s)	240	—	5	0	0	0	0	0	0	0
266	Lemonade, prepared from frozen concentrate	8	fluid ounce(s)	248	221.6	99	0.2	25.8	0	0.1	0	0	0
268	Limeade, prepared from frozen concentrate	8	fluid ounce(s)	247	212.6	128	0	34.1	0	0	0	0	0
14266	Odwalla strawberry C monster smoothie blend	8	fluid ounce(s)	240	—	160	2.0	38.0	0	0	0	0	0
10080	Odwalla strawberry lemonade quencher	8	fluid ounce(s)	240	—	110	0	28.0	0	0	0	0	0
10099	Snapple fruit punch fruit drink	8	fluid ounce(s)	240	—	110	0	29.0	0	0	0	0	0
10096	Snapple kiwi strawberry fruit drink	8	fluid ounce(s)	240	211.2	110	0	28.0	0	0	0	0	0
	Slim Fast ready-to-drink shake												
16054	French vanilla ready to drink shake	11	fluid ounce(s)	325	—	220	10.0	40.0	5.0	2.5	0.5	1.5	0.5
40447	Optima rich chocolate royal ready-to-drink shake	11	fluid ounce(s)	330	—	180	10.0	24.0	5.0	5.0	1.0	3.5	0.5
16055	Strawberries n cream ready to drink shake	11	fluid ounce(s)	325	—	220	10.0	40.0	5.0	2.5	0.5	1.5	0.5
	Tea												
33179	Decaffeinated, prepared	8	fluid ounce(s)	237	236.3	2	0	0.7	0	0	0	0	0
1877	Herbal, prepared	8	fluid ounce(s)	237	236.1	2	0	0.5	0	0	0	0	0
735	Instant tea mix, lemon flavored with sugar, prepared	8	fluid ounce(s)	259	236.2	91	0	22.3	0.3	0.2	0	0	0
734	Instant tea mix, unsweetened, prepared	8	fluid ounce(s)	237	236.1	2	0.1	0.4	0	0	0	0	0
733	Tea, prepared	8	fluid ounce(s)	237	236.3	2	0	0.7	0	0	0	0	0
	Water												
1413	Mineral water, carbonated	8	fluid ounce(s)	237	236.8	0	0	0	0	0	0	0	0
33183	Poland spring water, bottled	8	fluid ounce(s)	237	237.0	0	0	0	0	0	0	0	0
1821	Tap water	8	fluid ounce(s)	237	236.8	0	0	0	0	0	0	0	0
1879	Tonic water	8	fluid ounce(s)	244	222.3	83	0	21.5	0	0	0	0	0
Fats and Oils													
	Butter												
104	Butter	1	tablespoon(s)	14	2.3	102	0.1	0	0	11.5	7.3	3.0	0.4
2522	Butter Buds, dry butter substitute	1	teaspoon(s)	2	—	5	0	2.0	0	0	0	0	0
921	Unsalted	1	tablespoon(s)	14	2.5	102	0.1	0	0	11.5	7.3	3.0	0.4
107	Whipped	1	tablespoon(s)	9	1.5	67	0.1	0	0	7.6	4.7	2.2	0.3
944	Whipped, unsalted	1	tablespoon(s)	11	2.0	82	0.1	0	0	9.2	5.9	2.4	0.3
	Fats, cooking												
2671	Beef tallow, semisolid	1	tablespoon(s)	13	0	115	0	0	0	12.8	6.4	5.4	0.5
922	Chicken fat	1	tablespoon(s)	13	0	115	0	0	0	12.8	3.8	5.7	2.7
5454	Household shortening with vegetable oil	1	tablespoon(s)	13	0	115	0	0	0	13.0	3.4	5.5	2.7
111	Lard	1	tablespoon(s)	13	0	115	0	0	0	12.8	5.0	5.8	1.4
	Margarine												
114	Margarine	1	tablespoon(s)	14	2.3	101	0	0.1	0	11.4	2.1	5.5	3.4
5439	Soft	1	tablespoon(s)	14	2.3	103	0.1	0.1	0	11.6	1.7	4.4	2.1
32329	Soft, unsalted, with hydrogenated soybean and cottonseed oils	1	tablespoon(s)	14	2.5	101	0.1	0.1	0	11.3	2.0	5.4	3.5
928	Unsalted	1	tablespoon(s)	14	2.6	101	0.1	0.1	0	11.3	2.1	5.2	3.5
119	Whipped	1	tablespoon(s)	9	1.5	64	0.1	0.1	0	7.2	1.2	3.2	2.5
	Spreads												
54657	I Can't Believe It's Not Butter!, tub, soya oil (non-hydrogenated)	1	tablespoon(s)	14	2.3	103	0.1	0.1	0	11.6	2.8	2.0	5.1
2708	Mayonnaise with soybean and safflower oils	1	tablespoon(s)	14	2.1	99	0.2	0.4	0	11.0	1.2	1.8	7.6
16157	Promise vegetable oil spread, stick	1	tablespoon(s)	14	4.2	90	0	0	0	10.0	2.5	2.0	4.0
	Oils												
2681	Canola	1	tablespoon(s)	14	0	120	0	0	0	13.6	1.0	8.6	3.8
120	Corn	1	tablespoon(s)	14	0	120	0	0	0	13.6	1.8	3.8	7.4
122	Olive	1	tablespoon(s)	14	0	119	0	0	0	13.5	1.9	9.9	1.4

	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
0	0.00	—	10.1	10.1	—	0	—	—	—	—	—	—	6.0	—	—
10	0.39	5.0	37.2	9.9	0.05	0	0.01	0.02	0.05	0.04	0.01	2.5	9.7	0	0.2
5	0.00	4.9	24.7	7.4	0.02	0	0.01	0.00	0.01	0.02	0.01	2.5	7.7	0	0.2
20	0.72	—	0	20.0	—	0	—	—	—	—	—	—	600.0	0	—
0	0.00	—	70.0	10.0	—	0	—	—	—	—	—	—	54.0	0	—
0	0.00	—	20.0	10.0	—	0	—	—	—	—	—	—	0	0	—
0	0.00	—	40.0	10.0	—	0	—	—	—	—	—	—	0	0	—
400	2.70	140.0	600.0	220.0	2.25	—	0.52	—	0.59	7.00	0.70	120.0	60.0	2.1	17.5
1000	2.70	140.0	600.0	220.0	2.25	—	0.52	—	0.59	7.00	0.70	120 0	30.0	2.1	17.5
400	2.70	140.0	600 0	220.0	2.25	—	0.52	—	0 59	7.00	0.70	120 0	60.0	2.1	17.5
0	0.04	7 1	87.7	7 1	0 04	0	0 00	0 00	0.03	0 00	0.00	11 9	0	0	0
5	0 18	2.4	21.3	2 4	0.09	0	0 02	0 00	0.01	0 00	0 00	2 4	0	0	0
5	0.05	2.6	38 9	5.2	0 02	0	0 00	0 00	0 00	0 02	0.00	0	0	0	0.3
7	0.02	4 7	42.7	9.5	0.02	0	0 00	0 00	0 01	0.07	0 00	0	0	0	0
0	0.04	7 1	87.7	7 1	0 04	0	0 00	0 00	0 03	0.00	0 00	11 9	0	0	0
33	0.00	0	0	2.4	0 00	0	0.00	—	0.00	0.00	0 00	0	0	0	0
2	0.02	2.4	0	2.4	0.00	0	0.00	—	0.00	0.00	0.00	0	0	0	0
7	0.00	2.4	2 4	7 1	0 00	0	0 00	0 00	0 00	0 00	0 00	0	0	0	0
2	0.02	0	0	29.3	0.24	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
3	0.00	0.3	3.4	81.8	0 01	97.1	0 00	0 32	0.01	0.01	0.00	0.4	0	0	0.1
0	0.00	0	1.6	120.0	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	—
3	0.00	0.3	3.4	1.6	0 01	97.1	0 00	0.32	0.01	0.01	0 00	0.4	0	0	0.1
2	0.01	0.2	2.4	77.7	0 01	64.3	0 00	0.21	0 00	0.00	0 00	0.3	0	0	0.1
3	0.00	0.2	2.7	1.3	0.01	78.0	0.00	0.26	0 00	0.00	0.00	0.3	0	0	0.1
0	0.00	0	0	0	0.00	0	0.00	0.34	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	0.34	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0 00	0	0.00	—	0.00	0.00	0.00	0	0	0	—
0	0.00	0	0	0	0.01	0	0.00	0.07	0.00	0.00	0.00	0	0	0	0
4	0.01	0.4	5.9	133.0	0.00	115.5	0.00	1.26	0.01	0.00	0.00	0.1	0	0	0
4	0.00	0.3	5.5	155.4	0.00	142.7	0.00	1.00	0.00	0.00	0.00	0.1	0	0	0
4	0.00	0.3	5.4	3.9	0.00	103.1	0.00	0.98	0.00	0.00	0.00	0.1	0	0	0
2	0.00	0.3	3.5	0.3	0.00	115.5	0.00	1.80	0.00	0.00	0.00	0.1	0	0	0
2	0.00	0.2	3.4	97.1	0.00	73.7	0 00	0.45	0.00	0.00	0.00	0.1	0	0	0
4	0.00	0.3	5.5	155.3	0.00	142.6	0.00	0.72	0.00	0.00	0.00	0.1	0	0	0
2	0.06	0.1	4.7	78.4	0.01	11.6	0.00	3.03	0.00	0.00	0.08	1.1	0	0	0.2
10	0.18	—	8.7	90.0	—	—	0.00	—	0.00	0.00	—	—	0.6	—	
0	0.00	0	0	0	0.00	0	0.00	2.37	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	1.94	0.00	0.00	0.00	0	0	0	0
0	0.07	0	0.1	0.3	0.00	0	0.00	1.93	0.00	0.00	0.00	0	0	0	0

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

BAA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fats and Oils—*continued*													
124	Peanut	1	tablespoon(s)	14	0	119	0	0	0	13.5	2.3	6.2	4.3
2693	Safflower	1	tablespoon(s)	14	0	120	0	0	0	13.6	0.8	10.2	2.0
923	Sesame	1	tablespoon(s)	14	0	120	0	0	0	13.6	1.9	5.4	5.7
128	Soybean, hydrogenated	1	tablespoon(s)	14	0	120	0	0	0	13.6	2.0	5.8	5.1
130	Soybean, with soybean and cottonseed oil	1	tablespoon(s)	14	0	120	0	0	0	13.6	2.4	4.0	6.5
2700	Sunflower	1	tablespoon(s)	14	0	120	0	0	0	13.6	1.8	6.3	5.0
357	**Pam original no stick cooking spray**	1	serving(s)	0	0.2	0	0	0	0	0	0	0	0
	Salad dressing												
132	Blue cheese	2	tablespoon(s)	30	9.7	151	1.4	2.2	0	15.7	3.0	3.7	8.3
133	Blue cheese, low calorie	2	tablespoon(s)	32	25.4	32	1.6	0.9	0	2.3	0.8	0.6	0.8
1764	Caesar	2	tablespoon(s)	30	10.3	158	0.4	0.9	0	17.3	2.6	4.1	9.9
29654	Creamy, reduced calorie, fat-free, cholesterol-free, sour cream and/or buttermilk and oil	2	tablespoon(s)	32	23.9	34	0.4	6.4	0	0.9	0.2	0.2	0.5
29617	Creamy, reduced calorie, sour cream and/or buttermilk and oil	2	tablespoon(s)	30	22.2	48	0.5	2.1	0	4.2	0.6	1.0	2.4
134	French	2	tablespoon(s)	32	11.7	146	0.2	5.0	0	14.3	1.8	2.7	6.7
135	French, low fat	2	tablespoon(s)	32	17.4	74	0.2	9.4	0.4	4.3	0.4	1.9	1.6
136	Italian	2	tablespoon(s)	29	16.6	86	0.1	3.1	0	8.3	1.3	1.9	3.8
137	Italian, diet	2	tablespoon(s)	30	25.4	23	0.1	1.4	0	1.9	0.1	0.7	0.5
139	Mayonnaise-type	2	tablespoon(s)	29	11.7	115	0.3	7.0	0	9.8	1.4	2.6	5.3
942	Oil and vinegar	2	tablespoon(s)	32	15.2	144	0	0.8	0	16.0	2.9	4.7	7.7
1765	Ranch	2	tablespoon(s)	30	11.6	146	0.1	1.6	0	15.8	2.3	5.2	7.6
3666	Ranch, reduced calorie	2	tablespoon(s)	30	20.5	62	0.1	2.2	0	6.1	1.1	1.8	2.9
940	Russian	2	tablespoon(s)	30	11.6	107	0.5	9.3	0.7	7.8	1.2	1.8	4.4
939	Russian, low calorie	2	tablespoon(s)	32	20.8	45	0.2	8.8	0.1	1.3	0.2	0.3	0.7
941	Sesame seed	2	tablespoon(s)	30	11.8	133	0.9	2.6	0.3	13.6	1.9	3.6	7.5
142	Thousand Island	2	tablespoon(s)	32	14.9	118	0.3	4.7	0.3	11.2	1.6	2.5	5.8
143	Thousand Island, low calorie	2	tablespoon(s)	30	18.2	61	0.3	6.7	0.4	3.9	0.2	1.9	0.8
	Sandwich spreads												
138	Mayonnaise with soybean oil	1	tablespoon(s)	14	2.1	99	0.1	0.4	0	11.0	1.6	2.7	5.8
140	Mayonnaise, low calorie	1	tablespoon(s)	16	10.0	37	0	2.6	0	3.1	0.5	0.7	1.7
141	Tartar sauce	2	tablespoon(s)	28	8.7	144	0.3	4.1	0.1	14.4	2.2	3.8	7.7
Sweets													
4799	**Butterscotch or caramel topping**	2	tablespoon(s)	41	13.1	103	0.6	27.0	0.4	0	0	0	0
	Candy												
1786	Almond Joy candy bar	1	item(s)	45	4.3	220	2.0	27.0	2.0	12.0	8.0	3.3	0.7
1785	Bit-O-Honey candy	6	item(s)	40	—	190	1.0	39.0	0	3.5	2.5	—	—
33375	Butterscotch candy	2	piece(s)	12	0.6	47	0	10.8	0	0.4	0.2	0.1	0
1701	Chewing gum, stick	1	item(s)	3	0.1	7	0	2.0	0.1	0	0	0	0
33378	Chocolate fudge with nuts, prepared	2	piece(s)	38	2.9	175	1.7	25.8	1.0	7.2	2.5	1.5	2.9
1787	Jelly beans	15	item(s)	43	2.7	159	0	39.8	0.1	0	0	0	0
1784	Kit Kat wafer bar	1	item(s)	42	0.8	210	3.0	27.0	0.5	11.0	7.0	3.5	0.3
4674	Krackel candy bar	1	item(s)	41	0.6	210	2.0	28.0	0.5	10.0	6.0	3.9	0.4
4934	Licorice	4	piece(s)	44	7.3	154	1.1	35.1	0	1.0	0	0.1	0
1780	Life Savers candy	1	item(s)	2	—	8	0	2.0	0	0	0	0	0
1790	Lollipop	1	item(s)	28	—	108	0	28.0	0	0	0	0	0
4679	M & Ms peanut chocolate candy, small bag	1	item(s)	49	0.9	250	5.0	30.0	2.0	13.0	5.0	5.4	2.1
1781	M & Ms plain chocolate candy, small bag	1	item(s)	48	0.8	240	2.0	34.0	1.0	10.0	6.0	3.3	0.3
4673	Milk chocolate bar, Symphony	1	item(s)	91	0.9	483	7.7	52.8	1.5	27.8	16.7	7.2	0.6
1783	Milky Way bar	1	item(s)	58	3.7	270	2.0	41.0	1.0	10.0	5.0	3.5	0.3
1788	Peanut brittle	1½	ounce(s)	43	0.3	207	3.2	30.3	1.1	8.1	1.8	3.4	1.9
1789	Reese's peanut butter cups	2	piece(s)	51	0.8	280	6.0	19.0	2.0	15.5	6.0	7.2	2.7
4689	Reese's pieces candy, small bag	1	item(s)	43	1.1	220	5.0	26.0	1.0	11.0	7.0	0.9	0.4
33399	Semisweet chocolate candy, made with butter	½	ounce(s)	14	0.1	68	0.6	9.0	0.8	4.2	2.5	1.4	0.1
1782	Snickers bar	1	item(s)	59	3.2	280	4.0	35.0	1.0	14.0	5.0	6.1	2.9
4694	Special Dark chocolate bar	1	item(s)	41	0.4	220	2.0	25.0	3.0	12.0	8.0	4.6	0.4
4695	Starburst fruit chews, original fruits	1	package(s)	59	3.9	240	0	48.0	0	5.0	1.0	2.1	1.8

= Breads/Baked Goods H-10 = Cereal/Rice/Pasta H-14 = Fruit H-18 = Vegetables/Legumes H-28 = Nuts/Seeds H-30 = Vegetarian H-32 = Dairy H-40 = Eggs H-40 = Seafood H-42 = Meats H-46 = Poultry
sed Meats H-48 = Beverages H-52 = Fats/Oils H-54 = Sweets H-56 = Spices/Condiments/Sauces H-60 = Mixed Foods/Soups/Sandwiches H-64 = Fast Food H-84 = Convenience H-86 = Baby Foods

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-TE)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
0	0.00	0	0	0	0.00	0	0.00	2.11	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	4.63	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	0.19	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	1.10	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	1.64	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	0	0.00	0	0.00	5.58	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0.3	1.5	0.01	0.1	0.00	0.00	0.00	0.00	0.00	0	0	0	0
24	0.06	0	11.1	328.2	0.08	20.1	0.00	1.80	0.03	0.03	0.01	7.8	0.6	0.1	0.3
28	0.16	2.2	1.6	384.0	0.08	—	0.01	0.08	0.03	0.01	0.01	1.0	0.1	0.1	0.5
7	0.05	0.6	8.7	323.4	0.03	0.6	0.00	1.56	0.00	0.01	0.00	0.9	0	0	0.5
12	0.08	1.6	42.6	320.0	0.05	0.3	0.00	0.21	0.01	0.01	0.01	1.9	0	0	0.5
2	0.03	0.6	10.8	306.9	0.01	—	0.00	0.71	0.00	0.01	0.01	0	0.1	0	0.5
8	0.25	1.6	21.4	267.5	0.09	7.4	0.01	1.60	0.01	0.06	0.00	0	0	0	0
4	0.27	2.6	34.2	257.3	0.06	8.6	0.01	0.09	0.01	0.14	0.01	0.6	0	0	0.5
2	0.18	0.9	14.1	486.3	0.03	0.6	0.00	1.47	0.01	0.00	0.01	0	0	0	0.6
3	0.19	1.2	25.5	409.8	0.05	0.3	0.00	0.06	0.00	0.00	0.02	0	0	0	2.4
4	0.05	0.6	2.6	209.0	0.05	6.2	0.00	0.60	0.01	0.00	0.01	1.8	0	0.1	0.5
0	0.00	0	2.6	0.3	0.00	0	0.00	1.46	0.00	0.00	0.00	0	0	0	0.5
4	0.03	1.2	8.4	354.0	0.01	5.4	0.00	1.84	0.01	0.00	0.00	0.3	0.1	0	0.1
5	0.01	1.5	8.4	413.7	0.01	0.9	0.00	0.72	0.01	0.00	0.00	0.3	0.1	0	0.1
6	0.20	3.0	51.9	282.3	0.06	13.2	0.01	0.98	0.01	0.16	0.02	1.5	1.4	0	0.5
6	0.18	0	50.2	277.8	0.02	0.6	0.00	0.12	0.00	0.00	0.00	1.0	1.9	0	0.5
6	0.18	0	47.1	300.0	0.02	0.6	0.00	1.50	0.00	0.00	0.00	0	0	0	0.5
5	0.37	2.6	34.2	276.2	0.08	4.5	0.46	1.28	0.01	0.13	0.00	0	0	0	0.5
5	0.27	2.1	60.6	249.3	0.05	4.8	0.01	0.30	0.01	0.13	0.00	0	0	0	0
1	0.03	0.1	1.7	78.4	0.02	11.2	0.01	0.72	0.01	0.00	0.08	0.7	0	0	0.2
0	0.00	0	1.6	79.5	0.01	0	0.00	0.32	0.00	0.00	0.00	0	0	0	0.3
6	0.20	0.8	10.1	191.5	0.05	20.2	0.00	0.97	0.00	0.01	0.07	2.0	0.1	0.1	0.5
22	0.08	2.9	34.4	143.1	0.07	11.1	0.01	—	0.03	0.01	0.01	0.8	0.1	0	0
18	0.33	30.3	126.5	65.0	0.36	0	0.01	—	0.06	0.21	—	—	0	—	—
20	0.00	—	—	150.0	—	0	—	—	—	—	—	—	0	—	—
0	0.00	0	0.4	46.9	0.01	3.4	0.00	0.01	0.00	0.00	0.00	0	0	0	0.1
0	0.00	0	0.1	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
22	0.74	20.9	69.5	14.8	0.54	14.4	0.02	0.09	0.03	0.12	0.03	6.1	0.1	0	1.1
1	0.05	0.9	15.7	21.3	0.02	0	0.00	0.00	0.01	0.00	0.00	0	0	0	0.5
60	0.36	16.4	126.0	30.0	0.51	0	0.07	—	0.22	1.07	0.05	59.6	0	0.1	2.0
40	0.36	—	168.8	50.0	—	0	—	—	—	—	—	—	0	—	—
0	0.22	2.6	28.2	126.3	0.07	0	0.01	0.07	0.01	0.04	0.00	0	0	0	—
0	0.00	—	0	0	—	0	0.00	—	0.00	0.00	—	—	0	—	0
0	0.00	—	—	10.8	—	0	0.00	—	0.00	0.00	—	—	0	—	1.0
40	0.36	36.5	170.6	25.0	1.13	14.8	0.03	—	0.06	1.60	0.04	17.3	0.6	0.1	1.9
40	0.36	19.6	127.4	30.0	0.46	14.8	0.02	—	0.06	0.10	0.01	2.9	0.6	0.1	1.4
228	0.82	61.0	398.6	91.9	1.00	0	0.06	—	0.25	0.14	0.10	10.9	2.0	0.4	—
60	0.18	19.8	140.1	95.0	0.41	15.1	0.02	—	0.06	0.20	0.02	5.8	0.6	0.2	3.3
11	0.51	17.9	71.4	189.2	0.37	16.6	0.05	1.08	0.01	1.12	0.03	19.6	0	0	1.1
40	0.72	45.4	217.4	180.0	0.93	0	0.12	—	0.08	2.35	0.07	28.1	0	0.1	2.3
20	0.00	18.9	169.9	80.0	0.32	0	0.04	—	0.06	1.22	0.03	12.0	0	0.1	0.8
5	0.44	16.3	51.7	1.6	0.23	0.4	0.01	—	0.01	0.06	0.01	0.4	0	0	0.5
40	0.36	42.3	—	140.0	1.37	15.3	0.03	—	0.06	1.60	0.05	23.5	0.6	0.1	2.7
0	1.80	45.5	136.0	50.0	0.59	0	0.01	—	0.02	0.16	0.01	0.8	0	0	1.2
10	0.18	0.6	1.2	0	0.00	—	0.00	—	0.00	0.00	0.00	0	30	0	0.5

APPENDIX H

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Sweets—*continued*													
4698	Taffy	3	piece(s)	45	2.2	179	0	41.2	0	1.5	0.9	0.4	0.1
4699	Three Musketeers bar	1	item(s)	60	3.5	260	2.0	46.0	1.0	8.0	4.5	2.6	0.3
4702	Twix caramel cookie bars	2	item(s)	58	2.4	280	3.0	37.0	1.0	14.0	5.0	7.7	0.5
4705	York peppermint pattie	1	item(s)	39	3.9	160	0.5	32.0	0.5	3.0	1.5	1.2	0.1
	Frosting, icing												
4760	Chocolate frosting, ready to eat	2	tablespoon(s)	31	5.2	122	0.3	19.4	0.3	5.4	1.7	2.8	0.6
4771	Creamy vanilla frosting, ready to eat	2	tablespoon(s)	28	4.2	117	0	19.0	0	4.5	0.8	1.4	2.2
17291	Dec-A-Cake variety pack candy decoration	1	teaspoon(s)	4	—	15	0	3.0	0	0.5	0	—	—
536	White icing	2	tablespoon(s)	40	3.6	162	0.1	31.8	0	4.2	0.8	2.0	1.2
	Gelatin												
13697	Gelatin snack, all flavors	1	item(s)	99	96.8	70	1.0	17.0	0	0	0	0	0
2616	Sugar free, low calorie mixed fruit gelatin mix, prepared	½	cup(s)	121	—	10	1.0	0	0	0	0	0	0
548	**Honey**	1	tablespoon(s)	21	3.6	64	0.1	17.3	0	0	0	0	0
	Jams, jellies												
550	Jam or preserves	1	tablespoon(s)	20	6.1	56	0.1	13.8	0.2	0	0	0	0
42199	Jams, preserves, dietetic, all flavors, w/sodium saccharin	1	tablespoon(s)	14	6.4	18	0	7.5	0.4	0	0	0	0
552	Jelly	1	tablespoon(s)	21	6.3	56	0	14.7	0.2	0	0	0	0
545	**Marshmallows**	4	item(s)	29	4.7	92	0.5	23.4	0	0.1	0	0	0
4800	**Marshmallow cream topping**	2	tablespoon(s)	40	7.9	129	0.3	31.6	0	0.1	0	0	0
555	**Molasses**	1	tablespoon(s)	20	4.4	58	0	14.9	0	0	0	0	0
4780	**Popsicle or ice pop**	1	item(s)	59	47.5	47	0	11.3	0	0.1	0	0	0
	Sugar												
559	Brown sugar, packed	1	teaspoon(s)	5	0.1	17	0	4.5	0	0	0	0	0
563	Powdered sugar, sifted	⅓	cup(s)	33	0.1	130	0	33.2	0	0	0	0	0
561	White granulated sugar	1	teaspoon(s)	4	0	16	0	4.2	0	0	0	0	0
	Sugar substitute												
1760	Equal sweetener, packet size	1	item(s)	1	—	0	0	0.9	0	0	0	0	0
13029	Splenda granular no calorie sweetener	1	teaspoon(s)	1	—	0	0	0.5	0	0	0	0	0
1759	Sweet N Low sugar substitute, packet	1	item(s)	1	0.1	4	0	0.5	0	0	0	0	0
	Syrup												
3148	Chocolate syrup	2	tablespoon(s)	38	11.6	105	0.8	24.4	1.0	0.4	0.2	0.1	0
29676	Maple syrup	¼	cup(s)	80	25.7	209	0	53.7	0	0.2	0	0.1	0.1
4795	Pancake syrup	¼	cup(s)	80	30.4	187	0	49.2	0	0	0	0	0
Spices, Condiments, Sauces													
	Spices												
807	Allspice, ground	1	teaspoon(s)	2	0.2	5	0.1	1.4	0.4	0.2	0	0	0
1171	Anise seeds	1	teaspoon(s)	2	0.2	7	0.4	1.1	0.3	0.3	0	0.2	0.1
729	Bakers' yeast, active	1	teaspoon(s)	4	0.3	12	1.5	1.5	0.8	0.2	0	0.1	0
683	Baking powder, double acting with phosphate	1	teaspoon(s)	5	0.2	2	0	1.1	0	0	0	0	0
1611	Baking soda	1	teaspoon(s)	5	0	0	0	0	0	0	0	0	0
8552	Basil	1	teaspoon(s)	1	0.8	0	0	0	0	0	0	0	0
34959	Basil, fresh	1	piece(s)	1	0.5	0	0	0	0	0	0	0	0
808	Basil, ground	1	teaspoon(s)	1	0.1	4	0.2	0.9	0.6	0.1	0	0	0
809	Bay leaf	1	teaspoon(s)	1	0	2	0	0.5	0.2	0.1	0	0	0
11720	Betel leaves	1	ounce(s)	28	—	17	1.8	2.4	0	0	—	—	—
730	Brewers' yeast	1	teaspoon(s)	3	0.1	8	1.0	1.0	0.8	0	0	0	0
11710	Capers	1	teaspoon(s)	5	—	0	0	0	0	0	0	0	0
1172	Caraway seeds	1	teaspoon(s)	2	0.2	7	0.4	1.0	0.8	0.3	0	0.2	0.1
1173	Celery seeds	1	teaspoon(s)	2	0.1	8	0.4	0.8	0.2	0.5	0	0.3	0.1
1174	Chervil, dried	1	teaspoon(s)	1	0	1	0.1	0.3	0.1	0	0	0	0
810	Chili powder	1	teaspoon(s)	3	0.2	8	0.3	1.4	0.9	0.4	0.1	0.1	0.2
8553	Chives, chopped	1	teaspoon(s)	1	0.9	0	0	0	0	0	0	0	0
51420	Cilantro (coriander)	1	teaspoon(s)	0	0.3	0	0	0	0	0	0	0	0
811	Cinnamon, ground	1	teaspoon(s)	2	0.2	6	0.1	1.9	1.2	0	0	0	0
812	Cloves, ground	1	teaspoon(s)	2	0.1	7	0.1	1.3	0.7	0.4	0.1	0	0.1
1175	Coriander leaf, dried	1	teaspoon(s)	1	0	2	0.1	0.3	0.1	0	0	0	0
1176	Coriander seeds	1	teaspoon(s)	2	0.2	5	0.2	1.0	0.8	0.3	0	0.2	0
1706	Cornstarch	1	tablespoon(s)	8	0.7	30	0	7.3	0.1	0	0	0	0

Calc (mg)	Iron (mg)	Magn (mg)	[illegible] (mg)	[illegible] (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	[illegible] (mg)	Vit B_{12} (µg)	Sele (µg)
4	0.00	0	1.4	23.4	0.09	12.2	0.01	0.04	0.01	0.00	0.00	0	0	0	0.3
20	0.36	17.5	80.3	110.0	0.33	14.5	0.01	—	0.03	0 20	0 01	0	0.6	0.1	1.5
40	0.36	18.5	116.8	115.0	0.45	15.0	0.09	—	0.13	0.69	0.01	13 9	0.6	0.1	1.2
0	0.33	23.4	66.1	10.0	0.28	0	0.01	—	0.03	0.31	0 01	1.5	0	0	—
2	0.44	6.4	60.0	56.1	0.09	0	0.00	0.48	0.00	0.03	0.00	0.3	0	0	0.2
1	0.04	0.3	9.5	51.5	0 01	0	0.00	0 43	0.08	0.06	0.00	2.2	0	0	0
0	0.00	—	—	15.0	—	0	—	—	—	—	—	—	0	—	—
4	0.01	0.4	5.6	76.4	0.01	44 4	0.00	0.32	0.01	0 00	0.00	0	0	0	0.3
0	0.00	—	0	40.0	—	0	—	—	—	—	—	—	0	—	—
0	0.00	0	0	50.0	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	—
1	0.08	0.4	10.9	0.8	0.04	0	0 00	0.00	0.01	0.02	0.01	0.4	0.1	0	0.2
4	0.10	0.8	15.4	6.4	0.01	0	0 00	0 02	0 02	0.01	0.00	2.2	1.8	0	0.4
1	0.56	0.7	9.7	0	0.01	0	0.00	0.01	0.00	0.00	0.00	1.3	0	0	0.2
1	0.04	1.3	11.3	6.3	0 01	0	0 00	0 00	0 01	0 01	0 00	0.4	0.2	0	0.1
1	0.06	0.6	1.4	23.0	0 01	0	0 00	0 00	0 00	0.02	0 00	0 3	0	0	0.5
1	0.08	0.8	2.0	32.0	0.01	0	0.00	0.00	0.00	0.03	0.00	0.4	0	0	0.7
41	0.94	48.4	292 8	7.4	0.05	0	0 01	0 00	0 00	0 18	0 13	0	0	0	3.6
0	0.31	0.6	8.9	4.1	0.08	0	0 00	0.00	0 00	0 00	0.00	0	0.4	0	0.1
4	0.03	0.4	6.1	1.3	0 00	0	0 00	0 00	0 00	0 01	0 00	0	0	0	0.1
0	0.01	0	0.7	0.3	0.00	0	0 00	0.00	0 00	0 00	0 00	0	0	0	0.2
0	0 00	0	0.1	0	0 00	0	0 00	0 00	0 00	0 00	0 00	0	0	0	0
0	0 00	0	0	0	0 00	0	0 00	0 00	0 00	0 00	0 00	0	0	0	0
0	0 00	—	—	0	—	—	0 00	—	0 00	0.00	—	—	0	0	—
0	0.00	—	—	0	—	0	—	0.00	—	—	—	—	0	—	—
5	0.79	24.4	84 0	27.0	0.27	0	0 00	0 01	0 01	0 12	0 00	0.8	0.1	0	0.5
54	0.96	11.2	163 2	7.2	3.32	0	0 01	0 00	0.01	0 02	0 00	0	0	0	0.5
2	0.02	1.6	12.0	65.6	0.06	0	0.01	0.00	0.01	0.00	0.00	0	0	0	0
13	0.13	2.6	19.8	1.5	0.01	0 5	0.00	—	0.00	0.05	0.00	0.7	0.7	0	0.1
14	0.77	3.6	30.3	0.3	0.11	0.3	0 01	—	0.01	0.06	0.01	0.2	0.4	0	0.1
3	0.66	3.9	80.0	2.0	0.25	0	0.09	0.00	0.21	1.59	0.06	93.6	0	0	1.0
339	0.51	1.8	0.2	363.1	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
0	0.00	0	0	1258.6	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
2	0.02	0 6	2.6	0	0.01	2.3	0.00	0.01	0 00	0.01	0 00	0.6	0.2	0	0
1	0.01	0.4	2.3	0	0.00	1.3	0.00	—	0.00	0.00	0.00	0.3	0.1	0	0
30	0.58	5.9	48.1	0.5	0.08	6.6	0.00	0.10	0.00	0.09	0.03	3.8	0 9	0	0
5	0.25	0.7	3.2	0.1	0.02	1.9	0.00	—	0.00	0.01	0.01	1.1	0.3	0	0
110	2.29	—	155.9	2.0	—	—	0.04	—	0.07	0.19	—	—	0.9	0	—
6	0.46	6.1	50.7	3.3	0.21	0	0.41	—	0.11	1.00	0.06	104.3	0	0	0
—	—	—	—	105.0	—	—	—	—	—	—	—	—	—	0	—
14	0.34	5.4	28.4	0.4	0.11	0.4	0.01	0.05	0.01	0.07	0.01	0.2	0.4	0	0.3
35	0.89	8.8	28.0	3.2	0.13	0.1	0.01	0.02	0.01	0.06	0.01	0.2	0.3	0	0.2
8	0.19	0.8	28.4	0.5	0.05	1.8	0.00	—	0.00	0.03	0.01	1.6	0.3	0	0.2
7	0.37	4.4	49.8	26.3	0.07	38.6	0.01	0.75	0.02	0.20	0.09	2.6	1.7	0	0.2
1	0.01	0.4	3.0	0	0.01	2.2	0.00	0.00	0.00	0.01	0.00	1.1	0.6	0	0
0	0.01	0.1	1.7	0.2	0.00	1.1	0.00	0.01	0.00	0.00	0.00	0.2	0.1	0	0
23	0.19	1.4	9.9	0.2	0.04	0.3	0.00	0.05	0.00	0.03	0.00	0.1	0.1	0	0.1
14	0.18	5.5	23.1	5.1	0.02	0.6	0.00	0.17	0.01	0.03	0.01	2.0	1.7	0	0.1
7	0.25	4.2	26.8	1.3	0.02	1.8	0.01	0.01	0.01	0.06	0.00	1.6	3.4	0	0.2
13	0.29	5.9	22.8	0.6	0.08	0	0.00	—	0.01	0.03	—	0	0.4	0	0.5
0	0.03	0.2	0.2	0.7	0.01	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0.2

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Spices, Condiments, Sauces—*continued*													
1177	Cumin seeds	1	teaspoon(s)	2	0.2	8	0.4	0.9	0.2	0.5	0	0.3	0.1
11729	Cumin, ground	1	teaspoon(s)	5	—	11	0.4	0.8	0.8	0.4	—	—	—
1178	Curry powder	1	teaspoon(s)	2	0.2	7	0.3	1.2	0.7	0.3	0	0.1	0.1
1179	Dill seeds	1	teaspoon(s)	2	0.2	6	0.3	1.2	0.4	0.3	0	0.2	0
1180	Dill weed, dried	1	teaspoon(s)	1	0.1	3	0.2	0.6	0.1	0	0	0	0
34949	Dill weed, fresh	5	piece(s)	1	0.9	0	0	0.1	0	0	0	0	0
4949	Fennel leaves, fresh	1	teaspoon(s)	1	0.9	0	0	0.1	0	0	—	—	—
1181	Fennel seeds	1	teaspoon(s)	2	0.2	7	0.3	1.0	0.8	0.3	0	0.2	0
1182	Fenugreek seeds	1	teaspoon(s)	4	0.3	12	0.9	2.2	0.9	0.2	0.1	—	—
11733	Garam masala, powder	1	ounce(s)	28	—	107	4.4	12.8	0	4.3	—	—	—
1067	Garlic clove	1	item(s)	3	1.8	4	0.2	1.0	0.1	0	0	0	0
813	Garlic powder	1	teaspoon(s)	3	0.2	9	0.5	2.0	0.3	0	0	0	0
1068	Ginger root	2	teaspoon(s)	4	3.1	3	0.1	0.7	0.1	0	0	0	0
1183	Ginger, ground	1	teaspoon(s)	2	0.2	6	0.2	1.3	0.2	0.1	0	0	0
35497	Leeks, bulb and lower-leaf, freeze-dried	¼	cup(s)	1	0	3	0.1	0.6	0.1	0	0	0	0
1184	Mace, ground	1	teaspoon(s)	2	0.1	8	0.1	0.9	0.3	0.6	0.2	0.2	0.1
1185	Marjoram, dried	1	teaspoon(s)	1	0	2	0.1	0.4	0.2	0	0	0	0
1186	Mustard seeds, yellow	1	teaspoon(s)	3	0.2	15	0.8	1.2	0.5	0.9	0	0.7	0.2
814	Nutmeg, ground	1	teaspoon(s)	2	0.1	12	0.1	1.1	0.5	0.8	0.6	0.1	0
2747	Onion flakes, dehydrated	1	teaspoon(s)	2	0.1	6	0.1	1.4	0.2	0	0	0	0
1187	Onion powder	1	teaspoon(s)	2	0.1	7	0.2	1.7	0.1	0	0	0	0
815	Oregano, ground	1	teaspoon(s)	2	0.1	5	0.2	1.0	0.6	0.2	0	0	0.1
816	Paprika	1	teaspoon(s)	2	0.2	6	0.3	1.2	0.8	0.3	0	0	0.2
817	Parsley, dried	1	teaspoon(s)	0	0	1	0.1	0.2	0.1	0	0	0	0
818	Pepper, black	1	teaspoon(s)	2	0.2	5	0.2	1.4	0.6	0.1	0	0	0
819	Pepper, cayenne	1	teaspoon(s)	2	0.1	6	0.2	1.0	0.5	0.3	0.1	0	0.2
1188	Pepper, white	1	teaspoon(s)	2	0.3	7	0.3	1.6	0.6	0.1	0	0	0
1189	Poppy seeds	1	teaspoon(s)	3	0.2	15	0.5	0.7	0.3	1.3	0.1	0.2	0.9
1190	Poultry seasoning	1	teaspoon(s)	2	0.1	5	0.1	1.0	0.2	0.1	0	0	0
1191	Pumpkin pie spice, powder	1	teaspoon(s)	2	0.1	6	0.1	1.2	0.3	0.2	0.1	0	0
1192	Rosemary, dried	1	teaspoon(s)	1	0.1	4	0.1	0.8	0.5	0.2	0.1	0	0
11723	Rosemary, fresh	1	teaspoon(s)	1	0.5	1	0	0.1	0.1	0	0	0	0
2722	Saffron powder	1	teaspoon(s)	1	0.1	2	0.1	0.5	0	0	0	0	0
11724	Sage	1	teaspoon(s)	1	—	1	0	0.1	0	0	—	—	—
1193	Sage, ground	1	teaspoon(s)	1	0.1	2	0.1	0.4	0.3	0.1	0	0	0
30189	Salt substitute	¼	teaspoon(s)	1	—	0	0	0	0	0	0	0	0
30190	Salt substitute, seasoned	¼	teaspoon(s)	1	—	1	0	0.1	0	0	0	—	—
822	Salt, table	¼	teaspoon(s)	2	0	0	0	0	0	0	0	0	0
1194	Savory, ground	1	teaspoon(s)	1	0.1	4	0.1	1.0	0.6	0.1	0	—	—
820	Sesame seed kernels, toasted	1	teaspoon(s)	3	0.1	15	0.5	0.7	0.5	1.3	0.2	0.5	0.6
11725	Sorrel	1	teaspoon(s)	3	—	1	0.1	0.1	0	0	0	—	—
11721	Spearmint	1	teaspoon(s)	2	1.6	1	0.1	0.2	0.1	0	0	0	0
35498	Sweet green peppers, freeze-dried	¼	cup(s)	2	0	5	0.3	1.1	0.3	0	0	0	0
11726	Tamarind leaves	1	ounce(s)	28	—	33	1.6	5.2	0	0.6	—	—	—
11727	Tarragon	1	ounce(s)	28	—	14	1.0	1.8	0	0.3	—	—	—
1195	Tarragon, ground	1	teaspoon(s)	2	0.1	5	0.4	0.8	0.1	0.1	0	0	0.1
11728	Thyme, fresh	1	teaspoon(s)	1	0.5	1	0	0.2	0.1	0	0	0	0
821	Thyme, ground	1	teaspoon(s)	1	0.1	4	0.1	0.9	0.5	0.1	0	0	0
1196	Turmeric, ground	1	teaspoon(s)	2	0.3	8	0.2	1.4	0.5	0.2	0.1	0	0
11995	Wasabi	1	tablespoon(s)	14	10.7	10	0.7	2.3	0.2	0	—	—	—
	Condiments												
674	Catsup or ketchup	1	tablespoon(s)	15	10.4	15	0.3	3.8	0	0	0	0	0
703	Dill pickle	1	ounce(s)	28	26.7	3	0.2	0.7	0.3	0	0	0	0
138	Mayonnaise with soybean oil	1	tablespoon(s)	14	2.1	99	0.1	0.4	0	11.0	1.6	2.7	5.8
140	Mayonnaise, low calorie	1	tablespoon(s)	16	10.0	37	0	2.6	0	3.1	0.5	0.7	1.7
1682	Mustard, brown	1	teaspoon(s)	5	4.1	5	0.3	0.3	0	0.3	—	—	—
700	Mustard, yellow	1	teaspoon(s)	5	4.1	3	0.2	0.3	0.2	0.2	0	0.1	0
706	Sweet pickle relish	1	tablespoon(s)	15	9.3	20	0.1	5.3	0.2	0.1	0	0	0
141	Tartar sauce	2	tablespoon(s)	28	8.7	144	0.3	4.1	0.1	14.4	2.2	3.8	7.7
	Sauces												
685	Barbecue sauce	2	tablespoon(s)	31	18.9	47	0	11.3	0.2	0.1	0	0	0.1
834	Cheese sauce	¼	cup(s)	63	44.4	110	4.2	4.3	0.3	8.4	3.8	2.4	1.6
32123	Chili enchilada sauce, green	2	tablespoon(s)	57	53.0	15	0.6	3.1	0.7	0.3	0	0	0.1
32122	Chili enchilada sauce, red	2	tablespoon(s)	32	24.5	27	1.1	5.0	2.1	0.8	0.1	0	0.4

= Breads/Baked Goods H-10 = Cereal/Rice/Pasta H-14 = Fruit H-18 = Vegetables/Legumes H-28 = Nuts/Seeds H-30 = Vegetarian H-32 = Dairy H-40 = Eggs H-40 = Seafood H-42 = Meats H-46 = Poultry
ssed Meats H-48 = Beverages H-52 = Fats/Oils H-54 = Sweets H-56 = Spices/Condiments/Sauces H-60 = Mixed Foods/Soups/Sandwiches H-64 = Fast Food H-84 = Convenience H-86 = Baby Foods

Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-T)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
20	1.39	7.7	37.5	3.5	0.10	1.3	0.01	0.07	0.01	0.09	0.01	0.2	0.2	0	0.1
20	—	—	43.6	4.8	—	—	—	—	—	—	—	—	—	—	—
10	0.59	5.1	30.9	1.0	0.08	1.0	0.01	0.44	0.01	0.06	0.02	3.1	0.2	0	0.3
32	0.34	5.4	24.9	0.4	0.10	0.1	0.01	—	0.01	0.05	0.01	0.2	0.4	0	0.3
18	0.48	4.5	33.1	2.1	0.03	2.9	0.00	—	0.00	0.02	0.01	1.5	0.5	0	—
2	0.06	0.6	7.4	0.6	0.01	3.9	0.00	0.01	0.00	0.01	0.00	1.5	0.9	0	—
1	0.02	—	4.0	0.1	—	—	0.00	—	0.00	0.01	0.00	—	0.3	0	—
24	0.37	7.7	33.9	1.8	0.07	0.1	0.01	—	0.01	0.12	0.01	—	0.4	0	—
7	1.24	7.1	28.5	2.5	0.09	0.1	0.01	—	0.01	0.06	0.02	2.1	0.1	0	0.2
215	9.24	93.6	411.1	27.5	1.07	—	0.09	—	0.09	0.70	—	0	0	0	—
5	0.05	0.8	12.0	0.5	0.03	0	0.01	0.00	0.00	0.02	0.03	0.1	0.9	0	0.4
2	0.07	1.6	30.8	0.7	0.07	0	0.01	0.01	0.00	0.01	0.08	0.1	0.5	0	1.1
1	0.02	1.7	16.6	0.5	0.01	0	0.00	0.01	0.00	0.02	0.01	0.4	0.2	0	0
2	0.20	3.3	24.2	0.6	0.08	0.1	0.00	0.32	0.00	0.09	0.01	0.7	0.1	0	0.7
3	0.06	1.3	19.2	0.3	0.01	0.1	0.01	—	0.00	0.02	0.01	2.9	0.9	0	0
4	0.23	2.8	7.9	1.4	0.03	0.7	0.01	—	0.01	0.02	0.00	1.3	0.4	0	0
12	0.49	2.1	9.1	0.5	0.02	2.4	0.00	0.01	0.00	0.02	0.01	1.6	0.3	0	0
17	0.32	9.8	22.5	0.2	0.18	0.1	0.01	0.09	0.01	0.26	0.01	2.5	0.1	0	4.4
4	0.06	4.0	7.7	0.4	0.04	0.1	0.01	0.00	0.00	0.02	0.00	1.7	0.1	0	0
4	0.02	1.5	27.1	0.4	0.03	0	0.01	0.00	0.00	0.01	0.02	2.8	1.3	0	0.1
8	0.05	2.6	19.8	1.1	0.04	0	0.01	0.01	0.00	0.01	0.02	3.5	0.3	0	0
24	0.66	4.1	25.0	0.2	0.06	5.2	0.01	0.28	0.01	0.09	0.01	4.1	0.8	0	0.1
4	0.49	3.9	49.2	0.7	0.08	55.4	0.01	0.62	0.03	0.32	0.08	2.2	1.5	0	0.1
4	0.29	0.7	11.4	1.4	0.01	1.5	0.00	0.02	0.00	0.02	0.00	0.5	0.4	0	0.1
9	0.60	4.1	26.4	0.9	0.03	0.3	0.00	0.01	0.01	0.02	0.01	0.2	0.4	0	0.1
3	0.14	2.7	36.3	0.5	0.04	37.5	0.01	0.53	0.01	0.15	0.04	1.9	1.4	0	0.2
6	0.34	2.2	1.8	0.1	0.02	0	0.00	—	0.00	0.01	0.00	0.2	0.5	0	0.1
41	0.26	9.3	19.6	0.6	0.28	0	0.02	0.03	0.01	0.02	0.01	1.6	0.1	0	0
15	0.53	3.4	10.3	0.4	0.04	2.0	0.00	0.02	0.00	0.04	0.02	2.1	0.2	0	0.1
12	0.33	2.3	11.3	0.9	0.04	0.2	0.00	0.01	0.00	0.03	0.01	0.9	0.4	0	0.2
15	0.35	2.6	11.5	0.6	0.03	1.9	0.01	—	0.01	0.01	0.02	3.7	0.7	0	0.1
2	0.04	0.6	4.7	0.2	0.01	1.0	0.00	—	0.00	0.01	0.00	0.8	0.2	0	—
1	0.07	1.8	12.1	1.0	0.01	0.2	0.00	—	0.00	0.01	0.01	0.7	0.6	0	0
4	—	1.1	2.7	0	0.01	—	0.00	—	—	—	—	—	—	0	—
12	0.19	3.0	7.5	0.1	0.03	2.1	0.01	0.05	0.00	0.04	0.01	1.9	0.2	0	0
7	0.00	0	603.6	0.1	—	0	—	—	—	—	—	—	0	—	—
0	0.00	—	476.3	0.1	—	0	—	—	—	—	—	—	0	—	—
0	0.01	0	0.1	581.4	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	0
30	0.53	5.3	14.7	0.3	0.06	3.6	0.01	—	—	—	0.05	0.02	—	0.7	0	0.1
3	0.21	9.2	10.8	1.0	0.27	0.1	0.03	0.01	0.01	0.15	0.00	2.6	0	0	0
—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—
4	0.22	1.2	8.7	0.6	0.02	3.9	0.00	—	0.00	0.01	0.00	2.0	0.3	0	—
2	0.16	3.0	50.7	3.1	0.03	4.5	0.01	0.06	0.01	0.11	0.03	3.7	30.4	0	0.1
85	1.48	20.2	—	—	—	—	0.06	—	0.02	1.16	—	—	0.9	0	—
48	—	14.5	128.1	2.6	0.17	—	0.04	—	—	—	—	—	0.6	0	—
18	0.51	5.6	48.3	1.0	0.06	3.4	0.00	—	0.02	0.14	0.03	4.4	0.8	0	0.1
3	0.14	1.3	4.9	0.1	0.01	1.9	0.00	—	0.00	0.01	0.00	0.4	1.3	0	—
26	1.73	3.1	11.4	0.8	0.08	2.7	0.01	0.10	0.01	0.06	0.01	3.8	0.7	0	0.1
4	0.91	4.2	55.6	0.8	0.09	0	0.00	0.06	0.01	0.11	0.04	0.9	0.6	0	0.1
13	0.11	—	—	—	—	—	0.02	—	0.01	0.07	—	—	11.2	0	—
3	0.07	2.9	57.3	167.1	0.03	7.1	0.00	0.21	0.02	0.21	0.02	1.5	2.3	0	0
12	0.10	2.0	26.1	248.1	0.03	2.6	0.01	0.02	0.01	0.03	0.01	0.3	0.2	0	0
1	0.03	0.1	1.7	78.4	0.02	11.2	0.01	0.72	0.01	0.00	0.08	0.7	0	0	0.2
0	0.00	0	1.6	79.5	0.01	0	0.00	0.32	0.00	0.00	0.00	0	0	0	0.3
6	0.09	1.0	6.8	68.1	0.01	0	0.00	0.09	0.00	0.01	0.00	0.2	0.1	0	—
3	0.07	2.5	6.9	56.8	0.03	0.2	0.01	0.01	0.00	0.02	0.00	0.4	0.1	0	1.6
0	0.13	0.8	3.8	121.7	0.02	9.2	0.00	0.08	0.01	0.03	0.00	0.2	0.2	0	0
6	0.20	0.8	10.1	191.5	0.05	20.2	0.00	0.97	0.00	0.01	0.07	2.0	0.1	0.1	0.5
4	0.06	3.8	65.0	349.7	0.04	3.8	0.00	0.20	0.01	0.15	0.01	0.6	0.2	0	0.4
116	0.13	5.7	18.9	521.6	0.61	50.4	0.00	—	0.07	0.01	0.01	2.5	0.3	0.1	2.0
5	0.36	9.5	125.7	61.9	0.11	—	0.02	0.00	0.02	0.63	0.06	5.7	43.9	0	0
7	1.05	11.1	231.3	113.8	0.14	—	0.01	0.00	0.21	0.61	0.34	6.6	0.3	0	0.3

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA Code	Food Description	Quantity	Measure	Wt (g)	H2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Spices, Condiments, Sauces—*continued*													
29688	Hoisin sauce	1	tablespoon(s)	16	7.1	35	0.5	7.1	0.4	0.5	0.1	0.2	0.3
1641	Horseradish sauce, prepared	1	teaspoon(s)	5	3.3	10	0.1	0.2	0	1.0	0.6	0.3	0
16670	Mole poblano sauce	½	cup(s)	133	102.7	156	5.3	11.4	2.7	11.3	2.6	5.1	3.0
29689	Oyster sauce	1	tablespoon(s)	16	12.8	8	0.2	1.7	0	0	0	0	0
1655	Pepper sauce or Tabasco	1	teaspoon(s)	5	4.8	1	0.1	0	0	0	0	0	0
347	Salsa	2	tablespoon(s)	32	28.8	9	0.5	2.0	0.5	0.1	0	0	0
52206	Soy sauce, tamari	1	tablespoon(s)	18	12.0	11	1.9	1.0	0.1	0	0	0	0
839	Sweet and sour sauce	2	tablespoon(s)	39	29.8	37	0.1	9.1	0.1	0	0	0	0
1613	Teriyaki sauce	1	tablespoon(s)	18	12.2	16	1.1	2.8	0	0	0	0	0
25294	Tomato sauce	½	cup(s)	150	132.8	63	2.2	11.9	2.6	1.8	0.2	0.4	0.9
728	White sauce, medium	¼	cup(s)	63	46.8	92	2.4	5.7	0.1	6.7	1.8	2.8	1.8
1654	Worcestershire sauce	1	teaspoon(s)	6	4.5	4	0	1.1	0	0	0	0	0
	Vinegar												
30853	Balsamic	1	tablespoon(s)	15	—	10	0	2.0	0	0	0	0	0
727	Cider	1	tablespoon(s)	15	14.0	3	0	0.1	0	0	0	0	0
1673	Distilled	1	tablespoon(s)	15	14.3	2	0	0.8	0	0	0	0	0
12948	Tarragon	1	tablespoon(s)	15	13.8	2	0	0.1	0	0	0	0	0
Mixed Foods, Soups, Sandwiches													
	Mixed dishes												
16652	Almond chicken	1	cup(s)	242	186.8	281	21.8	15.8	3.4	14.7	1.8	6.3	5.6
25224	Barbecued chicken	1	serving(s)	177	99.3	327	27.1	15.7	0.5	17.1	4.8	6.8	3.8
25227	Bean burrito	1	item(s)	149	81.8	326	16.1	33.0	5.6	14.8	8.3	4.7	0.9
9516	Beef and vegetable fajita	1	item(s)	223	143.9	397	22.4	35.3	3.1	18.0	5.9	8.0	2.5
16796	Beef or pork egg roll	2	item(s)	128	85.2	225	9.9	18.4	1.4	12.4	2.9	6.0	2.6
177	Beef stew with vegetables, prepared	1	cup(s)	245	201.0	220	16.0	15.0	3.2	11.0	4.4	4.5	0.5
30233	Beef stroganoff with noodles	1	cup(s)	256	190.1	343	19.7	22.8	1.5	19.1	7.4	5.7	4.4
16651	Cashew chicken	1	cup(s)	242	186.8	281	21.8	15.8	3.4	14.7	1.8	6.3	5.6
30274	Cheese pizza with vegetables, thin crust	2	slice(s)	140	76.6	298	12.7	35.4	2.5	12.0	4.9	4.7	1.6
30330	Cheese quesadilla	1	item(s)	54	18.3	190	7.7	15.3	1.0	10.8	5.2	3.6	1.3
215	Chicken and noodles, prepared	1	cup(s)	240	170.0	365	22.0	26.0	1.3	18.0	5.1	7.1	3.9
30239	Chicken and vegetables with broccoli, onion, bamboo shoots in soy based sauce	1	cup(s)	162	125.5	180	15.8	9.3	1.8	8.6	1.7	3.0	3.1
25093	Chicken cacciatore	1	cup(s)	244	175.7	284	29.9	5.7	1.3	15.3	4.3	6.2	3.3
28020	Chicken fried turkey steak	3	ounce(s)	492	276.2	706	77.1	68.7	3.6	12.0	3.4	2.9	3.9
218	Chicken pot pie	1	cup(s)	252	154.6	542	22.6	41.4	3.5	31.3	9.8	12.5	7.1
30240	Chicken teriyaki	1	cup(s)	244	158.3	364	51.0	15.2	0.7	7.0	1.8	2.0	1.7
25119	Chicken waldorf salad	½	cup(s)	100	67.2	179	14.0	6.8	1.0	10.8	1.8	3.1	5.2
25099	Chili con carne	¾	cup(s)	215	174.4	198	13.7	21.4	7.5	6.9	2.5	2.8	0.5
1062	Coleslaw	¾	cup(s)	90	73.4	70	1.2	11.2	1.4	2.3	0.3	0.6	1.2
1574	Crab cakes, from blue crab	1	item(s)	60	42.6	93	12.1	0.3	0	4.5	0.9	1.7	1.4
32144	Enchiladas with green chili sauce (enchiladas verdes)	1	item(s)	144	103.8	207	9.3	17.6	2.6	11.7	6.4	3.6	1.0
2793	Falafel patty	3	item(s)	51	17.7	170	6.8	16.2	—	9.1	1.2	5.2	2.1
28546	Fettuccine alfredo	1	cup(s)	244	88.7	279	13.1	46.1	1.4	4.2	2.2	1.0	0.4
32146	Flautas	3	item(s)	162	78.0	438	24.9	36.3	4.1	21.6	8.2	8.8	2.3
29629	Fried rice with meat or poultry	1	cup(s)	198	128.5	333	12.3	41.8	1.4	12.3	2.2	3.5	5.7
16649	General Tso chicken	1	cup(s)	146	91.0	296	18.7	16.4	0.9	17.0	4.0	6.3	5.3
1826	Green salad	¾	cup(s)	104	98.9	17	1.3	3.3	2.2	0.1	0	0	0
1814	Hummus	½	cup(s)	123	79.8	218	6.0	24.7	4.9	10.6	1.4	6.0	2.6
16650	Kung pao chicken	1	cup(s)	162	87.2	434	28.8	11.7	2.3	30.6	5.2	13.9	9.7
16622	Lamb curry	1	cup(s)	236	187.9	257	28.2	3.7	0.9	13.8	3.9	4.9	3.3
25253	Lasagna with ground beef	1	cup(s)	237	158.4	284	16.9	22.3	2.4	14.5	7.5	4.9	0.8
442	Macaroni and cheese, prepared	1	cup(s)	200	122.3	390	14.9	40.6	1.6	18.6	7.9	6.4	2.9
29637	Meat filled ravioli with tomato or meat sauce, canned	1	cup(s)	251	198.7	208	7.8	36.5	1.3	3.7	1.5	1.4	0.3
25105	Meat loaf	1	slice(s)	115	84.5	245	17.0	6.6	0.4	16.0	6.1	6.9	0.9
16646	Moo shi pork	1	cup(s)	151	76.8	512	18.9	5.3	0.6	46.4	6.9	15.8	21.2
16788	Nachos with beef, beans, cheese, tomatoes and onions	1	serving(s)	551	253.5	1576	59.1	137.5	20.4	90.8	32.6	41.9	9.4
6116	Pepperoni pizza	2	slice(s)	142	66.1	362	20.2	39.7	2.9	13.9	4.5	6.3	2.3
29601	Pizza with meat and vegetables, thin crust	2	slice(s)	158	81.4	386	16.5	36.8	2.7	19.1	7.7	8.1	2.2
655	Potato salad	½	cup(s)	125	95.0	179	3.4	14.0	1.6	10.3	1.8	3.1	4.7

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	5	0.16	3.8	19.0	258.4	0 05	0	0.00	0.04	0 03	0 18	0.01	3.7	0.1	0	0.3
	5	0.00	0.5	6.7	14.6	0.01	8.0	0.00	0.02	0 01	0.00	0 00	0.5	0.1	0	0.1
	38	1.81	58.3	280.9	304.8	1 15	13.3	0 06	1.72	0.08	1.84	0.09	15 9	3.4	0.1	1.1
	5	0.02	0.6	8.6	437.3	0.01	0	0.00	0 00	0 02	0.23	0 00	2.4	0	0.1	0.7
	1	0 05	0.6	6.4	31.7	0.01	4.1	0.00	0.00	0.00	0 01	0.01	0.1	0.2	0	0
	9	0.14	4.8	95.0	192.0	0.11	4.8	0.01	0.37	0 01	0.02	0 05	1.3	0.6	0	0.3
	4	0.43	7.3	38.7	1018.9	0 08	0	0.01	0 00	0.03	0 72	0 04	3.3	0	0	0.1
	5	0.20	1.2	8.2	97.5	0 01	0	0.00	—	0.01	0 11	0 03	0.2	0	0	—
	5	0.30	11.0	40.5	689.9	0.01	0	0 01	0 00	0.01	0 22	0 01	1.4	0	0	0.2
	23	1.24	28.9	536 8	268.6	0 36	—	0 08	0 52	0.08	1 64	0 20	23.2	32.0	0	1.0
	74	0.20	8 8	97.5	221 3	0.25	—	0 04	—	0 11	0 25	0 02	3.1	0.5	0.2	—
	6	0.30	0.7	45.4	55.6	0.01	0.3	0.00	0.00	0.01	0 03	0 00	0.5	0.7	0	0
	0	0.00	—	—	0	—	0	—	—	—	—	—	—	0	—	—
	1	0.03	0.7	10.9	0.7	0.01	0	0 00	0 00	0.00	0 00	0 00	0	0	0	0
	1	0.09	0	2.3	0.1	0.00	0	0.00	0.00	0.00	0.00	0.00	0	0	0	5.0
	0	0.07	—	2.3	0.7	—	—	0.07	—	0.07	0.07	—	—	0.3	0	—
1	68	1.86	58.1	539.7	510.6	1 50	31 5	0 07	4 11	0 22	9 57	0 43	26.6	5.1	0.3	13.6
0	26	1.70	32.4	419.7	500.9	2.67	—	0 09	0 01	0 24	6 87	0.40	15.0	7.9	0.3	19.5
8	333	3.01	52 5	447.6	510.6	1 98	—	0 28	0 01	0 30	1 92	0 19	122.9	8.2	0.3	15.9
5	85	3.65	37.9	475.0	756.0	3 52	17 8	0 38	0 80	0 29	5 33	0 39	69.1	23.4	2.1	28.3
4	31	1.68	20.5	248.3	547 8	0.89	25 6	0 32	1 28	0 24	2 55	0.18	38.4	4.0	0.3	17.5
1	29	2.90	—	613.0	292.0	—	—	0 15	0.51	0.17	4 70	—	—	17.0	0	15.0
4	69	3.25	35.8	391 7	816 6	3 63	69.1	0.21	1 25	0 30	3.80	0 21	48 6	1.3	1.8	27 9
1	68	1.86	58.1	539.7	510 6	1.50	31 5	0 07	4 11	0 22	9 57	0 43	26.6	5.1	0.3	13.6
7	249	2.78	28.0	294 0	739.2	1 42	47 6	0 29	1 05	0.33	2.84	0.14	61 6	15 3	0.4	18.6
3	190	1.04	13.5	75 6	469 3	0.86	58.3	0 11	0.43	0 15	0 89	0.02	21.6	2 4	0 1	9 2
03	26	2.20	—	149.0	600 0	—	—	0.05	—	0 17	4.30	—	—	0	—	29 0
2	28	1.19	22.7	299.7	620 5	1.32	81 0	0 07	1.11	0 14	5.28	0 36	16.2	22.5	0 2	12.0
09	47	1.97	40.0	489.3	492.1	2.13	—	0.11	0 00	0 20	9 81	0.57	16.1	14.0	0 3	22.6
56	423	8.79	110.3	1182.9	880.4	6.18	—	0 72	0 00	1.05	20 16	1.20	113.9	2.7	1.3	97.6
58	66	3.32	37.8	390.6	652.7	1.94	259.6	0 39	1.05	0.39	7.25	0 23	80.6	10.3	0.2	27.0
56	51	3.26	68.3	588.0	3208.6	3.75	31 7	0.15	0.58	0.36	16 68	0.88	24.4	2.0	0.5	36.1
12	20	0.82	23.9	202.5	246.5	1.13	—	0.05	0 62	0 09	4.06	0.25	15.8	2.5	0.2	10.7
27	42	2.83	50.6	636.8	864.8	2.36	—	0 15	0.01	0.22	3.18	0.19	58.1	10.3	0.6	7.3
7	41	0.53	9.0	162.9	20.7	0.18	47 7	0 06	—	0.05	0.24	0.11	24.3	29.4	0	0.6
90	63	0.64	19.8	194.4	198 0	2.45	34.2	0.05	—	0.04	1 74	0.10	31.8	1.7	3.6	24.4
27	266	1.07	38.5	251.4	276.3	1.26	—	0 07	0.02	0.16	1.27	0.17	44.6	59.3	0.2	6.0
0	28	1.74	41.8	298.4	149.9	0.76	0.5	0.07	—	0 08	0.53	0.06	47.4	0.8	0	0.5
9	218	1.83	38.4	163.9	472.9	1.24	—	0.41	0.00	0.35	2.85	0.09	96 2	1.6	0.4	38.4
73	146	2.66	61.3	222.9	885.7	3.43	0	0.10	0 10	0.16	3 00	0.26	95 7	0	1.2	36.7
03	38	2.77	33.7	196.0	833.6	1.34	41.6	0.33	1.60	0.18	4.17	0 27	97 0	3.4	0.3	22.0
56	26	1.46	23.4	248.2	849.7	1.40	29 2	0 10	1.62	0.18	6.28	0.28	23 4	12.0	0.2	19.9
0	13	0.65	11.4	178.0	26 9	0 21	59.0	0.03	—	0.05	0.56	0 08	38.3	24.0	0	0.4
0	60	1.91	35.7	212.8	297.7	1.34	0	0.10	0.92	0.06	0.49	0.49	72.6	9.7	0	3.0
65	50	1.96	63.2	427.7	907.2	1.50	38.9	0.15	4.32	0.14	13.22	0.58	42.1	7.5	0.3	23.0
90	38	2.95	40.1	493.2	495.6	6.60	—	0.08	1.29	0.28	8.03	0.21	28.3	1.4	2.9	30.4
68	233	2.22	40.1	420.1	433.6	2.70	—	0.21	0.21	0.29	3.06	0.22	50.4	15.0	0.8	21.4
34	310	2.06	40.0	258.0	784.0	2.06	180.0	0.27	0.72	0.43	2.18	0.08	64.0	0	0.5	30.6
15	35	2.10	20.1	283.6	1352.9	1.28	27.6	0.19	0.70	0.16	2.77	0.14	42.7	21.6	0.4	13.3
85	59	1.87	21.8	300.8	411.7	3.40	—	0.08	0.00	0.27	3.72	0.13	18.7	0.9	1.6	17.9
172	32	1.57	25.7	333.7	1052.5	1.82	49.8	0.49	5.39	0.36	2.88	0.31	21.1	8.0	0.8	30.0
154	948	7.32	242.4	1201.2	1862.4	10.68	259.0	0.29	7.71	0.81	6.39	1.09	148.8	16.0	2.6	44.1
28	129	1.87	17.0	305.3	533.9	1.03	105.1	0.26	—	0.46	6.09	0.11	73.8	3.3	0.4	26.1
36	258	3.14	31.6	352.3	971.7	2.02	49.0	0.37	1.13	0.37	3.77	0.19	64.8	15.6	0.6	22.8
85	24	0.81	18.8	317.5	661.3	0.38	40.0	0.09	—	0.07	1.11	0.17	8.8	12.5	0	5.1

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA+ Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	
Mixed Foods, Soups, Sandwiches—*continued*														
25109	Salisbury steaks with mushroom sauce	1	serving(s)	135	101.8	251	17.1	9.3	0.5	15.5	6.0	6.7	0.8	
16637	Shrimp creole with rice	1	cup(s)	243	176.6	309	27.0	27.7	1.2	9.2	1.7	3.6	2.9	
497	Spaghetti and meatballs with tomato sauce, prepared	1	cup(s)	248	174.0	330	19.0	39.0	2.7	12.0	3.9	4.4	2.2	
28585	Spicy thai noodles (pad thai)	8	ounce(s)	227	73.3	221	8.9	35.7	3.0	6.4	0.8	3.3	1.8	
33073	Stir fried pork and vegetables with rice	1	cup(s)	235	173.6	348	15.4	33.5	1.9	16.3	5.6	6.9	2.6	
28588	Stuffed shells	2½	item(s)	249	157.5	243	15.0	28.0	2.5	8.1	3.1	3.0	1.3	
16821	Sushi with egg in seaweed	6	piece(s)	156	116.5	190	8.9	20.5	0.3	7.9	2.2	3.2	1.5	
16819	Sushi with vegetables and fish	6	piece(s)	156	101.6	218	8.4	43.7	1.7	0.6	0.2	0.1	0.2	
16820	Sushi with vegetables in seawéed	6	piece(s)	156	110.3	183	3.4	40.6	0.8	0.4	0.1	0.1	0.1	
25266	Sweet and sour pork	¾	cup(s)	249	205.9	265	29.2	17.1	1.0	8.1	2.6	3.5	1.5	
16824	Tabouli, tabbouleh or tabuli	1	cup(s)	160	123.7	198	2.6	15.9	3.7	14.9	2.0	10.9	1.6	
25276	Three bean salad	½	cup(s)	99	82.2	95	1.9	9.7	2.6	5.9	0.8	1.4	3.5	
160	Tuna salad	½	cup(s)	103	64.7	192	16.4	9.6	0	9.5	1.6	3.0	4.2	
25241	Turkey and noodles	1	cup(s)	319	228.5	270	24.0	21.2	1.0	9.2	2.4	3.5	2.3	
16794	Vegetable egg roll	2	item(s)	128	89.8	201	5.1	19.5	1.7	11.6	2.5	5.7	2.6	
16818	Vegetable sushi, no fish	6	piece(s)	156	99.0	226	4.8	49.9	2.0	0.4	0.1	0.1	0.1	
	Sandwiches													
1744	Bacon, lettuce and tomato with mayonnaise	1	item(s)	164	97.2	341	11.6	34.2	2.3	17.6	3.8	5.5	6.7	
30287	Bologna and cheese with margarine	1	item(s)	111	45.6	345	13.4	29.3	1.2	19.3	8.1	7.0	2.4	
30286	Bologna with margarine	1	item(s)	83	33.6	251	8.1	27.3	1.2	12.1	3.7	5.0	2.1	
16546	Cheese	1	item(s)	83	31.0	261	9.1	27.6	1.2	12.7	5.4	4.2	2.1	
8789	Cheeseburger, large, plain	1	item(s)	185	78.9	564	32.0	38.5	2.6	31.5	12.5	10.2	1.0	1.
8624	Cheeseburger, large, with bacon, vegetables, and condiments	1	item(s)	195	91.4	550	30.8	36.8	2.5	30.9	11.9	10.6	1.3	1.
1745	Club with bacon, chicken, tomato, lettuce, and mayonnaise	1	item(s)	246	137.5	546	31.0	48.9	3.0	24.5	5.3	7.5	9.4	
1908	Cold cut submarine with cheese and vegetables	1	item(s)	228	131.8	456	21.8	51.0	2.0	18.6	6.8	8.2	2.3	
30247	Corned beef	1	item(s)	130	74.9	265	18.2	25.3	1.6	9.6	3.6	3.5	1.0	
25283	Egg salad	1	item(s)	126	72.1	278	10.7	28.0	1.4	13.5	2.9	4.2	5.0	
16686	Fried egg	1	item(s)	96	49.7	226	10.0	26.2	1.2	8.6	2.3	3.2	1.9	
16547	Grilled cheese	1	item(s)	83	27.5	291	9.2	27.9	1.2	15.8	6.0	5.7	3.0	
16659	Gyro with onion and tomato	1	item(s)	105	68.3	163	12.0	20.0	1.1	3.5	1.3	1.3	0.5	
1906	Ham and cheese	1	item(s)	146	74.2	352	20.7	33.3	2.0	15.5	6.4	6.7	1.4	
31890	Ham with mayonnaise	1	item(s)	112	56.3	271	13.0	27.9	1.9	11.6	2.8	4.0	4.0	
756	Hamburger, double patty, large, with condiments and vegetables	1	item(s)	226	121.5	540	34.3	40.3	—	26.6	10.5	10.3	2.8	
8793	Hamburger, large, plain	1	item(s)	137	57.7	426	22.6	31.7	1.5	22.9	8.4	9.9	2.1	
8795	Hamburger, large, with vegetables and condiments	1	item(s)	218	121.4	512	25.8	40.0	3.1	27.4	10.4	11.4	2.2	
25134	Hot chicken salad	1	item(s)	98	48.4	242	15.2	23.8	1.3	9.2	2.9	2.5	3.0	
25133	Hot turkey salad	1	item(s)	98	50.1	224	15.6	23.8	1.3	6.9	2.3	1.6	2.5	
1411	Hotdog with bun, plain	1	item(s)	98	52.9	242	10.4	18.0	1.6	14.5	5.1	6.9	1.7	
30249	Pastrami	1	item(s)	134	71.2	328	13.4	27.8	1.6	17.7	6.1	8.3	1.2	
16701	Peanut butter	1	item(s)	93	23.6	345	12.2	37.6	3.3	17.4	3.4	7.7	5.2	
30306	Peanut butter and jelly	1	item(s)	93	24.2	330	10.3	41.9	2.9	14.7	2.9	6.5	4.4	
1909	Roast beef submarine with mayonnaise and vegetables	1	item(s)	216	127.4	410	28.6	44.3	—	13.0	7.1	1.8	2.6	
1910	Roast beef, plain	1	item(s)	139	67.6	346	21.5	33.4	1.2	13.8	3.6	6.8	1.7	
1907	Steak with mayonnaise and vegetables	1	item(s)	204	104.2	459	30.3	52.0	2.3	14.1	3.8	5.3	3.3	
25288	Tuna salad	1	item(s)	179	102.2	415	24.5	28.4	1.6	22.4	3.5	6.2	11.4	
30283	Turkey submarine with cheese, lettuce, tomato, and mayonnaise	1	item(s)	277	168.0	529	30.4	49.4	3.0	22.8	6.8	6.0	8.6	
31891	Turkey with mayonnaise	1	item(s)	143	74.5	329	28.7	26.4	1.3	11.2	2.6	2.6	4.8	
	Soups													
25296	Bean	1	cup(s)	301	253.1	191	13.8	29.0	6.5	2.3	0.7	0.8	0.5	0
711	Bean with pork, condensed, prepared with water	1	cup(s)	253	215.9	159	7.3	21.0	7.3	5.5	1.4	2.0	1.7	

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	74	1.94	23.8	314.5	360.5	3.45	—	0.10	0.00	0.27	3.95	0.13	20.8	0.7	1.6	17.4
0	102	4.68	63.2	413.1	330.5	1.72	94.8	0.29	2.06	0.11	4.75	0.21	75 3	12 9	1 2	49.3
)	124	3.70	—	665.0	1009.0	—	81.5	0.25	—	0.30	4.00	—	—	22.0	—	22.0
	31	1.56	49.4	181 3	591.6	1 05	—	0 18	0.35	0 13	1 82	0 17	44.6	22.6	0.1	3 2
5	38	2.71	33.0	396.9	569.5	2.08	—	0.51	0 38	0.20	5 07	0 30	103.0	18 8	0.4	22.8
)	188	2.26	49.4	403.0	471.5	1.41	—	0.26	0.00	0.26	3.83	0.24	80.0	17.9	0.2	28.9
4	45	1.84	18.7	135.7	463.3	0.98	106.1	0.13	0.67	0.28	1.35	0.13	62.4	1.9	0.7	20.3
	23	2.15	25.0	202.8	340.1	0.78	45.2	0.26	0.24	0.07	2.76	0.14	76.4	3.6	0.3	13.9
	20	1.54	18.7	96.7	152.9	0.68	25.0	0.19	0.12	0 03	1 86	0.13	73.3	2 3	0	9.8
4	40	1.76	35.6	619 9	621.8	2 53	—	0 81	0 20	0 37	6 69	0 66	14 7	11 9	0.7	49 6
	30	1.21	35.2	249 6	796.8	0.48	54.4	0 07	2 43	0 04	1 11	0 11	30 4	26 1	0	0.5
	26	0.96	15 5	144.8	224.2	0.30	—	0.02	0.88	0 04	0 26	0 04	32 2	10.0	0	2.7
3	17	1.02	19 5	182 5	412.1	0 57	24 6	0 03	—	0 07	6 86	0 08	8 2	2 3	1 2	42 2
7	69	2.56	33 2	400 8	577 1	2.51	—	0 23	0 28	0 30	6 41	0 29	61 4	1 4	1 1	33 4
0	29	1 65	17 9	193 3	549.1	0 48	25 6	0 15	1 28	0 20	1 59	0 09	46 1	5 5	0 2	11 3
)	23	2.38	21 8	157 6	369.7	0 82	48 4	0 28	0 15	0 05	2 44	0 12	85 8	3.7	0	8.1
1	79	2.36	27.9	351.0	944.6	1.08	44.3	0 32	1.16	0 24	4 36	0.21	73 8	9.7	0.2	27.1
0	258	2 38	24 4	215.3	941.3	1.88	102 1	0 31	0 55	0 35	2 97	0.14	59 9	0 2	0.8	20.4
7	100	2.24	16.6	138 6	579 3	1 02	44 8	0 29	0 49	0 21	2 92	0 12	58 1	0.2	0 5	16.0
2	233	2 04	19 9	127 0	733 7	1.24	97 1	0 25	0 47	0 30	2 25	0 05	58 1	0	0.3	13.1
04	309	4 47	44 4	401 5	986 1	5 75	0	0 35	—	0 77	8 26	0 49	109 2	0	2 8	38 9
8	267	4.03	44.9	464 1	1314.3	5 20	0	0 33	—	0 67	8 25	0.47	95.6	1.4	2.4	6.6
1	157	4.57	46 7	464 9	1087.3	1.82	41 8	0 54	1 52	0.40	12.82	0.61	118.1	6.4	0.4	42.3
6	189	2.50	68.4	394.4	1650 7	2 57	70 7	1.00	—	0.79	5.49	0.13	86.6	12.3	1.1	30.8
6	81	3 04	19 5	127 4	1206 4	2 26	2 6	0 23	0 20	0 24	3 42	0 11	59.8	0 3	0 9	31 2
19	85	2 25	18 8	159 0	423 1	0 87	—	0 27	0 12	0 43	2 06	0 15	73 6	0 9	0 6	29 9
06	104	2 79	17 3	117 1	438 7	0 92	89 3	0 26	0 66	0 40	2 26	0 10	79 7	0	0 6	24 2
2	235	2 05	19 9	128 7	763 6	1 26	129 5	0 19	0 72	0 28	2 05	0 05	38 2	0	0 2	13 2
8	47	1.77	22 1	218 4	235 2	2 33	9 5	0 23	0 26	0 20	3 12	0 13	44 1	3 2	0 9	18.3
58	130	3.24	16 1	290 5	770 9	1 37	96 4	0 30	0 29	0 48	2 68	0 20	75 9	2 8	0 5	23 1
34	91	2 47	23.5	210 6	1097.6	1 13	5.6	0 57	0 50	0 26	3 80	0 25	60 5	2 2	0.2	20.2
22	102	5.85	49.7	569 5	791 0	5 67	0	0 36	—	0 38	7 57	0.54	76 8	1.1	4.1	25 5
71	74	3 57	27 4	267 2	474 0	4 11	0	0 28	—	0 28	6 24	0 23	60 3	0	2.1	27 1
37	96	4 92	43.6	479 6	824 0	4 88	0	0 41	—	0 37	7 28	0 32	82 8	2 6	2 4	33 6
39	115	1 88	20 0	172 4	505 1	1 19	—	0 23	0 28	0 22	4 84	0.19	46 4	0 5	0 2	19 9
37	114	1.99	21 3	189 0	494 5	1 07	—	0 22	0 28	0 20	4.26	0.22	46 4	0 5	0 2	23.4
44	24	2.31	12.7	143 1	670 3	1.98	0	0 23	—	0.27	3 64	0 04	48 0	0 1	0.5	26 0
51	80	3 02	22 8	182 2	1364.1	2.70	2.7	0 28	0 26	0 26	4 97	0.14	60 3	0.3	1 0	14 3
0	110	2.92	66 0	226 0	580 3	1 32	0	0 31	2 39	0.23	6 72	0 18	92.1	0	0	13 2
0	94	2.50	56.7	198.1	492.9	1.12	—	0 26	2 01	0 20	5 66	0.15	78 1	0 1	0	11 2
73	41	2.80	67.0	330.5	844.6	4.38	30.2	0.41	—	0.41	5.96	0.32	71.3	5.6	1.8	25.7
51	54	4.22	30.6	315.5	792.3	3.39	11.1	0 37	—	0 30	5 86	0.26	57 0	2.1	1 2	29 2
73	92	5.16	49.0	524.3	797.6	4.52	0	0.40	—	0.36	7.30	0.36	89.8	5.5	1.6	42.0
59	78	2 97	35 9	316 3	724 7	1.02	—	0 27	0 34	0 26	12.07	0.46	60.8	1 8	2.4	76.9
64	307	4.59	49 9	534.6	1759.0	2.74	74.8	0.49	1 19	0.65	3.91	0.31	121.9	10.5	0.6	42.1
67	100	3.46	34.3	304.6	564 9	3.00	5.7	0.28	0 74	0.32	6.84	0.46	64.4	0	0.3	40
5	79	3.05	61.8	588.8	689.0	1.41	—	0 27	0 02	0.15	3 63	0.23	140 1	3 6	0.2	7 9
3	78	1.89	43.0	371.9	883.0	0.96	43.0	0.08	1.08	0.03	0.52	0.03	30.4	1.5	0	7.8

APPENDIX H

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

UA-Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	T
Mixed Foods, Soups, Sandwiches—*continued*														
713	Beef noodle, condensed, prepared with water	1	cup(s)	244	224.9	83	4.7	8.7	0.7	3.0	1.1	1.2	0.5	
825	Cheese, condensed, prepared with milk	1	cup(s)	251	206.9	231	9.5	16.2	1.0	14.6	9.1	4.1	0.5	
826	Chicken broth, condensed, prepared with water	1	cup(s)	244	234.1	39	4.9	0.9	0	1.4	0.4	0.6	0.3	
25297	Chicken noodle soup	1	cup(s)	286	258.4	117	10.8	10.9	0.9	2.9	0.8	1.1	0.7	
827	Chicken noodle, condensed, prepared with water	1	cup(s)	241	226.1	60	3.1	7.1	0.5	2.3	0.6	1.0	0.6	
724	Chicken noodle, dehydrated, prepared with water	1	cup(s)	252	237.3	58	2.1	9.2	0.3	1.4	0.3	0.5	0.4	
823	Cream of asparagus, condensed, prepared with milk	1	cup(s)	248	213.3	161	6.3	16.4	0.7	8.2	3.3	2.1	2.2	
824	Cream of celery, condensed, prepared with milk	1	cup(s)	248	214.4	164	5.7	14.5	0.7	9.7	3.9	2.5	2.7	
708	Cream of chicken, condensed, prepared with milk	1	cup(s)	248	210.4	191	7.5	15.0	0.2	11.5	4.6	4.5	1.6	
715	Cream of chicken, condensed, prepared with water	1	cup(s)	244	221.1	117	3.4	9.3	0.2	7.4	2.1	3.3	1.5	
709	Cream of mushroom, condensed, prepared with milk	1	cup(s)	248	215.0	166	6.2	14.0	0	9.6	3.3	2.0	1.8	
716	Cream of mushroom, condensed, prepared with water	1	cup(s)	244	224.6	102	1.9	8.0	0	7.0	1.6	1.3	1.7	
25298	Cream of vegetable	1	cup(s)	285	250.7	165	7.2	15.2	1.9	8.6	1.6	4.6	1.9	
16689	Egg drop	1	cup(s)	244	228.9	73	7.5	1.1	0	3.8	1.1	1.5	0.6	
25138	Golden squash	1	cup(s)	258	223.9	145	7.6	20.4	0.4	4.1	0.8	2.2	0.9	
16663	Hot and sour	1	cup(s)	244	209.7	161	15.0	5.4	0.5	7.9	2.7	3.4	1.1	
28054	Lentil chowder	1	cup(s)	244	202.8	153	11.4	27.7	12.6	0.5	0.1	0.1	0.2	
28560	Macaroni and bean	1	cup(s)	246	138.8	146	5.8	22.9	5.1	3.7	0.5	2.2	0.6	
714	Manhattan clam chowder, condensed, prepared with water	1	cup(s)	244	225.1	73	2.1	11.6	1.5	2.1	0.4	0.4	1.2	
28561	Minestrone	1	cup(s)	241	185.4	103	4.5	16.8	4.8	2.3	0.3	1.4	0.4	
717	Minestrone, condensed, prepared with water	1	cup(s)	241	220.1	82	4.3	11.2	1.0	2.5	0.6	0.7	1.1	
28038	Mushroom and wild rice	1	cup(s)	244	199.7	86	4.7	13.2	1.7	0.3	0	0	0.2	
828	New England clam chowder, condensed, prepared with milk	1	cup(s)	248	212.2	151	8.0	18.4	0.7	5.0	2.1	0.7	0.6	
28036	New England style clam chowder	1	cup(s)	244	227.5	61	3.8	8.8	1.8	0.2	0.1	0	0	
28566	Old country pasta	1	cup(s)	252	183.3	146	6.5	18.3	3.6	4.5	2.0	2.4	0.9	
725	Onion, dehydrated, prepared with water	1	cup(s)	246	235.7	30	0.8	6.8	0.7	0	0	0	0	
16667	Shrimp gumbo	1	cup(s)	244	207.2	166	9.5	18.2	2.4	6.7	1.3	2.9	2.0	
28037	Southwestern corn chowder	1	cup(s)	244	217.8	98	4.9	17.0	2.4	0.5	0.1	0.1	0.2	
30282	Soybean (miso)	1	cup(s)	240	218.6	84	6.0	8.0	1.9	3.4	0.6	1.1	1.4	
25140	Split pea	1	cup(s)	165	119.7	72	4.5	16.0	1.6	0.3	0.1	0	0.2	
718	Split pea with ham, condensed, prepared with water	1	cup(s)	253	206.9	190	10.3	28.0	2.3	4.4	1.8	1.8	0.6	
726	Tomato vegetable, dehydrated, prepared with water	1	cup(s)	253	238.4	56	2.0	10.2	0.8	0.9	0.4	0.3	0.1	
710	Tomato, condensed, prepared with milk	1	cup(s)	248	213.4	136	6.2	22.0	1.5	3.2	1.8	0.9	0.3	
719	Tomato, condensed, prepared with water	1	cup(s)	244	223.0	73	1.9	16.0	1.5	0.7	0.2	0.2	0.2	
28595	Turkey noodle	1	cup(s)	244	216.9	114	8.1	15.1	1.9	2.4	0.3	1.1	0.7	
28051	Turkey vegetable	1	cup(s)	244	220.8	96	12.2	6.6	2.0	1.1	0.3	0.2	0.3	
25141	Vegetable	1	cup(s)	252	228.1	82	5.2	16.5	4.5	0.3	0	0	0.1	
720	Vegetable beef, condensed, prepared with water	1	cup(s)	244	224.0	76	5.4	9.9	2.0	1.9	0.8	0.8	0.1	
28598	Vegetable gumbo	1	cup(s)	252	184.5	170	4.4	28.9	3.6	4.7	0.7	3.2	0.5	
721	Vegetarian vegetable, condensed, prepared with water	1	cup(s)	241	222.7	67	2.1	11.8	0.7	1.9	0.3	0.8	0.7	
Fast Food														
	Arby's													
36094	Au jus sauce	1	serving(s)	85	—	43	1.0	7.0	0	1.3	0.4	—	—	0.4
751	Beef 'n cheddar sandwich	1	item(s)	195	—	445	22.0	44.0	2.0	21.0	6.0	—	—	1.0
9279	Cheddar curly fries	1	serving(s)	198	—	631	8.0	73.0	7.0	37.4	6.8	—	—	5.7

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	20	1.07	7.3	97.6	929.6	1.51	12.2	0.06	1.22	0.05	1.03	0.03	19.5	0.5	0.2	7.3
	289	0.80	20.1	341.4	1019.1	0.67	358.9	0.06	—	0.33	0.50	0.07	10.0	1.3	0.4	7.0
	10	0.51	2.4	209.8	775.9	0.24	0	0.01	0.04	0.07	3.34	0.02	4.9	0	0.2	0
	25	1.38	16.4	340.1	774.5	0.77	—	0.15	0.02	0.16	5.57	0.13	37.2	1.8	0.3	10.2
	14	1.59	9.6	53.0	638.7	0.38	26.5	0.13	0.07	0.10	1.30	0.04	19.3	0	0	11.6
	5	0.50	7.6	32.8	577.1	0.20	2.5	0.20	0.12	0.07	1.08	0.02	17.6	0	0.1	9.6
	174	0.86	19.8	359.6	1041.6	0.91	62.0	0.10	—	0.27	0.88	0.06	29.8	4.0	0.5	8.0
	186	0.69	22.3	310.0	1009.4	0.19	114.1	0.07	—	0.24	0.43	0.06	7.4	1.5	0.5	4.7
	181	0.67	17.4	272.8	1046.6	0.67	178.6	0.07	—	0.25	0.92	0.06	7.4	1.2	0.5	8.0
	34	0.61	2.4	87.8	985.8	0.63	163.5	0.02	—	0.06	0.82	0.01	2.4	0.2	0.1	7.0
	164	1.36	19.8	267.8	823.4	0.79	81.8	0.10	1.01	0.29	0.62	0.05	7.4	0.2	0.6	6.0
	17	1.31	4.9	73.2	775.9	0.24	9.8	0.05	0.97	0.05	0.50	0.00	2.4	0	0	2.9
	80	1.20	17.5	340.7	787.9	0.56	—	0.12	1.05	0.18	3.32	0.12	39.5	10.7	0.3	4.3
2	22	0.75	4.9	219.6	729.6	0.48	41.5	0.02	0.29	0.19	3.02	0.05	14.6	0	0.5	7.6
	262	0.78	42.4	542.2	515.6	0.88	—	0.16	0.52	0.30	1.14	0.16	32.7	12.5	0.7	6.0
4	29	1.24	19.5	373.3	1561.6	1.43	—	0.26	0.12	0.24	4.96	0.20	14.6	0.5	0.4	19.3
	48	4.38	59.3	626.2	26.7	1.57	—	0.24	0.06	0.12	1.87	0.32	176.3	16.1	0	3.5
	59	1.90	32.4	275.9	531.0	0.51	—	0.16	0.37	0.12	1.44	0.10	58.2	9.1	0	8.8
	27	1.56	9.8	180.6	551.4	0.87	48.8	0.02	1.22	0.03	0.77	0.09	9.8	3.9	3.9	9.0
	62	1.70	29.9	287.5	442.7	0.42	—	0.09	0.23	0.09	0.70	0.07	47.3	13.3	0	3.5
	34	0.91	7.2	313.3	911.0	0.74	118.1	0.05	—	0.04	0.94	0.09	36.2	1.2	0	8.0
	30	1.38	27.3	376.9	283.8	1.00	—	0.06	0.07	0.23	3.21	0.14	18.1	3.7	0.1	4.7
7	169	3.00	29.8	456.3	887.8	0.99	91.8	0.20	0.54	0.43	1.96	0.17	22.3	5.2	11.9	10.9
3	89	1.30	29.2	503.7	256.8	0.52	—	0.06	0.02	0.10	1.30	0.15	24.2	11.8	3.0	3.8
5	57	2.43	51.9	500.4	355.7	0.78	—	0.21	0.01	0.14	2.64	0.20	80.0	22.0	0.1	10.3
0	22	0.12	9.8	76.3	851.2	0.12	0	0.03	0.02	0.03	0.15	0.06	0	0.2	0	0.5
1	105	2.85	48.8	461.2	441.6	0.90	80.5	0.18	1.90	0.12	2.52	0.19	85.4	17.6	0.3	14.9
1	83	1.03	26.3	434.4	217.4	0.57	—	0.08	0.09	0.13	1.81	0.21	32.1	39.6	0.2	1.7
0	65	1.87	36.0	362.4	988.8	0.86	232.8	0.06	0.96	0.16	2.61	0.15	57.6	4.6	0.2	1.0
0	28	1.26	29.8	328.1	602.4	0.52	—	0.10	0.00	0.07	1.50	0.16	49.5	8.1	0	0.7
8	23	2.27	48.1	399.7	1006.9	1.31	22.8	0.14	—	0.07	1.47	0.06	2.5	1.5	0.3	8.0
0	20	0.60	10.1	169.5	334.0	0.20	10.1	0.06	0.43	0.09	1.26	0.06	12.7	3.0	0.1	2.0
0	166	1.36	29.8	466.2	711.8	0.84	94.2	0.09	0.44	0.31	1.35	0.15	5.0	15.6	0.6	9.2
0	20	1.31	17.1	273.3	663.7	0.29	24.4	0.04	0.41	0.07	1.23	0.10	0	15.4	0	6.1
6	28	1.40	24.1	223.8	395.9	0.75	—	0.21	0.01	0.12	2.85	0.15	45.0	7.1	0.1	13.7
1	38	1.48	25.0	423.4	348.7	0.99	—	0.09	0.01	0.09	3.64	0.27	23.9	10.6	0.2	10.3
0	40	2.08	39.1	681.5	670.3	0.67	—	0.16	0.00	0.09	2.70	0.26	36.3	22.4	0	2.2
5	20	1.09	7.3	168.4	773.5	1.51	190.3	0.03	0.58	0.04	1.00	0.07	9.8	2.4	0.3	2.7
0	56	1.85	38.9	360.2	518.4	0.64	—	0.18	0.64	0.08	1.77	0.17	57.6	21.9	0	4.1
0	24	1.06	7.2	207.3	814.6	0.45	171.1	0.05	1.39	0.04	0.90	0.05	9.6	1.4	0	4.3
0	0	—	—	—	1510.0	—	—	—	—	—	—	—	—	—	—	—
51	80	3.96	—	—	1274.0	—	—	—	—	—	—	—	—	1.8	—	—
0	80	3.24	—	—	1476.0	—	—	—	—	—	—	—	—	9.6	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

FNI Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tr
Fast Food—*continued*														
34770	Chicken breast fillet sandwich, grilled	1	item(s)	233	—	414	32.0	36.0	3.0	17.0	3.0	—	—	
36131	Chocolate shake, regular	1	serving(s)	397	—	507	13.0	83.0	0	13.0	8.0	—	—	
36045	Curly fries, large size	1	serving(s)	198	—	631	8.0	73.0	7.0	37.0	7.0	—	—	6
36044	Curly fries, medium size	1	serving(s)	128	—	406	5.0	47.0	5.0	24.0	4.0	—	—	4
752	Ham 'n cheese sandwich	1	item(s)	167	—	304	23.0	35.0	1.0	7.0	2.0	—	—	
36048	Homestyle fries, large size	1	serving(s)	213	—	566	6.0	82.0	6.0	37.0	7.0	—	—	5
36047	Homestyle fries, medium size	1	serving(s)	142	—	377	4.0	55.0	4.0	25.0	4.0	—	—	4
33465	Homestyle fries, small size	1	serving(s)	113	—	302	3.0	44.0	3.0	20.0	4.0	—	—	3
9249	Junior roast beef sandwich	1	item(s)	125	—	272	16.0	34.0	2.0	10.0	4.0	—	—	
9251	Large roast beef sandwich	1	item(s)	281	—	547	42.0	41.0	3.0	28.0	12.0	—	—	2
39640	Market Fresh chicken salad with pecans sandwich	1	item(s)	322	—	769	30.0	79.0	9.0	39.0	10.0	—	—	
39641	Market Fresh Martha's Vineyard salad, without dressing	1	serving(s)	330	—	277	26.0	24.0	5.0	8.0	4.0	—	—	
34769	Market Fresh roast turkey and Swiss sandwich	1	serving(s)	359	—	725	45.0	75.0	5.0	30.0	8.0	—	—	1
9267	Market Fresh roast turkey ranch and bacon sandwich	1	serving(s)	382	—	834	49.0	75.0	5.0	38.0	11.0	—	—	1
39642	Market Fresh Santa Fe salad, without dressing	1	serving(s)	372	—	499	30.0	42.0	7.0	23.0	8.0	—	—	2
39650	Market Fresh Southwest chicken wrap	1	serving(s)	251	—	567	36.0	42.0	4.0	29.0	9.0	—	—	1
37021	Market Fresh Ultimate BLT sandwich	1	item(s)	294	—	779	23.0	75.0	6.0	45.0	11.0	—	—	1
750	Roast beef sandwich, regular	1	item(s)	154	—	320	21.0	34.0	2.0	14.0	5.0	—	—	1
36132	Strawberry shake, regular	1	serving(s)	397	—	498	13.0	81.0	0	13.0	8.0	—	—	0
2009	Super roast beef sandwich	1	item(s)	198	—	398	21.0	40.0	2.0	19.0	6.0	—	—	1
36130	Vanilla shake, regular	1	serving(s)	369	—	437	13.0	66.0	0	13.0	8.0	—	—	0
	Auntie Anne's													
35371	Cheese dipping sauce	1	serving(s)	35	—	100	3.0	4.0	0	8.0	4.0	—	—	0
35353	Cinnamon sugar soft pretzel	1	item(s)	120	—	350	9.0	74.0	2.0	2.0	0	—	—	0
35354	Cinnamon sugar soft pretzel with butter	1	item(s)	120	—	450	8.0	83.0	3.0	9.0	5.0	—	—	0
35372	Marinara dipping sauce	1	serving(s)	35	—	10	0	4.0	0	0	0	0	0	0
35357	Original soft pretzel	1	serving(s)	120	—	340	10.0	72.0	3.0	1.0	0	—	—	0
35358	Original soft pretzel with butter	1	item(s)	120	—	370	10.0	72.0	3.0	4.0	2.0	—	—	0
35359	Parmesan herb soft pretzel	1	item(s)	120	—	390	11.0	74.0	4.0	5.0	2.5	—	—	
35360	Parmesan herb soft pretzel with butter	1	item(s)	120	—	440	10.0	72.0	9.0	13.0	7.0	—	—	
35361	Sesame soft pretzel	1	item(s)	120	—	350	11.0	63.0	3.0	6.0	1.0	—	—	0
35362	Sesame soft pretzel with butter	1	item(s)	120	—	410	12.0	64.0	7.0	12.0	4.0	—	—	0
35364	Sour cream and onion soft pretzel	1	item(s)	120	—	310	9.0	66.0	2.0	1.0	0	—	—	0
35366	Sour cream and onion soft pretzel with butter	1	item(s)	120	—	340	9.0	66.0	2.0	5.0	3.0	—	—	0
35373	Sweet mustard dipping sauce	1	serving(s)	35	—	60	0.5	8.0	0	1.5	1.0	—	—	0
35367	Whole wheat soft pretzel	1	item(s)	120	—	350	11.0	72.0	7.0	1.5	0	—	—	0
35368	Whole wheat soft pretzel with butter	1	item(s)	120	—	370	11.0	72.0	7.0	4.5	1.5	—	—	0
	Boston Market													
34978	Butternut squash	¾	cup(s)	143	—	140	2.0	25.0	2.0	4.5	3.0	—	—	0
35006	Caesar side salad	1	serving(s)	71	—	40	3.0	3.0	1.0	20.0	2.0	—	—	1.5
35013	Chicken Carver sandwich with cheese and sauce	1	item(s)	321	—	700	44.0	68.0	3.0	29.0	7.0	—	—	0
34979	Chicken gravy	4	ounce(s)	113	—	15	1.0	4.0	0	0.5	0	—	—	0
35053	Chicken noodle soup	¾	cup(s)	283	—	180	13.0	16.0	1.0	7.0	2.0	—	—	0
34973	Chicken pot pie	1	item(s)	425	—	800	29.0	59.0	4.0	49.0	18.0	—	—	7.0
35054	Chicken tortilla soup with toppings	¾	cup(s)	227	—	340	12.0	24.0	1.0	22.0	7.0	—	—	0
35007	Cole slaw	¾	cup(s)	125	—	170	2.0	21.0	2.0	9.0	2.0	—	—	0
35057	Cornbread	1	item(s)	45	—	130	1.0	21.0	0	3.5	1.0	—	—	1.0
34980	Creamed spinach	¾	cup(s)	191	—	280	9.0	12.0	4.0	23.0	15.0	—	—	0
34998	Fresh vegetable stuffing	1	cup(s)	136	—	190	3.0	25.0	2.0	8.0	1.0	—	—	0
34991	Garlic dill new potatoes	¾	cup(s)	156	—	140	3.0	24.0	3.0	3.0	1.0	—	—	0
34983	Green bean casserole	¾	cup(s)	170	—	60	2.0	9.0	2.0	2.0	1.0	—	—	0
34982	Green beans	¾	cup(s)	91	—	60	2.0	7.0	3.0	3.5	1.5	—	—	0

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	90	3.06	—	—	913.0	—	—	—	—	—	—	—	—	10.8	—	—
	510	0.54	—	—	357.0	—	—	—	—	—	—	—	—	5.4	—	—
	80	3.24	—	—	1476 0	—	—	—	—	—	—	—	—	9.6	—	—
	50	1.98	—	—	949.0	—	—	—	—	—	—	—	—	6 0	—	—
5	160	2 70	—	—	1420.0	—	—	—	—	—	—	—	—	1 2	—	—
	50	1.62	—	—	1029.0	—	—	—	—	—	—	—	—	12.6	—	—
	30	1 08	—	—	686.0	—	—	—	—	—	—	—	—	8 4	—	—
	30	0.90	—	—	549.0	—	—	—	—	—	—	—	—	6.6	—	—
9	60	3.06	—	—	740.0	—	0	—	—	—	—	—	—	0	—	—
2	70	6 30	—	—	1869.0	—	0	—	—	—	—	—	—	0 6	—	—
4	180	4.32	—	—	1240.0	—	—	—	—	—	—	—	—	30.0	—	—
2	200	1.62	—	—	454.0	—	—	—	—	—	—	—	—	33 6	—	—
1	360	5.22	—	—	1788.0	—	—	—	—	—	—	—	—	10.2	—	—
9	330	5.40	—	—	2258.0	—	—	—	—	—	—	—	—	11.4	—	—
9	420	3.60	—	—	1231.0	—	—	—	—	—	—	—	—	36.6	—	—
8	240	4.50	—	—	1451.0	—	—	—	—	—	—	—	—	7 8	—	—
1	170	4 68	—	—	1571.0	—	—	—	—	—	—	—	—	16 8	—	—
4	60	3.60	—	—	953.0	—	0	—	—	—	—	—	—	0	—	—
4	510	0.72	—	—	363.0	—	—	—	—	—	—	—	—	6 6	—	—
4	70	3 78	—	—	1060.0	—	—	—	—	—	—	—	—	6.0	—	—
4	510	0.36	—	—	350.0	—	—	—	—	—	—	—	—	5.4	—	—
0	100	0 00	—	—	510.0	—	—	—	—	—	—	—	—	0	—	—
0	20	1.98	—	—	410.0	—	0	—	—	—	—	—	—	0	—	—
5	30	2.34	—	—	430.0	—	—	—	—	—	—	—	—	0	—	—
0	0	0.00	—	—	180.0	—	0	—	—	—	—	—	—	0	—	—
0	30	2.34	—	—	900.0	—	0	—	—	—	—	—	—	0	—	—
0	30	2.16	—	—	930.0	—	—	—	—	—	—	—	—	0	—	—
0	80	1.80	—	—	780.0	—	—	—	—	—	—	—	—	1 2	—	—
0	60	1.80	—	—	660.0	—	—	—	—	—	—	—	—	1 2	—	—
0	20	2.88	—	—	840.0	—	0	—	—	—	—	—	—	0	—	—
5	20	2.70	—	—	860.0	—	—	—	—	—	—	—	—	0	—	—
0	30	1.98	—	—	920.0	—	—	—	—	—	—	—	—	0	—	—
10	40	2.16	—	—	930.0	—	—	—	—	—	—	—	—	0	—	—
0	0	0 00	—	—	120.0	—	0	—	—	—	—	—	—	0	—	—
0	30	1.98	—	—	1100.0	—	0	—	—	—	—	—	—	0	—	—
10	30	2.34	—	—	1120.0	—	—	—	—	—	—	—	—	0	—	—
10	59	0.80	—	—	35.0	—	—	—	—	—	—	—	—	22 2	—	—
0	60	0.43	—	—	75.0	—	—	—	—	—	—	—	—	5.4	—	—
90	211	2.85	—	—	1560.0	—	—	—	—	—	—	—	—	15 8	—	—
0	0	0.00	—	—	570.0	—	0	—	—	—	—	—	—	0	—	—
55	0	1.07	—	—	220.0	—	—	—	—	—	—	—	—	1 8	—	—
15	40	4 50	—	—	800.0	—	—	—	—	—	—	—	—	1.2	—	—
45	123	1.32	—	—	1310.0	—	—	—	—	—	—	—	—	18.4	—	—
10	41	0.48	—	—	270.0	—	—	—	—	—	—	—	—	24.5	—	—
5	0	0.71	—	—	220.0	—	0	—	—	—	—	—	—	0	—	—
70	264	2.84	—	—	580.0	—	—	—	—	—	—	—	—	9.5	—	—
0	41	1 48	—	—	580.0	—	—	—	—	—	—	—	—	2.5	—	—
0	0	0.85	—	—	120.0	—	0	—	—	—	—	—	—	14.3	—	—
5	20	0.72	—	—	620.0	—	—	—	—	—	—	—	—	2.4	—	—
0	43	0.38	—	—	180.0	—	—	—	—	—	—	—	—	5.1	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	
Fast Food—*continued*														
34984	Homestyle mashed potatoes	¾	cup(s)	221	—	210	4.0	29.0	3.0	9.0	6.0	—	—	
34985	Homestyle mashed potatoes and gravy	1	cup(s)	334	—	225	5.0	33.0	3.0	9.5	6.0	—	—	
34988	Hot cinnamon apples	¾	cup(s)	145	—	210	0	47.0	3.0	3.0	0	—	—	
34989	Macaroni and cheese	¾	cup(s)	221	—	330	14.0	39.0	1.0	12.0	7.0	—	—	0
51193	Market chopped salad with dressing	1	item(s)	563	—	580	11.0	31.0	9.0	48.0	9.0	—	—	
34970	Meatloaf	1	serving(s)	218	—	480	29.0	23.0	2.0	33.0	13.0	—	—	
39383	Nestle Toll House chocolate chip cookie	1	item(s)	78	—	370	4.0	49.0	2.0	19.0	9.0	—	—	
34965	Quarter chicken, dark meat, no skin	1	item(s)	134	—	260	30.0	2.0	0	13.0	4.0	—	—	
34966	Quarter chicken, dark meat, with skin	1	item(s)	149	—	280	31.0	3.0	0	15.0	4.5	—	—	
34963	Quarter chicken, white meat, no skin or wing	1	item(s)	173	—	250	41.0	4.0	0	8.0	2.5	—	—	
34964	Quarter chicken, white meat, with skin and wing	1	item(s)	110	—	330	50.0	3.0	0	12.0	4.0	—	—	
34968	Roasted turkey breast	5	ounce(s)	142	—	180	38.0	0	0	3.0	1.0	—	—	
35011	Seasonal fresh fruit salad	1	serving(s)	142	—	60	1.0	15.0	1.0	0	0	0	0	
51192	Spinach with garlic butter sauce	1	serving(s)	170	—	130	5.0	9.0	5.0	9.0	6.0	—	—	
34969	Spiral sliced holiday ham	8	ounce(s)	227	—	450	40.0	13.0	0	26.0	10.0	—	—	
35003	Steamed vegetables	1	cup(s)	136	—	50	2.0	8.0	3.0	2.0	0	—	—	
35005	Sweet corn	¾	cup(s)	176	—	170	6.0	37.0	2.0	4.0	1.0	—	—	
35004	Sweet potato casserole	¾	cup(s)	198	—	460	4.0	77.0	3.0	17.0	6.0	—	—	
	Burger King													
29731	Biscuit with sausage, egg, and cheese	1	item(s)	191	—	610	20.0	33.0	1.0	45.0	15.0	—	—	1
14249	Cheeseburger	1	item(s)	133	—	330	17.0	31.0	1.0	16.0	7.0	—	—	0
14251	Chicken sandwich	1	item(s)	219	—	660	24.0	52.0	4.0	40.0	8.0	—	—	2
3808	Chicken Tenders, 8 pieces	1	serving(s)	123	—	340	19.0	21.0	0.5	20.0	5.0	—	—	3
14259	Chocolate shake, small	1	item(s)	315	—	470	8.0	75.0	1.0	14.0	9.0	—	—	0
29732	Croissanwich with sausage and cheese	1	item(s)	106	37.2	370	14.0	23.0	0.5	25.0	9.0	12.7	3.3	2
14261	Croissanwich with sausage, egg, and cheese	1	item(s)	159	71.4	470	19.0	26.0	0.5	32.0	11.0	15.8	6.1	2
3809	Double cheeseburger	1	item(s)	189	—	500	30.0	31.0	1.0	29.0	14.0	—	—	1
14244	Double Whopper sandwich	1	item(s)	373	—	900	47.0	51.0	3.0	57.0	19.0	—	—	2
14245	Double Whopper with cheese sandwich	1	item(s)	398	—	990	52.0	52.0	3.0	64.0	24.0	—	—	2
14250	Fish Filet sandwich	1	item(s)	250	—	630	24.0	67.0	4.0	30.0	6.0	—	—	2
14255	French fries, medium, salted	1	serving(s)	116	—	360	4.0	41.0	4.0	20.0	4.5	—	—	4
14262	French toast sticks, 5 pieces	1	serving(s)	112	37.6	390	6.0	46.0	2.0	20.0	4.5	10.6	2.9	4
14248	Hamburger	1	item(s)	121	—	290	15.0	30.0	1.0	12.0	4.5	—	—	0
14263	Hash brown rounds, small	1	serving(s)	75	27.1	230	2.0	23.0	2.0	15.0	4.0	—	—	5
14256	Onion rings, medium	1	serving(s)	91	—	320	4.0	40.0	3.0	16.0	4.0	—	—	3
39000	Tendercrisp chicken sandwich	1	item(s)	286	—	780	25.0	73.0	4.0	43.0	8.0	—	—	4
37514	TenderGrill chicken sandwich	1	item(s)	258	—	450	37.0	53.0	4.0	10.0	2.0	—	—	0
14258	Vanilla shake, small	1	item(s)	296	—	400	8.0	57.0	0	15.0	9.0	—	—	0
1736	Whopper sandwich	1	item(s)	290	—	670	28.0	51.0	3.0	39.0	11.0	—	—	1
14243	Whopper with cheese sandwich	1	item(s)	315	—	760	33.0	52.0	3.0	47.0	16.0	—	—	1
	Carl's Jr													
33962	Carl's bacon Swiss crispy chicken sandwich	1	item(s)	268	—	750	31.0	91.0	—	28.0	28.0	—	—	—
10801	Carl's Catch fish sandwich	1	item(s)	215	—	560	19.0	58.0	2.0	27.0	7.0	—	1.9	—
10862	Carl's Famous Star hamburger	1	item(s)	254	—	590	24.0	50.0	3.0	32.0	9.0	—	—	—
10785	Charbroiled chicken club sandwich	1	item(s)	270	—	550	42.0	43.0	4.0	23.0	7.0	—	2.9	—
10866	Charbroiled chicken salad	1	item(s)	437	—	330	34.0	17.0	5.0	7.0	4.0	—	1.0	—
10855	Charbroiled Santa Fe chicken sandwich	1	item(s)	266	—	610	38.0	43.0	4.0	32.0	8.0	—	—	—
10790	Chicken stars, 6 pieces	1	serving(s)	85	—	260	13.0	14.0	1.0	16.0	4.0	—	1.6	—
34864	Chocolate shake, small	1	serving(s)	595	—	540	15.0	98.0	0	11.0	7.0	—	—	—
10797	Crisscut fries	1	serving(s)	139	—	410	5.0	43.0	4.0	24.0	5.0	—	—	—
10799	Double Western Bacon cheeseburger	1	item(s)	308	—	920	51.0	65.0	2.0	50	21.0	—	6.6	—

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	51	0.46	—	—	660.0	—	—	—	—	—	—	—	—	19.2	—	—
	100	0.59	—	—	1230.0	—	—	—	—	—	—	—	—	24.9	—	—
	16	0.28	—	—	15.0	—	—	—	—	—	—	—	—	0	—	—
	345	1.65	—	—	1290.0	—	—	—	—	—	—	—	—	0	—	—
	—	—	—	—	2010.0	—	—	—	—	—	—	—	—	—	—	—
5	140	3.77	—	—	970.0	—	—	—	—	—	—	—	—	1.8	—	—
	0	1.32	—	—	340.0	—	—	—	—	—	—	—	—	0	—	—
5	0	1.52	—	—	260.0	—	0	—	—	—	—	—	—	0	—	—
5	0	2.14	—	—	660.0	—	0	—	—	—	—	—	—	0	—	—
5	0	0.89	—	—	480.0	—	0	—	—	—	—	—	—	0	—	—
5	0	0.78	—	—	960.0	—	0	—	—	—	—	—	—	0	—	—
	20	1.80	—	—	620.0	—	0	—	—	—	—	—	—	0	—	—
	16	0.29	—	—	20.0	—	—	—	—	—	—	—	—	29.5	—	—
	—	—	—	—	200.0	—	—	—	—	—	—	—	—	—	—	—
0	0	1.73	—	—	2230.0	—	0	—	—	—	—	—	—	0	—	—
	53	0.46	—	—	45.0	—	—	—	—	—	—	—	—	24.0	—	—
	0	0.43	—	—	95.0	—	—	—	—	—	—	—	—	5.8	—	—
	44	1.18	—	—	210.0	—	—	—	—	—	—	—	—	9.8	—	—
0	250	2.70	—	—	1620.0	—	89.9	—	—	—	—	—	—	0	—	—
5	150	2.70	—	—	780.0	—	—	0.24	—	0.31	4.17	—	—	1.2	—	—
	64	2.89	—	—	1440.0	—	—	0.50	—	0.32	10.29	—	—	0	—	—
5	20	0.72	—	—	960.0	—	—	0.14	—	0.11	10.93	—	—	0	—	—
5	333	0.79	—	—	350.0	—	—	0.11	—	0.61	0.26	—	—	2.7	0	—
0	99	1.78	20.1	217.3	810.0	1.51	—	0.34	1.03	0.33	4.33	—	—	0	0.6	22.2
30	146	2.63	28.6	313.2	1060.0	2.08	—	0.38	1.66	0.51	4.72	0.28	—	0	1.1	38.0
05	250	4.50	—	—	1030.0	—	—	0.26	—	0.44	6.37	—	—	1.2	—	—
75	150	8.07	—	—	1090.0	—	—	0.39	—	0.59	11.05	—	—	9.0	—	—
05	299	8.08	—	—	1520.0	—	—	0.39	—	0.66	11.03	—	—	9.0	—	—
0	101	3.62	—	—	1380.0	—	—	—	—	—	—	—	—	3.6	—	—
0	20	0.71	—	—	590.0	—	0	0.15	—	0.48	2.30	—	—	8.9	—	—
0	60	1.80	21.3	124.3	440.0	0.57	—	0.31	0.98	0.19	2.88	0.05	—	0	0	13.7
0	80	2.70	—	—	560.0	—	—	0.25	—	0.28	4.25	—	—	1.2	—	—
0	0	0.36	—	—	450.0	—	0	0.11	0.83	0.06	1.35	0.17	—	1.2	—	—
0	100	0.00	—	—	460.0	—	0	0.14	—	0.09	2.32	—	—	0	—	—
5	79	4.43	—	—	1730.0	—	—	—	—	—	—	—	—	8.9	—	—
5	57	6.82	—	—	1210.0	—	—	—	—	—	—	—	—	5.7	—	—
0	348	0.00	—	—	240.0	—	—	0.11	—	0.63	0.21	—	—	2.4	0	—
1	100	5.38	—	—	1020.0	—	—	0.38	—	0.43	7.30	—	—	9.0	—	—
15	249	5.38	—	—	1450.0	—	—	0.38	—	0.51	7.28	—	—	9.0	—	—
0	200	5.40	—	—	1900.0	—	—	—	—	—	—	—	—	2.4	—	—
0	150	2.70	—	—	990.0	—	60.0	—	—	—	—	—	—	2.4	—	—
0	100	4.50	—	—	910.0	—	—	—	—	—	—	—	—	6.0	—	—
95	200	3.60	—	—	1330.0	—	—	—	—	—	—	—	—	9.0	—	—
75	200	1.80	—	—	880.0	—	—	—	—	—	—	—	—	30.0	—	—
00	200	3.60	—	—	1440.0	—	—	—	—	—	—	—	—	9.0	—	—
35	19	1.02	—	—	470.0	—	0	—	—	—	—	—	—	0	—	—
45	600	1.08	—	—	360.0	—	0	—	—	—	—	—	—	0	—	—
0	20	1.80	—	—	950.0	—	0	—	—	—	—	—	—	12.0	—	—
55	300	7.20	—	—	1730.0	—	—	—	—	—	—	—	—	1.2	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Diet Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fast Food—*continued*													
14238	French fries, small	1	serving(s)	92	—	290	5.0	37.0	3.0	14.0	3.0	—	—
10798	French toast dips without syrup, 5 pieces	1	serving(s)	155	—	370	8.0	49.0	0	17.0	5.0	—	1.4
10802	Onion rings	1	serving(s)	128	—	440	7.0	53.0	3.0	22.0	5.0	—	0.8
34858	Spicy chicken sandwich	1	item(s)	198	—	480	14.0	48.0	2.0	26.0	5.0	—	—
34867	Strawberry shake, small	1	serving(s)	595	—	520	14.0	93.0	0	11.0	7.0	—	—
10865	Super Star hamburger	1	item(s)	348	—	790	41.0	52.0	3.0	47.0	14.0	—	—
38925	The Six Dollar burger	1	item(s)	429	—	1010	40.0	60.0	3.0	66.0	26.0	—	—
10818	Vanilla shake, small	1	item(s)	398	—	314	10.0	51.5	0	7.4	4.7	—	—
10770	Western Bacon cheeseburger	1	item(s)	225	—	660	32.0	64.0	2.0	30.0	12.0	—	4.8
	Chick Fil-A												
38746	Biscuit with bacon, egg, and cheese	1	item(s)	163	—	470	18.0	39.0	1.0	26.0	9.0	—	—
38747	Biscuit with egg	1	item(s)	135	—	350	11.0	38.0	1.0	16.0	4.5	—	—
38748	Biscuit with egg and cheese	1	item(s)	149	—	400	14.0	38.0	1.0	21.0	7.0	—	—
38753	Biscuit with gravy	1	item(s)	192	—	330	5.0	43.0	1.0	15.0	4.0	—	—
38752	Biscuit with sausage, egg, and cheese	1	item(s)	212	—	620	22.0	39.0	2.0	42.0	14.0	—	—
38771	Carrot and raisin salad	1	item(s)	113	—	170	1.0	28.0	2.0	6.0	1.0	—	—
38761	Chargrilled chicken Cool Wrap	1	item(s)	245	—	390	29.0	54.0	3.0	7.0	3.0	—	—
38766	Chargrilled chicken garden salad	1	item(s)	275	—	180	22.0	9.0	3.0	6.0	3.0	—	—
38758	Chargrilled chicken sandwich	1	item(s)	193	—	270	28.0	33.0	3.0	3.5	1.0	—	—
38742	Chicken biscuit	1	item(s)	145	—	420	18.0	44.0	2.0	19.0	4.5	—	—
38743	Chicken biscuit with cheese	1	item(s)	159	—	470	21.0	45.0	2.0	23.0	8.0	—	—
38762	Chicken Caesar Cool Wrap	1	item(s)	227	—	460	36.0	52.0	3.0	10.0	6.0	—	—
38757	Chicken deluxe sandwich	1	item(s)	208	—	420	28.0	39.0	2.0	16.0	3.5	—	—
38764	Chicken salad sandwich on wheat bun	1	item(s)	153	—	350	20.0	32.0	5.0	15.0	3.0	—	—
38756	Chicken sandwich	1	item(s)	170	—	410	28.0	38.0	1.0	16.0	3.5	—	—
38768	Chick-n-Strip salad	1	item(s)	327	—	400	34.0	21.0	4.0	20.0	6.0	—	—
38763	Chick-n-Strips	4	item(s)	127	—	300	28.0	14.0	1.0	15.0	2.5	—	—
38770	Cole slaw	1	item(s)	128	—	260	2.0	17.0	2.0	21.0	3.5	—	—
38776	Diet lemonade, small	1	cup(s)	255	—	25	0	5.0	0	0	0	0	0
38755	Hashbrowns	1	serving(s)	84	—	260	2.0	25.0	3.0	17.0	3.5	—	—
38765	Hearty breast of chicken soup	1	cup(s)	241	—	140	8.0	18.0	1.0	3.5	1.0	—	—
38741	Hot buttered biscuit	1	item(s)	79	—	270	4.0	38.0	1.0	12.0	3.0	—	—
38778	IceDream, small cone	1	item(s)	135	—	160	4.0	28.0	0	4.0	2.0	—	—
38774	IceDream, small cup	1	serving(s)	227	—	240	6.0	41.0	0	6.0	3.5	—	—
38775	Lemonade, small	1	cup(s)	255	—	170	0	41.0	0	0.5	0	—	—
38777	Nuggets	8	item(s)	113	—	260	26.0	12.0	0.5	12.0	2.5	—	—
38769	Side salad	1	item(s)	108	—	60	3.0	4.0	2.0	3.0	1.5	—	—
38767	Southwest chargrilled salad	1	item(s)	303	—	240	25.0	17.0	5.0	8.0	3.5	—	—
40481	Spicy chicken cool wrap	1	serving(s)	230	—	380	30.0	52.0	3.0	6.0	3.0	—	—
38772	Waffle potato fries, small, salted	1	serving(s)	85	—	270	3.0	34.0	4.0	13.0	3.0	—	—
	Cinnabon												
39572	Caramellata Chill w/whipped cream	16	fluid ounce(s)	480	—	406	10.0	61.0	0	14.0	8.0	—	—
39571	Cinnabon Bites	1	serving(s)	149	—	510	8.0	77.0	2.0	19.0	5.0	—	—
39570	Cinnabon Stix	5	item(s)	85	—	379	6.0	41.0	1.0	21.0	6.0	—	—
39567	Classic roll	1	item(s)	221	—	813	15.0	117.0	4.0	32.0	8.0	—	—
39568	Minibon	1	item(s)	92	—	339	6.0	49.0	2.0	13.0	3.0	—	—
39573	Mochalatta Chill w/whipped cream	16	fluid ounce(s)	480	—	362	9.0	55.0	0	13.0	8.0	—	—
39569	Pecanbon	1	item(s)	272	—	1100	16.0	141.0	8.0	56.0	10.0	—	—
	Dairy Queen												
1466	Banana split	1	item(s)	369	—	510	8.0	96.0	3.0	12.0	8.0	—	—
38552	Brownie Earthquake®	1	serving(s)	304	—	740	10.0	112.0	0	27.0	16.0	—	—
38561	Chocolate chip cookie dough blizzard,® small	1	item(s)	319	—	720	12.0	105.0	0	28.0	14.0	—	—
1464	Chocolate malt, small	1	item(s)	418	—	640	15.0	111.0	1.0	16.0	11.0	—	—
38541	Chocolate shake, small	1	item(s)	397	—	560	13.0	93.0	1.0	15.0	10.0	—	—
17257	Chocolate soft serve	½	cup(s)	94	—	150	4.0	22.0	0	5.0	3.5	—	—
1463	Chocolate sundae, small	1	item(s)	163	—	280	5.0	49.0	0	7.0	4.5	—	—

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	0	1.08	—	—	170.0	—	0	—	—	—	—	—	—	21.0	—	—
	0	0.00	—	—	470.0	—	0	0.25	—	0.23	2.00	—	—	0	—	—
	20	0.72	—	—	700.0	—	0	—	—	—	—	—	—	3.6	—	—
	100	3.60	—	—	1220.0	—	—	—	—	—	—	—	—	6.0	—	—
	600	0.00	—	—	340.0	—	0	—	—	—	—	—	—	0	—	—
0	100	7.20	—	—	980.0	—	—	—	—	—	—	—	—	9.0	—	—
5	279	4.29	—	—	1960.0	—	—	—	—	—	—	—	—	16.7	—	—
	401	0.00	—	—	234.0	—	0	—	—	—	—	—	—	0	—	—
	200	5.40	—	—	1410.0	—	60.0	—	—	—	—	—	—	1.2	—	—
0	150	2.70	—	—	1190.0	—	—	—	—	—	—	—	—	0	—	—
0	80	2.70	—	—	740.0	—	—	—	—	—	—	—	—	0	—	—
5	150	2.70	—	—	970.0	—	—	—	—	—	—	—	—	0	—	—
	60	1.80	—	—	930.0	—	0	—	—	—	—	—	—	0	—	—
0	200	3.60	—	—	1360.0	—	—	—	—	—	—	—	—	0	—	—
	40	0.36	—	—	110.0	—	—	—	—	—	—	—	—	4.8	—	—
5	200	3.60	—	—	1020.0	—	—	—	—	—	—	—	—	6.0	—	—
5	150	0.72	—	—	620.0	—	—	—	—	—	—	—	—	30	—	—
5	80	2.70	—	—	940.0	—	—	—	—	—	—	—	—	6.0	—	—
5	60	2.70	—	—	1270.0	—	0	—	—	—	—	—	—	0	—	—
0	150	2.70	—	—	1500.0	—	—	—	—	—	—	—	—	0	—	—
0	500	3.60	—	—	1350.0	—	—	—	—	—	—	—	—	1.2	—	—
0	100	2.70	—	—	1300.0	—	—	—	—	—	—	—	—	2.4	—	—
5	150	1.80	—	—	880.0	—	—	—	—	—	—	—	—	0	—	—
0	100	2.70	—	—	1300.0	—	—	—	—	—	—	—	—	0	—	—
0	150	1.44	—	—	1070.0	—	—	—	—	—	—	—	—	6.0	—	—
5	40	1.44	—	—	940.0	—	—	—	—	—	—	—	—	0	—	—
5	60	0.36	—	—	220.0	—	—	—	—	—	—	—	—	36.0	—	—
	0	0.36	—	—	5.0	—	0	—	—	—	—	—	—	15.0	—	—
	20	0.72	—	—	380.0	—	—	—	—	—	—	—	—	0	—	—
5	40	1.08	—	—	900.0	—	—	—	—	—	—	—	—	0	—	—
0	60	1.80	—	—	660.0	—	0	—	—	—	—	—	—	0	—	—
5	100	0.36	—	—	80.0	—	—	—	—	—	—	—	—	0	—	—
5	200	0.36	—	—	105.0	—	—	—	—	—	—	—	—	0	—	—
0	0	0.36	—	—	10.0	—	0	—	—	—	—	—	—	15.0	—	—
0	40	1.08	—	—	1090.0	—	0	—	—	—	—	—	—	0	—	—
0	100	0.00	—	—	75.0	—	—	—	—	—	—	—	—	15.0	—	—
0	200	1.08	—	—	770.0	—	—	—	—	—	—	—	—	24.0	—	—
0	200	3.60	—	—	1090.0	—	—	—	—	—	—	—	—	3.6	—	—
0	20	1.08	—	—	115.0	—	0	—	—	—	—	—	—	1.2	—	—
6	—	—	—	—	187.0	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	—	530.0	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	413.0	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	801.0	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	337.0	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	252.0	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	600.0	—	—	—	—	—	—	—	—	—	—	—
0	250	1.80	—	—	180.0	—	—	—	—	—	—	—	—	15.0	—	—
0	250	1.80	—	—	350.0	—	—	—	—	—	—	—	—	0	—	—
0	350	2.70	—	—	370.0	—	—	—	—	—	—	—	—	1.2	—	—
5	450	1.80	—	—	340.0	—	—	—	—	—	—	—	—	2.4	—	—
0	450	1.44	—	—	280.0	—	—	—	—	—	—	—	—	2.4	—	—
5	100	0.72	—	—	75.0	—	—	—	—	—	—	—	—	0	—	—
0	200	1.08	—	—	140.0	—	—	—	—	—	—	—	—	0	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

BAT Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tr
Fast Food—*continued*														
1462	Dipped cone, small	1	item(s)	156	—	340	6.0	42.0	1.0	17.0	9.0	4.0	3.0	
38555	Oreo cookies blizzard, small	1	item(s)	283	—	570	11.0	83.0	0.5	21.0	10.0	—	—	2
38547	Royal Treats Peanut Buster® Parfait	1	item(s)	305	—	730	16.0	99.0	2.0	31.0	17.0	—	—	
17256	Vanilla soft serve	½	cup(s)	94	—	140	3.0	22.0	0	4.5	3.0	—	—	
	Domino's													
31606	Barbeque buffalo wings	1	item(s)	25	—	50	6.0	2.0	0	2.5	0.5	—	—	
31604	Breadsticks	1	item(s)	30	—	115	2.0	12.0	0	6.3	1.1	—	—	
37551	Buffalo Chicken Kickers	1	item(s)	24	—	47	4.0	3.0	0	2.0	0.5	—	—	
37548	CinnaStix	1	item(s)	30	—	123	2.0	15.0	1.0	6.1	1.1	—	—	
37549	Dot, cinnamon	1	item(s)	28	7.6	99	1.9	14.9	0.7	3.7	0.7	—	—	
31605	Double cheesy bread	1	item(s)	35	—	123	4.0	13.0	0	6.5	1.9	—	—	
31607	Hot buffalo wings	1	item(s)	25	—	45	5.0	1.0	0	2.5	0.5	—	—	
	Domino's Classic hand tossed pizza													
31573	America's favorite feast, 12"	1	slice(s)	102	—	257	10.0	29.0	2.0	11.5	4.5	—	—	
31574	America's favorite feast, 14"	1	slice(s)	141	—	353	14.0	39.0	2.0	16.0	6.0	—	—	
37543	Bacon cheeseburger feast, 12"	1	slice(s)	99	—	273	12.0	28.0	2.0	13.0	5.5	—	—	
37545	Bacon cheeseburger feast, 14"	1	slice(s)	137	—	379	17.0	38.0	2.0	18.0	8.0	—	—	
37546	Barbeque feast, 12"	1	slice(s)	96	—	252	11.0	31.0	1.0	10.0	4.5	—	—	
37547	Barbeque feast, 14"	1	slice(s)	131	—	344	14.0	43.0	2.0	13.5	6.0	—	—	
31569	Cheese, 12"	1	slice(s)	55	—	160	6.0	28.0	1.0	3.0	1.0	—	—	
31570	Cheese, 14"	1	slice(s)	75	—	220	8.0	38.0	2.0	4.0	1.0	—	—	
37538	Deluxe feast, 12"	1	slice(s)	201	101.8	465	19.5	57.4	3.5	18.2	7.7	—	—	
37540	Deluxe feast, 14"	1	slice(s)	273	138.4	627	26.4	78.3	4.7	24.1	10.2	—	—	
31685	Deluxe, 12"	1	slice(s)	100	—	234	9.0	29.0	2.0	9.5	3.5	—	—	
31694	Deluxe, 14"	1	slice(s)	136	—	316	13.0	39.0	2.0	12.5	5.0	—	—	
31686	Extravaganzza, 12"	1	slice(s)	122	—	289	13.0	30.0	2.0	14.0	5.5	—	—	
31695	Extravaganzza, 14"	1	slice(s)	165	—	388	17.0	40.0	3.0	18.5	7.5	—	—	
31575	Hawaiian feast, 12"	1	slice(s)	102	—	223	10.0	30.0	2.0	8.0	3.5	—	—	
31576	Hawaiian feast, 14"	1	slice(s)	141	—	309	14.0	41.0	2.0	11.0	4.5	—	—	
31687	Meatzza, 12"	1	slice(s)	108	—	281	13.0	29.0	2.0	13.5	5.5	—	—	
31696	Meatzza, 14"	1	slice(s)	146	—	378	17.0	39.0	2.0	18.0	7.5	—	—	
31571	Pepperoni feast, extra pepperoni and cheese, 12"	1	slice(s)	98	—	265	11.0	28.0	2.0	12.5	5.0	—	—	
31572	Pepperoni feast, extra pepperoni and cheese, 14"	1	slice(s)	135	—	363	16.0	39.0	2.0	17.0	7.0	—	—	
31577	Vegi feast, 12"	1	slice(s)	102	—	218	9.0	29.0	2.0	8.0	3.5	—	—	
31578	Vegi feast, 14"	1	slice(s)	139	—	300	13.0	40.0	3.0	11.0	4.5	—	—	
	Domino's thin crust pizza													
31583	America's favorite, 12"	1	slice(s)	72	—	208	8.0	15.0	1.0	13.5	5.0	—	—	
31584	America's favorite, 14"	1	slice(s)	100	—	285	11.0	20.0	2.0	18.5	7.0	—	—	
31579	Cheese, 12"	1	slice(s)	49	—	137	5.0	14.0	1.0	7.0	2.5	—	—	
31580	Cheese, 14"	1	slice(s)	68	27.0	214	8.8	19.0	1.4	11.4	4.6	2.9	2.5	
31688	Deluxe, 12"	1	slice(s)	70	—	185	7.0	15.0	1.0	11.5	4.0	—	—	
31697	Deluxe, 14"	1	slice(s)	94	—	248	10.0	20.0	2.0	15.0	5.5	—	—	
31689	Extravaganzza, 12"	1	slice(s)	92	—	240	11.0	16.0	1.0	15.5	6.0	—	—	
31698	Extravaganzza, 14"	1	slice(s)	123	—	320	14.0	21.0	2.0	20.5	8.0	—	—	
31585	Hawaiian, 12"	1	slice(s)	71	—	174	8.0	16.0	1.0	9.5	3.5	—	—	
31586	Hawaiian, 14"	1	slice(s)	100	—	240	11.0	21.0	2.0	13.0	5.0	—	—	
31690	Meatzza, 12"	1	slice(s)	78	—	232	11.0	15.0	1.0	15.0	6.0	—	—	
31699	Meatzza, 14"	1	slice(s)	104	—	310	14.0	20.0	2.0	20	8.0	—	—	
31581	Pepperoni, extra pepperoni and cheese, 12"	1	slice(s)	68	—	216	9.0	14.0	1.0	14.0	5.5	—	—	
31582	Pepperoni, extra pepperoni and cheese, 14"	1	slice(s)	93	—	295	13.0	20.0	1.0	19.0	7.5	—	—	
31587	Vegi, 12"	1	slice(s)	71	—	168	7.0	15.0	1.0	9.5	3.5	—	—	
31588	Vegi, 14"	1	slice(s)	97	—	231	10.0	21.0	2.0	13.5	5.0	—	—	
	Domino's Ultimate deep dish pizza													
31596	America's favorite, 12"	1	slice(s)	115	—	309	12.0	29.0	2.0	17.0	6.0	—	—	
31702	America's favorite, 14"	1	slice(s)	162	—	433	17.0	42.0	3.0	23.5	8.0	—	—	
31590	Cheese, 12"	1	slice(s)	90	—	238	9.0	28.0	2.0	11.0	3.5	—	—	
31591	Cheese, 14"	1	slice(s)	128	53.9	351	14.5	41.0	2.9	13.2	5.2	3.8	2.5	
31589	Cheese, 6"	1	item(s)	215	—	598	22.9	68.4	3.9	27.6	9.9	—	—	
31691	Deluxe, 12"	1	slice(s)	122	—	287	11.0	29.0	2.0	15.0	5.0	—	—	

	(mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
)	200	1.08	—	—	130.0	—	—	—	—	—	—	—	—	1.2	—	—
)	350	2.70	—	—	430.0	—	—	—	—	—	—	—	—	1.2	—	—
5	300	1.80	—	—	400.0	—	—	—	—	—	—	—	—	1.2	—	—
	150	0.72	—	—	70.0	—	—	—	—	—	—	—	—	0	—	—
5	10	0.36	—	—	175.5	—	—	—	—	—	—	—	—	0	—	—
	0	0.72	—	—	122.1	—	—	—	—	—	—	—	—	0	—	—
	0	0.00	—	—	162.5	—	—	—	—	—	—	—	—	0	—	—
	0	0.72	—	—	111.4	—	—	—	—	—	—	—	—	0	—	—
	6	0.59	—	—	85.7	—	—	—	—	—	—	—	—	0	—	—
	40	0.72	—	—	162 3	—	—	—	—	—	—	—	—	0	—	—
6	10	0.36	—	—	254.5	—	—	—	—	—	—	—	—	1.2	—	—
																—
2	100	1.80	—	—	625.5	—	—	—	—	—	—	—	—	0.6	—	—
1	140	2.52	—	—	865.5	—	—	—	—	—	—	—	—	0.6	—	—
7	140	1.80	—	—	634.0	—	—	—	—	—	—	—	—	0	—	—
3	190	2.52	—	—	900.0	—	—	—	—	—	—	—	—	0	—	—
0	140	1.62	—	—	600.0	—	—	—	—	—	—	—	—	0.6	—	—
7	190	2.16	—	—	831 5	—	—	—	—	—	—	—	—	0.6	—	—
	0	1.80	—	—	110.0	—	0	—	—	—	—	—	—	0	—	—
	0	2.70	—	—	150.0	—	0	—	—	—	—	—	—	0	—	—
0	199	3.56	—	—	1063 1	—	—	—	—	—	—	—	—	1.4	—	—
3	276	4.84	—	—	1432.2	—	—	—	—	—	—	—	—	1.8	—	—
7	100	1.80	—	—	541.5	—	—	—	—	—	—	—	—	0.6	—	—
3	130	2.34	—	—	728 5	—	—	—	—	—	—	—	—	1.2	—	—
3	140	1.98	—	—	764 0	—	—	—	—	—	—	—	—	0.6	—	—
7	190	2.70	—	—	1014.0	—	—	—	—	—	—	—	—	1.2	—	—
6	130	1.62	—	—	546.5	—	—	—	—	—	—	—	—	1.2	—	—
3	180	2.34	—	—	765.0	—	—	—	—	—	—	—	—	1.2	—	—
8	130	1.80	—	—	739.5	—	—	—	—	—	—	—	—	0	—	—
7	190	2.52	—	—	983 5	—	—	—	—	—	—	—	—	0	—	—
4	130	1.62	—	—	670.0	—	70.9	—	—	—	—	—	—	0	—	—
3	180	2.34	—	—	920.0	—	104.7	—	—	—	—	—	—	0	—	—
3	130	1.62	—	—	489.0	—	—	—	—	—	—	—	—	0.6	—	—
8	180	2.34	—	—	678.0	—	—	—	—	—	—	—	—	0.6	—	—
3	100	0.90	—	—	533.0	—	—	—	—	—	—	—	—	2.4	—	—
2	140	1.26	—	—	736.5	—	—	—	—	—	—	—	—	3.0	—	—
0	90	0.54	—	—	292.5	—	60.0	—	—	—	—	—	—	1.8	—	—
4	151	0.48	17.7	125.1	338.0	0.02	64.6	0.05	1.01	0.07	0.69	—	—	2.4	0.5	24.1
9	100	0.90	—	—	449.0	—	—	—	—	—	—	—	—	2.4	—	—
4	130	1.08	—	—	601.0	—	—	—	—	—	—	—	—	3.6	—	—
9	140	1.08	—	—	671.5	—	—	—	—	—	—	—	—	2.4	—	—
8	190	1.44	—	—	886.5	—	—	—	—	—	—	—	—	3.6	—	—
7	130	0.72	—	—	454.0	—	—	—	—	—	—	—	—	3.0	—	—
4	180	0.90	—	—	637.5	—	—	—	—	—	—	—	—	3.6	—	—
9	140	0.90	—	—	647.0	—	—	—	—	—	—	—	—	1.8	—	—
8	190	1.26	—	—	865.5	—	—	—	—	—	—	—	—	2.4	—	—
6	130	0.72	—	—	577.0	—	80.0	—	—	—	—	—	—	1.8	—	—
5	80	1.08	—	—	792.5	—	105.8	—	—	—	—	—	—	2.4	—	—
4	130	0.72	—	—	396.5	—	—	—	—	—	—	—	—	2.4	—	—
9	180	1.08	—	—	550.5	—	—	—	—	—	—	—	—	3.0	—	—
5	120	2.34	—	—	796.5	—	—	—	—	—	—	—	—	0.6	—	—
4	170	3.24	—	—	1110.0	—	—	—	—	—	—	—	—	0.6	—	—
1	110	1.98	—	—	555.5	—	70.0	—	—	—	—	—	—	0	—	—
8	189	3.78	32.0	209.9	718.1	1.75	99.8	0.29	1.13	0.31	5.44	—	—	0	0.6	45.6
6	295	4.67	—	—	1241.4	—	174.0	—	—	—	—	—	—	0.5	—	—
0	120	2.16	—	—	712.0	—	—	—	—	—	—	—	—	1.2	—	—

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA* Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fast Food—*continued*													
31700	Deluxe, 14"	1	slice(s)	156	—	396	15.0	42.0	3.0	20.0	7.0	—	+
31692	Extravaganzza, 12"	1	slice(s)	136	—	341	14.0	30.0	2.0	19.0	7.0	—	—
31701	Extravaganzza, 14"	1	slice(s)	186	—	468	20.0	43.0	3.0	25.5	9.5	—	—
31599	Hawaiian, 12"	1	slice(s)	114	—	275	12.0	30.0	2.0	13.0	5.0	—	—
31600	Hawaiian, 14"	1	slice(s)	162	—	389	17.0	43.0	3.0	18.0	6.5	—	—
31693	Meatzza, 12"	1	slice(s)	121	—	333	14.0	29.0	2.0	19.0	7.0	—	—
31703	Meatzza, 14"	1	slice(s)	167	—	458	19.0	42.0	3.0	25.0	9.5	—	—
31593	Pepperoni, extra pepperoni and cheese, 12"	1	slice(s)	110	—	317	13.0	29.0	2.0	17.5	6.5	—	—
31594	Pepperoni, extra pepperoni and cheese, 14"	1	slice(s)	155	—	443	18.0	42.0	3.0	24.0	9.0	—	—
31602	Vegi, 12"	1	slice(s)	114	—	270	11.0	30.0	2.0	13.5	5.0	—	—
31603	Vegi, 14"	1	slice(s)	159	—	380	15.0	43.0	3.0	18.0	6.5	—	—
31598	With ham and pineapple tidbits, 6"	1	item(s)	430	—	619	25.2	69.9	4.0	28.3	10.2	—	—
31595	With Italian sausage, 6"	1	item(s)	430	—	642	24.8	69.6	4.2	31.1	11.3	—	—
31592	With pepperoni, 6"	1	item(s)	430	—	647	25.1	68.5	3.9	32.0	11.7	—	—
31601	With vegetables, 6"	1	item(s)	430	—	619	23.4	70.8	4.6	28.7	10.1	—	—
	In-n-Out Burger												
34391	Cheeseburger with mustard and ketchup	1	serving(s)	268	—	400	22.0	41.0	3.0	18.0	9.0	—	—
34374	Cheeseburger	1	serving(s)	268	—	480	22.0	39.0	3.0	27.0	10.0	—	—
34390	Cheeseburger, lettuce leaves instead of buns	1	serving(s)	300	—	330	18.0	11.0	3.0	25.0	9.0	—	—
34377	Chocolate shake	1	serving(s)	425	—	690	9.0	83.0	0	36.0	24.0	—	—
34375	Double-Double cheeseburger	1	serving(s)	330	—	670	37.0	39.0	3.0	41.0	18.0	—	—
34393	Double-Double cheeseburger with mustard and ketchup	1	serving(s)	330	—	590	37.0	41.0	3.0	32.0	17.0	—	—
34392	Double-Double cheese-burger, lettuce leaves instead of buns	1	serving(s)	362	—	520	33.0	11.0	3.0	39.0	17.0	—	—
34376	French fries	1	serving(s)	125	—	400	7.0	54.0	2.0	18.0	5.0	—	—
34373	Hamburger	1	item(s)	243	—	390	16.0	39.0	3.0	19.0	5.0	—	—
34389	Hamburger with mustard and ketchup	1	serving(s)	243	—	310	16.0	41.0	3.0	10.0	4.0	—	—
34388	Hamburger, lettuce leaves instead of buns	1	serving(s)	275	—	240	13.0	11.0	3.0	17.0	4.0	—	—
34379	Strawberry shake	1	serving(s)	425	—	690	9.0	91.0	0	33.0	22.0	—	—
34378	Vanilla shake	1	serving(s)	425	—	680	9.0	78.0	0	37.0	25.0	—	—
	Jack in the Box												
30392	Bacon ultimate cheeseburger	1	item(s)	338	—	1090	46.0	53.0	2.0	77.0	30.0	—	—
1740	Breakfast Jack	1	item(s)	125	—	290	17.0	29.0	1.0	12.0	4.5	—	—
14074	Cheeseburger	1	item(s)	131	—	350	18.0	31.0	1.0	17.0	8.0	—	—
14106	Chicken breast strips, 4 pieces	1	serving(s)	201	—	500	35.0	36.0	3.0	25.0	6.0	—	—
37241	Chicken club salad, plain, without salad dressing	1	serving(s)	431	—	300	27.0	13.0	4.0	15.0	6.0	—	—
14064	Chicken sandwich	1	item(s)	145	—	400	15.0	38.0	2.0	21.0	4.5	—	—
14111	Chocolate ice cream shake, small	1	serving(s)	414	—	880	14.0	107.0	1.0	45.0	31.0	—	—
14073	Hamburger	1	item(s)	118	—	310	16.0	30.0	1.0	14.0	6.0	—	—
14090	Hash browns	1	serving(s)	57	—	150	1.0	13.0	2.0	10.0	2.5	—	—
14072	Jack's Spicy Chicken sandwich	1	item(s)	270	—	620	25.0	61.0	4.0	31.0	6.0	—	—
1468	Jumbo Jack hamburger	1	item(s)	261	—	600	21.0	51.0	3.0	35.0	12.0	—	—
1469	Jumbo Jack hamburger with cheese	1	item(s)	286	—	690	25.0	54.0	3.0	42.0	16.0	—	—
14099	Natural cut french fries, large	1	serving(s)	196	—	530	8.0	69.0	5.0	25.0	6.0	—	—
14098	Natural cut french fries, medium	1	serving(s)	133	—	360	5.0	47.0	4.0	17.0	4.0	—	—
1470	Onion rings	1	serving(s)	119	—	500	6.0	51.0	3.0	30.0	6.0	—	—
33141	Sausage, egg, and cheese biscuit	1	item(s)	234	—	740	27.0	35.0	2.0	55.0	17.0	—	—
14095	Seasoned curly fries, medium	1	serving(s)	125	—	400	6.0	45.0	5.0	23.0	5.0	—	—
14077	Sourdough Jack	1	item(s)	245	—	710	27.0	36.0	3.0	51.0	18.0	—	—
37249	Southwest chicken salad, plain, without salad dressing	1	serving(s)	488	—	300	24.0	29.0	7.0	11.0	5.0	—	—
14112	Strawberry ice cream shake, small	1	serving(s)	417	—	880	13.0	105.0	0	44.0	31.0	—	—

ol (g)	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
26	170	3.06	—	—	974.5	—	—	—	—	—	—	—	—	1.2	—	—
31	160	2.52	—	—	934.5	—	—	—	—	—	—	—	—	1.2	—	—
40	220	3.42	—	—	1260.0	—	—	—	—	—	—	—	—	1.2	—	—
19	150	1.98	—	—	717.0	—	—	—	—	—	—	—	—	1.2	—	—
26	210	2.88	—	—	1011.0	—	—	—	—	—	—	—	—	1.8	—	—
31	160	2.34	—	—	910.5	—	—	—	—	—	—	—	—	0	—	—
40	220	3.24	—	—	1230.0	—	—	—	—	—	—	—	—	0.6	—	—
27	150	2.16	—	—	840.5	—	86.5	—	—	—	—	—	—	0	—	—
37	220	3.06	—	—	1166.0	—	115.4	—	—	—	—	—	—	0.6	—	—
15	150	2.16	—	—	659.5	—	—	—	—	—	—	—	—	0.6	—	—
21	220	3.06	—	—	924.0	—	—	—	—	—	—	—	—	1.2	—	—
43	298	4.84	—	—	1497.8	—	—	—	—	—	—	—	—	1.5	—	—
45	302	4.89	—	—	1478.1	—	—	—	—	—	—	—	—	0.6	—	—
47	299	4.81	—	—	1523.7	—	167.9	—	—	—	—	—	—	0.6	—	—
36	307	5.10	—	—	1472.5	—	—	—	—	—	—	—	—	4.7	—	—
60	200	3.60	—	—	1080.0	—	—	—	—	—	—	—	—	12.0	—	—
60	200	3.60	—	—	1000.0	—	—	—	—	—	—	—	—	9.0	—	—
60	200	2.70	—	—	720.0	—	—	—	—	—	—	—	—	12.0	—	—
95	300	0.72	—	—	350.0	—	—	—	—	—	—	—	—	0	—	—
120	350	5.40	—	—	1440.0	—	—	—	—	—	—	—	—	9.0	—	—
115	350	5.40	—	—	1520.0	—	—	—	—	—	—	—	—	12.0	—	—
120	350	4.50	—	—	1160.0	—	—	—	—	—	—	—	—	12.0	—	—
0	20	1.80	—	—	245.0	—	0	—	—	—	—	—	—	0	—	—
40	40	3.60	—	—	650.0	—	—	—	—	—	—	—	—	9.0	—	—
35	40	3.60	—	—	730.0	—	—	—	—	—	—	—	—	12.0	—	—
40	40	2.70	—	—	370.0	—	—	—	—	—	—	—	—	12.0	—	—
85	300	0.00	—	—	280.0	—	—	—	—	—	—	—	—	0	—	—
90	300	0.00	—	—	390.0	—	—	—	—	—	—	—	—	0	—	—
140	308	7.38	—	540.0	2040.0	—	—	—	—	—	—	—	—	0.6	—	—
220	145	3.48	—	210.0	760.0	—	—	—	—	—	—	—	—	3.5	—	—
50	151	3.61	—	270.0	790.0	—	40.2	—	—	—	—	—	—	0	—	—
80	18	1.60	—	530.0	1260.0	—	—	—	—	—	—	—	—	1.1	—	—
65	280	3.35	—	560.0	880.0	—	—	—	—	—	—	—	—	50.4	—	—
35	100	2.70	—	240.0	730.0	—	—	—	—	—	—	—	—	4.8	—	—
135	460	0.47	—	840.0	330.0	—	—	—	—	—	—	—	—	0	—	—
40	100	3.60	—	250.0	600.0	—	0	—	—	—	—	—	—	0	—	—
0	10	0.18	—	190.0	230.0	—	0	—	—	—	—	—	—	0	—	—
50	150	1.80	—	450.0	1100.0	—	—	—	—	—	—	—	—	9.0	—	—
45	164	4.92	—	380.0	940.0	—	—	—	—	—	—	—	—	9.8	—	—
70	234	4.20	—	410.0	1310.0	—	—	—	—	—	—	—	—	8.4	—	—
0	20	1.42	—	1240.0	870.0	—	0	—	—	—	—	—	—	8.9	—	—
0	19	1.01	—	840.0	590.0	—	0	—	—	—	—	—	—	5.6	—	—
0	40	2.70	—	140.0	420.0	—	40.0	—	—	—	—	—	—	18.0	—	—
280	88	2.36	—	310.0	1430.0	—	—	—	—	—	—	—	—	0	—	—
0	40	1.80	—	580.0	890.0	—	—	—	—	—	—	—	—	0	—	—
75	200	4.50	—	430.0	1230.0	—	—	—	—	—	—	—	—	9.0	—	—
55	274	4.10	—	670.0	860.0	—	—	—	—	—	—	—	—	43.8	—	—
135	466	0.00	—	750.0	290.0	—	—	—	—	—	—	—	—	0	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

OA Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)			
											Sat	Mono	Poly	Tr
Fast Food—*continued*														
14078	Ultimate cheeseburger	1	item(s)	323	—	1010	40.0	53.0	2.0	71.0	28.0	—	—	3
14110	Vanilla ice cream shake, small	1	serving(s)	379	—	790	13.0	83.0	0	44.0	31.0	—	—	2
	Jamba Juice													
31645	Aloha Pineapple smoothie	24	fluid ounce(s)	730	—	500	8.0	117.0	4.0	1.5	1.0	—	—	
31646	Banana Berry smoothie	24	fluid ounce(s)	719	—	480	5.0	112.0	4.0	1.0	0	—	—	
31656	Berry Lime Sublime smoothie	24	fluid ounce(s)	728	—	460	3.0	106.0	5.0	2.0	1.0	—	—	
31647	Carribean Passion smoothie	24	fluid ounce(s)	730	—	440	4.0	102.0	4.0	2.0	1.0	—	—	
38422	Carrot juice	16	fluid ounce(s)	472	—	100	3.0	23.0	0	0.5	0	—	—	
31648	Chocolate Moo'd smoothie	24	fluid ounce(s)	634	—	720	17.0	148.0	3.0	8.0	5.0	—	—	
31649	Citrus Squeeze smoothie	24	fluid ounce(s)	727	—	470	5.0	110.0	4.0	2.0	1.0	—	—	
31651	Coldbuster smoothie	24	fluid ounce(s)	724	—	430	5.0	100.0	5.0	2.5	1.0	—	—	
31652	Cranberry Craze smoothie	24	fluid ounce(s)	793	—	460	6.0	104.0	4.0	0.5	0	—	—	
31654	Jamba Powerboost smoothie	24	fluid ounce(s)	738	—	440	6.0	105.0	6.0	1.0	0	—	—	
38423	Lemonade	16	fluid ounce(s)	483	—	300	1.0	75.0	0	0	0	0	0	
31657	Mango-a-go-go smoothie	24	fluid ounce(s)	690	—	440	3.0	104.0	4.0	1.5	0.5	—	—	
38424	Orange juice, freshly squeezed	16	fluid ounce(s)	496	—	220	3.0	52.0	0.5	1.0	0	—	—	
38426	Orange/carrot juice	16	fluid ounce(s)	484	—	160	3.0	37.0	0	1.0	0	—	—	
31660	Orange-a-peel smoothie	24	fluid ounce(s)	726	—	440	8.0	102.0	5.0	1.5	0	—	—	
31662	Peach Pleasure smoothie	24	fluid ounce(s)	720	—	460	4.0	108.0	4.0	2.0	1.0	—	—	
31665	Protein Berry Pizzaz smoothie	24	fluid ounce(s)	710	—	440	20.0	92.0	5.0	1.5	0	—	—	
31668	Razzmatazz smoothie	24	fluid ounce(s)	730	—	480	3.0	112.0	4.0	2.0	1.0	—	—	
31669	Strawberries Wild smoothie	24	fluid ounce(s)	725	—	450	6.0	105.0	4.0	0.5	0	—	—	
38421	Strawberry Tsunami smoothie	24	fluid ounce(s)	740	—	530	4.0	128.0	4.0	2.0	1.0	—	—	
38427	Vibrant C juice	16	fluid ounce(s)	448	—	210	2.0	50.0	1.0	0	0	0	0	
38428	Wheatgrass juice, freshly squeezed	1	ounce(s)	28	—	5	0.5	1.0	0	0	0	0	0	
	Kentucky Fried Chicken (KFC)													
31850	BBQ baked beans	1	serving(s)	136	—	220	8.0	45.0	7.0	1.0	0	—	—	
31853	Biscuit	1	item(s)	57	—	220	4.0	24.0	1.0	11.0	2.5	—	—	3
51223	Boneless Fiery Buffalo Wings	6	item(s)	211	—	530	30.0	44.0	3.0	26.0	5.0	—	—	2
39386	Boneless Honey BBQ Wings	6	item(s)	213	—	570	30.0	54.0	5.0	26.0	5.0	—	—	2
51224	Boneless Sweet & Spicy Wings	6	item(s)	203	—	550	30.0	50.0	3.0	26.0	5.0	—	—	2
31851	Cole slaw	1	serving(s)	130	—	180	1.0	22.0	3.0	10.0	1.5	—	—	
31842	Colonel's Crispy Strips	3	item(s)	151	—	370	28.0	17.0	1.0	20.0	4.0	—	—	2
31849	Corn on the cob	1	item(s)	162	—	150	5.0	26.0	7.0	3.0	1.0	—	—	
51221	Double Crunch sandwich	1	item(s)	213	—	520	27.0	39.0	3.0	29.0	5.0	—	—	1
3761	Extra Crispy chicken, breast	1	item(s)	162	—	370	33.0	10.0	2.0	22.0	5.0	—	—	1
3762	Extra Crispy chicken, drumstick	1	item(s)	60	—	150	12.0	4.0	0	10.0	2.5	—	—	1
3763	Extra Crispy chicken, thigh	1	item(s)	114	—	290	17.0	16.0	1.0	18.0	4.0	—	—	1
3764	Extra Crispy chicken, whole wing	1	item(s)	52	—	150	11.0	11.0	1.0	7.0	1.5	—	—	
51218	Famous Bowls mashed potatoes with gravy	1	serving(s)	531	—	720	26.0	79.0	6.0	34.0	9.0	—	—	3
51219	Famous Bowls rice with gravy	1	serving(s)	384	—	610	25.0	67.0	5.0	27.0	8.0	—	—	2
31841	Honey BBQ chicken sandwich	1	item(s)	147	—	290	23.0	40.0	2.0	4.0	1.0	—	—	
31833	Honey BBQ wing pieces	6	item(s)	157	—	460	27.0	26.0	3.0	27.0	6.0	—	—	2
10859	Hot wings pieces	6	piece(s)	134	—	450	26.0	19.0	2.0	30.0	7.0	—	—	2
42382	KFC Snacker sandwich	1	serving(s)	119	—	320	14.0	29.0	2.0	17.0	3.0	—	—	1
31848	Macaroni and cheese	1	serving(s)	136	—	180	8.0	18.0	0	8.0	3.5	—	—	1
31847	Mashed potatoes with gravy	1	serving(s)	151	—	140	2.0	20.0	1.0	5.0	1.0	—	—	0
10825	Original Recipe chicken, breast	1	item(s)	161	—	340	38.0	9.0	2.0	17.0	4.0	—	—	1
10826	Original Recipe chicken, drumstick	1	item(s)	59	—	140	13.0	3.0	0	8.0	2.0	—	—	0
10827	Original Recipe chicken, thigh	1	item(s)	126	—	350	19.0	7.0	1.0	27.0	7.0	—	—	1
10828	Original Recipe chicken, whole wing	1	item(s)	47	—	140	10.0	4.0	0	9.0	2.0	—	—	0
51222	Oven roasted Twister chicken wrap	1	item(s)	269	—	520	30.0	46.0	4.0	23.0	3.5	—	—	0
31844	Popcorn chicken, small or individual	1	item(s)	114	—	370	19.0	21.0	2.0	24.0	4.5	—	—	2
31852	Potato salad	1	serving(s)	128	—	180	2.0	22.0	2.0	9.0	1.5	—	—	0
10845	Potato wedges, small	1	serving(s)	102	—	250	4.0	32.0	3.0	12.0	2.0	—	—	1
31839	Tender Roast chicken sandwich with sauce	1	item(s)	236	—	430	37.0	29.0	2.0	18.0	3.5	—	—	0

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-TE)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
5	308	7.39	—	480.0	1580.0	—	—	—	—	—	—	—	—	0.6	—	—
5	532	0.00	—	750.0	280.0	—	—	—	—	—	—	—	—	0	—	—
	200	1.80	60.0	1000.0	30.0	0.30	—	0.37	—	0.34	2.00	0.60	60.0	102.0	0	1.4
	200	1.44	40.0	1010.0	115.0	0.60	—	0.09	—	0.25	0.80	0.70	24.0	15.0	0.2	1.4
	200	1.80	16.0	510.0	35.0	0.30	—	0.06	—	0.25	6.00	0.70	140.0	54.0	0	1.4
	100	1.80	24.0	810.0	60.0	0.30	—	0.09	—	0.25	5.00	0.50	100.0	78.0	0	1.4
	150	2.70	80.0	1030.0	250.0	0.90	—	0.52	—	0.25	5.00	0.70	80.0	18.0	0	5.6
0	500	1.08	60.0	810.0	380.0	1.50	—	0.22	—	0.76	0.40	0.16	16.0	6.0	1.5	4.2
	100	1.80	80.0	1170.0	35.0	0.30	—	0.37	—	0.34	1.90	0.60	100.0	180.0	0	1.4
	100	1.08	60.0	1260.0	35.0	16.50	—	0.37	—	0.34	3.00	0.40	121.5	1302.0	0	1.4
	250	1.44	16.0	500.0	50.0	0.30	—	0.03	—	0.25	5.00	0.60	120.0	54.0	0	1.4
	1200	1.80	480.0	1070.0	45.0	16.50	—	5.55	—	6.12	68.00	7.40	640.0	288.0	10.8	77.0
	20	0.00	8.0	200.0	10.0	0.00	—	0.03	—	0.17	14.00	1.80	320.0	36.0	0	0
	100	1.08	24.0	780.0	50.0	0.30	—	0.15	—	0.25	5.00	0.70	120.0	72.0	0	1.4
	60	1.08	60.0	990.0	0	0.30	—	0.45	—	0.13	2.00	0.20	160.0	246.0	0	0
	100	1.80	60.0	1010.0	125.0	0.60	—	0.45	—	0.25	3.00	0.50	120.0	132.0	0	2.8
	250	1.80	80.0	1380.0	160.0	0.90	—	0.45	—	0.42	2.00	0.50	140.0	240.0	0.6	1.4
5	100	0.72	32.0	740.0	60.0	0.30	—	0.06	—	0.25	4.00	0.60	80.0	18.0	0	1.4
0	1100	2.62	60.0	650.0	240.0	0.58	—	0.08	—	0.17	1.20	0.70	58.3	60.0	0	5.6
5	150	1.80	32.0	810.0	70.0	0.30	—	0.09	—	0.34	6.00	1.00	160.0	60.0	0	1.4
5	250	1.80	40.0	1050.0	180.0	0.90	—	0.12	—	0.34	0.80	0.40	40.0	60.0	0.6	1.4
5	100	1.08	24.0	480.0	10.0	0.30	—	0.06	—	0.34	14.00	1.80	320.0	90.0	0	1.4
0	20	1.08	40.0	720.0	0	0.30	—	0.30	—	0.10	1.60	0.40	80.0	678.0	0	0
0	0	1.80	8.0	80.0	0	0.00	0	0.03	—	0.03	0.40	0.04	16.0	3.6	0	2.8
0	100	2.70	—	—	730.0	—	—	—	—	—	—	—	—	1.2	—	—
0	40	1.80	—	—	640.0	—	—	—	—	—	—	—	—	0	—	—
5	40	1.80	—	—	2670.0	—	—	—	—	—	—	—	—	1.2	—	—
5	40	1.80	—	—	2210.0	—	—	—	—	—	—	—	—	1.2	—	—
5	60	1.80	—	—	2000.0	—	—	—	—	—	—	—	—	1.2	—	—
5	40	0.72	—	—	270.0	—	—	—	—	—	—	—	—	12.0	—	—
5	40	1.44	—	—	1220.0	—	0	—	—	—	—	—	—	1.2	—	—
0	60	1.08	—	—	10.0	—	—	—	—	—	—	—	—	6.0	—	—
5	100	2.70	—	—	1220.0	—	—	—	—	—	—	—	—	6.0	—	—
5	20	2.70	—	—	1020.0	—	—	—	—	—	—	—	—	1.2	—	—
5	0	1.44	—	—	300.0	—	0	—	—	—	—	—	—	0	—	—
5	20	2.70	—	—	700.0	—	—	—	—	—	—	—	—	—	—	—
5	20	1.08	—	—	340.0	—	—	—	—	—	—	—	—	0	—	—
5	200	5.40	—	—	2330.0	—	—	—	—	—	—	—	—	6.0	—	—
5	200	4.50	—	—	2130.0	—	—	—	—	—	—	—	—	6.0	—	—
0	80	2.70	—	—	710.0	—	—	—	—	—	—	—	—	2.4	—	—
0	40	1.80	—	—	970.0	—	—	—	—	—	—	—	—	21.0	—	—
5	40	1.44	—	—	990.0	—	—	—	—	—	—	—	—	1.2	—	—
5	60	2.70	—	—	690.0	—	—	—	—	—	—	—	—	2.4	—	—
5	150	0.72	—	—	800.0	—	—	—	—	—	—	—	—	1.2	—	—
0	40	1.44	—	—	560.0	—	—	—	—	—	—	—	—	1.2	—	—
5	20	2.70	—	—	960.0	—	—	—	—	—	—	—	—	6.0	—	—
0	20	1.08	—	—	340.0	—	—	—	—	—	—	—	—	0	—	—
0	20	2.70	—	—	870.0	—	—	—	—	—	—	—	—	1.2	—	—
0	20	1.44	—	—	350.0	—	0	—	—	—	—	—	—	1.2	—	—
0	40	6.30	—	—	1380.0	—	—	—	—	—	—	—	—	15.0	—	—
5	40	1.80	—	—	1110.0	—	0	—	—	—	—	—	—	0	—	—
5	0	0.36	—	—	470.0	—	—	—	—	—	—	—	—	6.0	—	—
0	20	1.08	—	—	700.0	—	0	—	—	—	—	—	—	0	—	—
0	80	2.70	—	—	1180.0	—	—	—	—	—	—	—	—	9.0	—	—

TABLE H-1 Table of Food Composition (*continued*)

(Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Diet Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fast Food—*continued*													
	Long John Silver												
39392	Baked cod	1	serving(s)	101	—	120	22.0	1.0	0	4.5	1.0	—	—
3777	Batter dipped fish sandwich	1	item(s)	177	—	470	18.0	48.0	3.0	23.0	5.0	—	—
37568	Battered fish	1	item(s)	92	—	260	12.0	17.0	0.5	16.0	4.0	—	—
37569	Breaded clams	1	serving(s)	85	—	240	8.0	22.0	1.0	13.0	2.0	—	—
37566	Chicken plank	1	item(s)	52	—	140	8.0	9.0	0.5	8.0	2.0	—	—
39404	Clam chowder	1	item(s)	227	—	220	9.0	23.0	0	10.0	4.0	—	—
39398	Cocktail sauce	1	ounce(s)	28	—	25	0	6.0	0	0	0	0	0
3770	Coleslaw	1	serving(s)	113	—	200	1.0	15.0	3.0	15.0	2.5	1.8	4.1
39400	French fries, large	1	item(s)	142	—	390	4.0	56.0	5.0	17.0	4.0	—	—
3774	Fries, regular	1	serving(s)	85	—	230	3.0	34.0	3.0	10.0	2.5	—	—
3779	Hushpuppy	1	piece(s)	23	—	60	1.0	9.0	1.0	2.5	0.5	—	—
3781	Shrimp, batter-dipped, 1 piece	1	piece(s)	14	—	45	2.0	3.0	0	3.0	1.0	—	—
39399	Tartar sauce	1	ounce(s)	28	—	100	0	4.0	0	9.0	1.5	—	—
39395	Ultimate Fish sandwich	1	item(s)	199	—	530	21.0	49.0	3.0	28.0	8.0	—	—
	McDonald's												
50828	Asian salad with grilled chicken	1	item(s)	362	—	290	31.0	23.0	6.0	10.0	1.0	—	—
2247	Barbecue sauce	1	item(s)	28	—	45	0	11.0	0	0	0	0	0
737	Big Mac hamburger	1	item(s)	219	—	560	25.0	47.0	3.0	30.0	10.0	—	—
29777	Caesar salad dressing	1	package(s)	44	—	150	1.0	5.0	0	13.0	2.5	—	—
38391	Caesar salad with grilled chicken, no dressing	1	serving(s)	278	230.6	181	26.4	10.5	3.1	6.0	2.9	1.7	0.8
38393	Caesar salad without chicken, no dressing	1	serving(s)	190	170.4	84	6.0	8.1	3.0	3.9	2.2	0.9	0.3
738	Cheeseburger	1	item(s)	119	—	310	15.0	35.0	1.0	12.0	6.0	—	—
29775	Chicken McGrill sandwich	1	item(s)	213	—	400	27.0	38.0	3.0	16.0	3.0	—	—
1873	Chicken McNuggets, 6 piece	1	serving(s)	96	—	250	15.0	15.0	0	15.0	3.0	—	—
3792	Chicken McNuggets, 4 piece	1	serving(s)	64	—	170	10.0	10.0	0	10.0	2.0	—	—
29774	Crispy chicken sandwich	1	item(s)	232	121.8	500	27.0	63.0	3.0	16.0	3.0	5.7	7.4
743	Egg McMuffin	1	item(s)	139	76.8	300	17.0	30.0	2.0	12.0	4.5	3.8	2.5
742	Filet-O-Fish sandwich	1	item(s)	141	—	400	14.0	42.0	1.0	18.0	4.0	—	—
2257	French fries, large	1	serving(s)	170	—	570	6.0	70.0	7.0	30.0	6.0	—	—
1872	French fries, small	1	serving(s)	74	—	250	2.0	30.0	3.0	13.0	2.5	—	—
33822	Fruit 'n Yogurt Parfait	1	item(s)	149	111.2	160	4.0	31.0	1.0	2.0	1.0	0.2	0.1
739	Hamburger	1	item(s)	105	—	260	13.0	33.0	1.0	9.0	3.5	—	—
2003	Hash browns	1	item(s)	53	—	140	1.0	15.0	2.0	8.0	1.5	—	—
2249	Honey sauce	1	item(s)	14	—	50	0	12.0	0	0	0	0	0
38397	Newman's Own creamy caesar salad dressing	1	item(s)	59	32.5	190	2.0	4.0	0	18.0	3.5	4.6	9.6
38398	Newman's Own low fat balsamic vinaigrette salad dressing	1	item(s)	44	29.1	40	0	4.0	0	3.0	0	1.0	1.2
38399	Newman's Own ranch salad dressing	1	item(s)	59	30.1	170	1.0	9.0	0	15.0	2.5	9.0	3.7
1874	Plain Hotcakes with syrup and margarine	3	item(s)	221	—	600	9.0	102.0	2.0	17.0	4.0	—	—
740	Quarter Pounder hamburger	1	item(s)	171	—	420	24.0	40.0	3.0	18.0	7.0	—	—
741	Quarter Pounder hamburger with cheese	1	item(s)	199	—	510	29.0	43.0	3.0	25.0	12.0	—	—
2005	Sausage McMuffin with egg	1	item(s)	165	82.4	450	20.0	31.0	2.0	27.0	10.0	10.9	4.6
50831	Side salad	1	item(s)	87	—	20	1.0	4.0	1.0	0	0	0	0
	Pizza Hut												
39009	Hot chicken wings	2	item(s)	57	—	110	11.0	1.0	0	6.0	2.0	—	—
14025	Meat Lovers hand tossed pizza	1	slice(s)	118	—	300	15.0	29.0	2.0	13.0	6.0	—	—
14026	Meat Lovers pan pizza	1	slice(s)	123	—	340	15.0	29.0	2.0	19.0	7.0	—	—
31009	Meat Lovers stuffed crust pizza	1	slice(s)	169	—	450	21.0	43.0	3.0	21.0	10.0	—	—
14024	Meat Lovers thin 'n crispy pizza	1	slice(s)	98	—	270	13.0	21.0	2.0	14.0	6.0	—	—
14031	Pepperoni Lovers hand tossed pizza	1	slice(s)	113	—	300	15.0	30.0	2.0	13.0	7.0	—	—
14032	Pepperoni Lovers pan pizza	1	slice(s)	118	—	340	15.0	29.0	2.0	19.0	7.0	—	—
31011	Pepperoni Lovers stuffed crust pizza	1	slice(s)	163	—	420	21.0	43.0	3.0	19.0	10.0	—	—
14030	Pepperoni Lovers thin 'n crispy pizza	1	slice(s)	92	—	260	13.0	21.0	2.0	14.0	7.0	—	—
10834	Personal Pan pepperoni pizza	1	slice(s)	61	—	170	7.0	18.0	0.5	8.0	3.0	—	—
10842	Personal Pan supreme pizza	1	slice(s)	77	—	190	8.0	19.0	1.0	9.0	3.5	—	—

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
0	20	0.72	—	—	240 0	—	—	—	—	—	—	—	—	0	—	—
5	60	2.70	—	—	1210.0	—	—	—	—	—	—	—	—	2.4	—	—
5	20	0.72	—	—	790 0	—	—	—	—	—	—	—	—	4.8	—	—
0	20	1 08	—	—	1110.0	—	0	—	—	—	—	—	—	0	—	—
0	0	0 72	—	—	480 0	—	0	—	—	—	—	—	—	2.4	—	—
5	150	0 72	—	—	810.0	—	—	—	—	—	—	—	—	0	—	—
0	0	0 00	—	—	250 0	—	—	—	—	—	—	—	—	0	—	—
0	40	0 36	—	222.7	340 0	0.70	—	0.07	—	0.08	2.34	—	—	18.0	—	—
0	0	0.00	—	—	580.0	—	0	—	—	—	—	—	—	24.0	—	—
0	0	0 00	—	370 0	350 0	0 30	0	0 09	—	0 01	1.60	—	—	15.0	—	—
0	20	0 36	—	—	200 0	—	0	—	—	—	—	—	—	0	—	—
15	0	0 00	—	—	160 0	—	0	—	—	—	—	—	—	1.2	—	—
5	0	0 00	—	—	250 0	—	0	—	—	—	—	—	—	0	—	—
60	150	2 70	—	—	1400.0	—	—	—	—	—	—	—	—	4.8	—	—
55	150	3.60	—	—	890 0	—	—	—	—	—	—	—	—	54 0	—	—
0	0	0 00	—	55 0	260.0	—	—	—	—	—	—	—	—	0	—	—
30	250	4 50	—	400 0	1010 0	—	—	—	—	—	—	—	—	1.2	—	—
10	40	0 18	—	30 0	400 0	—	—	—	—	—	—	—	—	0 6	—	—
67	178	1 77	—	708 9	767 3	—	—	0 15	—	0.19	10 62	—	127.9	29.2	0.2	—
10	163	1.15	17.1	410 4	157 7	—	—	0 08	—	0.07	0.40	—	102.6	26.8	0	0.4
40	200	2 70	—	240 0	740 0	—	60 0	—	—	—	—	—	—	1 2	—	—
70	150	2 70	—	510 0	1010 0	—	—	—	—	—	—	—	—	6.0	—	—
35	20	0 72	—	240 0	670 0	—	—	—	—	—	—	—	—	1 2	—	—
25	0	0 36	—	160 0	450 0	—	—	—	—	—	—	—	—	1.2	—	—
60	80	3 60	62 6	526 6	1380 0	1 53	41 8	0 46	2 27	0.39	12.85	—	104 4	6.0	0.4	—
230	300	2 70	26 4	218 2	860 0	1 59	—	0 36	0 82	0 51	4 31	0 20	109.8	1.2	0.9	—
40	150	1.80	—	250 0	640 0	—	36 2	—	—	—	—	—	—	0	—	—
0	20	1 80	—	—	330 0	—	0	—	—	—	—	—	—	9 0	—	—
0	20	0 72	—	—	140 0	—	0	—	—	—	—	—	—	3.6	—	—
5	150	0 67	20.9	248 8	85 0	0.53	0	0 06	—	0.17	0 35	—	19.4	9.0	0.3	—
30	150	2 70	—	210 0	530 0	—	5.0	—	—	—	—	—	—	1.2	—	—
0	0	0 36	—	210 0	290 0	—	0	—	—	—	—	—	—	1.2	—	—
0	0	0 00	—	0	0	—	0	—	—	—	—	—	—	0	—	—
20	61	0 00	3.0	16 0	500 0	0.20	—	0.01	15 43	0 02	0.01	0.64	2.4	0	0.1	0.1
0	4	0.00	1.3	8.8	730.0	0 01	—	0 00	0.00	0.00	0.00	0.00	0	2.4	0	0
0	40	0 00	1.8	70.4	530.0	0 03	0	0.01	—	0.08	0.01	0.02	0.6	0	0	0.2
20	150	2.70	—	280.0	620 0	—	—	—	—	—	—	—	—	0	—	—
70	150	4 50	—	390 0	730 0	—	10 0	—	—	—	—	—	—	1.2	—	—
95	300	4.50	—	440 0	1150 0	—	100.0	—	—	—	—	—	—	1.2	—	—
255	300	3.60	29.7	282.2	950.0	2.01	—	0.43	0.82	0.56	4.83	0.24	—	0	1.2	—
0	20	0.72	—	—	10.0	—	—	—	—	—	—	—	—	15.0	—	—
70	0	0.36	—	—	450 0	—	—	—	—	—	—	—	—	0	—	—
35	150	1.80	—	—	760.0	—	—	—	—	—	—	—	—	6.0	—	—
35	150	2.70	—	—	750.0	—	—	—	—	—	—	—	—	6.0	—	—
55	250	2.70	—	—	1250 0	—	—	—	—	—	—	—	—	9.0	—	—
35	150	1.44	—	—	740.0	—	—	—	—	—	—	—	—	6.0	—	—
40	200	1.80	—	—	710.0	—	57.7	—	—	—	—	—	—	2.4	—	—
40	200	2.70	—	—	700.0	—	57.7	—	—	—	—	—	—	2.4	—	—
55	300	2.70	—	—	1120.0	—	—	—	—	—	—	—	—	3.6	—	—
40	200	1.44	—	—	690.0	—	58.0	—	—	—	—	—	—	2.4	—	—
15	80	1.44	—	—	340.0	—	38.5	—	—	—	—	—	—	1.4	—	—
20	80	1.86	—	—	420.0	—	—	—	—	—	—	—	—	3.6	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

NAL Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fast Food—*continued*													
39013	Personal Pan Veggie Lovers pizza	1	slice(s)	69	—	150	6.0	19.0	1.0	6.0	2.0	—	—
14028	Veggie Lovers hand tossed pizza	1	slice(s)	118	—	220	10.0	31.0	2.0	6.0	3.0	—	—
14029	Veggie Lovers pan pizza	1	slice(s)	119	—	260	10.0	30.0	2.0	12.0	4.0	—	—
31010	Veggie Lovers stuffed crust pizza	1	slice(s)	172	—	360	16.0	45.0	3.0	14.0	7.0	—	—
14027	Veggie Lovers thin 'n crispy pizza	1	slice(s)	101	—	180	8.0	23.0	2.0	7.0	3.0	—	—
39012	Wing blue cheese dipping sauce	1	item(s)	43	—	230	2.0	2.0	0	24.0	5.0	—	—
39011	Wing ranch dipping sauce	1	item(s)	43	—	210	0.5	4.0	0	22.0	3.5	—	—
	Starbucks												
38052	Cappuccino, tall	12	fluid ounce(s)	360	—	120	7.0	10.0	0	6.0	4.0	—	—
38053	Cappuccino, tall nonfat	12	fluid ounce(s)	360	—	80	7.0	11.0	0	0	0	0	0
38054	Cappuccino, tall soymilk	12	fluid ounce(s)	360	—	100	5.0	13.0	0.5	2.5	0	—	—
38059	Cinnamon spice mocha, tall nonfat w/o whipped cream	12	fluid ounce(s)	360	—	170	11.0	32.0	0	0.5	—	—	—
38057	Cinnamon spice mocha, tall w/whipped cream	12	fluid ounce(s)	360	—	320	10.0	31.0	0	17.0	11.0	—	—
38051	Espresso, single shot	1	fluid ounce(s)	30	—	5	0	1.0	0	0	0	0	0
38088	Flavored syrup, 1 pump	1	serving(s)	10	—	20	0	5.0	0	0	0	0	0
32562	Frappuccino bottled coffee drink, mocha	9½	fluid ounce(s)	298	—	190	6.0	39.0	3.0	3.0	2.0	—	—
32561	Frappuccino coffee drink, all bottled flavors	9½	fluid ounce(s)	281	—	190	7.0	35.0	0	3.5	2.5	—	—
38073	Frappuccino, mocha	12	fluid ounce(s)	360	—	220	5.0	44.0	0	3.0	1.5	—	—
38067	Frappuccino, tall caramel w/o whipped cream	12	fluid ounce(s)	360	—	210	4.0	43.0	0	2.5	1.5	—	—
38070	Frappuccino, tall coffee	12	fluid ounce(s)	360	—	190	4.0	38.0	0	2.5	1.5	—	—
39894	Frappuccino, tall coffee, light blend	12	fluid ounce(s)	360	—	110	5.0	22.0	2.0	1.0	0	—	—
38071	Frappuccino, tall espresso	12	fluid ounce(s)	360	—	160	4.0	33.0	0	2.0	1.5	—	—
39897	Frappuccino, tall mocha, light blend	12	fluid ounce(s)	360	—	140	5.0	28.0	3.0	1.5	0	—	—
39887	Frappuccino, tall Strawberries and Creme, w/o whipped cream	12	fluid ounce(s)	360	—	330	10.0	65.0	0	3.5	1.0	—	—
38063	Frappuccino, tall Tazo chai creme w/o whipped cream	12	fluid ounce(s)	360	—	280	10.0	52.0	0	3.5	1.0	—	—
38066	Frappuccino, tall Tazoberry	12	fluid ounce(s)	360	—	140	0.5	36.0	0.5	0	0	0	0
38065	Frappuccino, tall Tazoberry Crème	12	fluid ounce(s)	360	—	240	4.0	54.0	0.5	1.0	0	—	—
38080	Frappuccino, tall vanilla w/o whipped cream	12	fluid ounce(s)	360	—	270	10.0	51.0	0	3.5	1.0	—	—
39898	Frappuccino, tall white chocolate mocha, light blend	12	fluid ounce(s)	360	—	160	6.0	32.0	2.0	2.0	1.0	—	—
38074	Frappuccino, tall white chocolate w/o whipped cream	12	fluid ounce(s)	360	—	240	5.0	48.0	0	3.5	2.5	—	—
39883	Java Chip Frappuccino, tall w/o whipped cream	12	fluid ounce(s)	360	—	270	5.0	51.0	1.0	7.0	4.5	—	—
33111	Latte, tall w/nonfat milk	12	fluid ounce(s)	360	335.3	120	12.0	18.0	0	0	0	0	0
33112	Latte, tall w/whole milk	12	fluid ounce(s)	360	—	200	11.0	16.0	0	11.0	7.0	—	—
33109	Macchiato, tall caramel w/nonfat milk	12	fluid ounce(s)	360	—	170	11.0	30.0	0	1.0	0	—	—
33110	Macchiato, tall caramel w/whole milk	12	fluid ounce(s)	360	—	240	10.0	28.0	0	10.0	6.0	—	—
33107	Mocha coffee drink, tall nonfat, w/o whipped cream	12	fluid ounce(s)	360	—	170	11.0	33.0	1.0	1.5	0	—	—
38089	Mocha syrup	1	serving(s)	17	—	25	1.0	6.0	0	0.5	0	—	—
33108	Mocha, tall mocha w/whole milk	12	fluid ounce(s)	360	—	310	10.0	32.0	1.0	17.0	10.0	—	—
38042	Steamed apple cider, tall	12	fluid ounce(s)	360	—	180	0	45.0	0	0	0	0	0
38087	Tazo chai black tea, soymilk, tall	12	fluid ounce(s)	360	—	190	4.0	39.0	0.5	2.0	0	—	—
38084	Tazo chai black tea, tall	12	fluid ounce(s)	360	—	210	6.0	36.0	0	5.0	3.5	—	—
38083	Tazo chai black tea, tall nonfat	12	fluid ounce(s)	360	—	170	6.0	37.0	0	0	0	0	0
38076	Tazo iced tea, tall	12	fluid ounce(s)	360	—	60	0	16.0	0	0	0	0	0
38077	Tazo tea, grande lemonade	16	fluid ounce(s)	480	—	120	0	31.0	0	0	0	0	0

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-t)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	80	1.80	—	—	280.0	—	—	—	—	—	—	—	—	3.6	—	—
	150	1.80	—	—	490.0	—	—	—	—	—	—	—	—	9.0	—	—
	150	2.70	—	—	470.0	—	—	—	—	—	—	—	—	9.0	—	—
5	250	2.70	—	—	980.0	—	—	—	—	—	—	—	—	9.0	—	—
5	150	1.44	—	—	480.0	—	—	—	—	—	—	—	—	9.0	—	—
5	20	0.00	—	—	550.0	—	0	—	—	—	—	—	—	0	—	—
0	0	0.00	—	—	340.0	—	0	—	—	—	—	—	—	0	—	—
5	250	0.00	—	—	95.0	—	—	—	—	—	—	—	—	1.2	0	—
	200	0.00	—	—	100.0	—	—	—	—	—	—	—	—	0	0	—
	250	0.72	—	—	75.0	—	—	—	—	—	—	—	—	0	0	—
	300	0.72	—	—	150.0	—	—	—	—	—	—	—	—	0	0	—
0	350	1.08	—	—	140.0	—	—	—	—	—	—	—	—	2.4	0	—
0	0	0.00	—	—	0	—	0	—	—	—	—	—	—	0	0	—
0	0	0.00	—	—	0	—	0	—	—	—	—	—	—	0	0	—
2	219	1.08	—	530.0	110.0	—	—	—	—	—	—	—	—	0	—	—
5	250	0.36	—	510.0	105.0	—	—	—	—	—	—	—	—	0	—	—
0	150	0.72	—	—	180.0	—	—	—	—	—	—	—	—	0	0	—
0	150	0.00	—	—	180.0	—	—	—	—	—	—	—	—	0	0	—
0	150	0.00	—	—	180.0	—	—	—	—	—	—	—	—	0	0	—
0	150	0.00	—	—	220.0	—	—	—	—	—	—	—	—	0	—	—
0	100	0.00	—	—	160.0	—	—	—	—	—	—	—	—	0	0	—
0	150	0.72	—	—	220.0	—	—	—	—	—	—	—	—	0	—	—
3	350	0.00	—	—	270.0	—	—	—	—	—	—	—	—	21.0	—	—
3	350	0.00	—	—	270.0	—	—	—	—	—	—	—	—	3.6	0	—
0	0	0.00	—	—	30.0	—	0	—	—	—	—	—	—	0	0	—
0	150	0.00	—	—	125.0	—	0	—	—	—	—	—	—	1.2	0	—
3	350	0.00	—	—	370.0	—	—	—	—	—	—	—	—	3.6	0	—
3	150	0.00	—	—	250.0	—	—	—	—	—	—	—	—	0	—	—
10	150	0.00	—	—	210.0	—	—	—	—	—	—	—	—	0	0	—
10	150	1.44	—	—	220.0	—	—	—	—	—	—	—	—	0	—	—
5	350	0.00	39.8	—	170.0	1.35	—	0.12	—	0.47	0.36	0.13	17.5	0	1.3	—
45	400	0.00	46.6	—	160.0	1.28	—	0.12	—	0.54	0.34	0.14	16.8	2.4	1.2	—
5	300	0.00	—	—	160.0	—	—	—	—	—	—	—	—	1.2	—	—
30	300	0.00	—	—	135.0	—	—	—	—	—	—	—	—	2.4	—	—
5	300	2.70	—	—	135.0	—	—	—	—	—	—	—	—	0	—	—
0	0	0.72	—	—	0	—	0	—	—	—	—	—	—	0	0	—
55	300	2.70	—	—	115.0	—	—	—	—	—	—	—	—	0	—	—
0	0	1.08	—	—	15.0	—	0	—	—	—	—	—	—	0	0	—
0	200	0.72	—	—	70.0	—	—	—	—	—	—	—	—	0	0	—
20	200	0.36	—	—	85.0	—	—	—	—	—	—	—	—	1.2	0	—
5	200	0.36	—	—	95.0	—	—	—	—	—	—	—	—	0	0	—
0	0	0.00	—	—	0	—	0	—	—	—	—	—	—	0	0	—
0	0	0.00	—	—	15.0	—	0	—	—	—	—	—	—	4.8	0	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

DA* Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fast Food—*continued*													
38045	Vanilla crème steamed nonfat milk, tall w/whipped cream	12	fluid ounce(s)	360	—	260	11.0	33.0	0	8.0	5.0	—	—
38046	Vanilla crème steamed soy-milk, tall w/whipped cream	12	fluid ounce(s)	360	—	300	8.0	37.0	1.0	12.0	6.0	—	—
38044	Vanilla crème steamed whole milk, tall w/whipped cream	12	fluid ounce(s)	360	—	330	10.0	31.0	0	18.0	11.0	—	—
38090	Whipped cream	1	serving(s)	27	—	100	0	2.0	0	9.0	6.0	—	—
38062	White chocolate mocha, tall nonfat w/o whipped cream	12	fluid ounce(s)	360	—	260	12.0	45.0	0	4.0	3.0	—	—
38061	White chocolate mocha, tall w/whipped cream	12	fluid ounce(s)	360	—	410	11.0	44.0	0	20.0	13.0	—	—
38048	White hot chocolate, tall non-fat w/o whipped cream	12	fluid ounce(s)	360	—	300	15.0	51.0	0	4.5	3.5	—	—
38050	White hot chocolate, tall soy-milk w/whipped cream	12	fluid ounce(s)	360	—	420	11.0	56.0	1.0	16.0	9.0	—	—
38047	White hot chocolate, tall w/whipped cream	12	fluid ounce(s)	360	—	460	13.0	50.0	0	22.0	15.0	—	—
	Subway												
15842	Cheese steak sandwich, 6", wheat bread	1	item(s)	250	—	360	24.0	47.0	5.0	10.0	4.5	—	—
40478	Chicken and bacon ranch sandwich, 6", white or wheat bread	1	serving(s)	297	—	540	36.0	47.0	5.0	25.0	10.0	—	—
38622	Chicken and bacon ranch wrap with cheese	1	item(s)	257	—	440	41.0	18.0	9.0	27.0	10.0	—	—
32045	Chocolate chip cookie	1	item(s)	45	—	210	2.0	30.0	1.0	10.0	6.0	—	—
32048	Chocolate chip M&M cookie	1	item(s)	45	—	210	2.0	32.0	0.5	10.0	5.0	—	—
32049	Chocolate chunk cookie	1	item(s)	45	—	220	2.0	30.0	0.5	10.0	5.0	—	—
4024	Classic Italian B.M.T. sandwich, 6", white bread	1	item(s)	236	—	440	22.0	45.0	2.0	21.0	8.5	—	—
15838	Classic tuna sandwich, 6", wheat bread	1	item(s)	250	—	530	22.0	45.0	4.0	31.0	7.0	—	—
15837	Classic tuna sandwich, 6", white bread	1	item(s)	243	—	520	21.0	43.0	2.0	31.0	7.5	—	—
16397	Club salad, no dressing and croutons	1	item(s)	412	—	160	18.0	15.0	4.0	4.0	1.5	—	—
3422	Club sandwich, 6", white bread	1	item(s)	250	—	310	23.0	45.0	2.0	6.0	2.5	—	—
4030	Cold cut combo sandwich, 6", white bread	1	item(s)	242	—	400	20.0	45.0	2.0	17.0	7.5	—	—
34030	Ham and egg breakfast sandwich	1	item(s)	142	—	310	16.0	35.0	3.0	13.0	3.5	—	—
3885	Ham sandwich, 6", white bread	1	item(s)	238	—	310	17.0	52.0	2.0	5.0	2.0	—	—
3888	Meatball marinara sandwich, 6", wheat bread	1	item(s)	377	—	560	24.0	63.0	7.0	24.0	11.0	—	—
4651	Meatball sandwich, 6", white bread	1	item(s)	370	—	550	23.0	61.0	5.0	24.0	11.5	—	—
15839	Melt sandwich, 6", white bread	1	item(s)	260	—	410	25.0	47.0	4.0	15.0	5.0	—	—
32046	Oatmeal raisin cookie	1	item(s)	45	—	200	3.0	30.0	1.0	8.0	4.0	—	—
16379	Oven-roasted chicken breast sandwich, 6", wheat bread	1	item(s)	238	—	330	24.0	48.0	5.0	5.0	1.5	—	—
32047	Peanut butter cookie	1	item(s)	45	—	220	4.0	26.0	1.0	12.0	5.0	—	—
4655	Roast beef sandwich, 6", wheat bread	1	item(s)	224	—	290	19.0	45.0	4.0	5.0	2.0	—	—
3957	Roast beef sandwich, 6", white bread	1	item(s)	217	—	280	18.0	43.0	2.0	5.0	2.5	—	—
16378	Roasted chicken breast, 6", white bread	1	item(s)	231	—	320	23.0	46.0	3.0	5.0	2.0	—	—
34028	Southwest steak and cheese sandwich, 6", Italian bread	1	item(s)	271	—	450	24.0	48.0	6.0	20.0	6.0	—	—
4032	Spicy Italian sandwich, 6", white bread	1	item(s)	220	—	470	20.0	43.0	2.0	25.0	9.5	—	—
4031	Steak and cheese sandwich, 6", white bread	1	item(s)	243	—	350	23.0	45.0	3.0	10.0	5.0	—	—
32050	Sugar cookie	1	item(s)	45	—	220	2.0	28.0	0.5	12.0	6.0	—	—
40477	Sweet onion chicken teriyaki sandwich, 6", white or wheat bread	1	serving(s)	281	—	370	26.0	59.0	4.0	5.0	1.5	—	—
38623	Turkey breast and bacon melt wrap with chipotle sauce	1	item(s)	228	—	380	31.0	20.0	9.0	24.0	7.0	—	—

		Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α-)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
5	350	0.00	—	—	170.0	—	—	—	—	—	—	—	—	0	0	—
0	400	1.44	—	—	130.0	—	—	—	—	—	—	—	—	0	0	—
5	350	0.00	—	—	140 0	—	—	—	—	—	—	—	—	0	0	—
0	0	0 00	—	—	10.0	—	—	—	—	—	—	—	—	0	0	—
5	400	0.00	—	—	210.0	—	—	—	—	—	—	—	—	0	0	—
0	400	0.00	—	—	210.0	—	—	—	—	—	—	—	—	2.4	0	—
0	450	0.00	—	—	250.0	—	—	—	—	—	—	—	—	0	0	—
5	500	1 44	—	—	210.0	—	—	—	—	—	—	—	—	0	0	—
5	500	0.00	—	—	250.0	—	—	—	—	—	—	—	—	3.6	0	—
5	150	8.10	—	—	1090.0	—	—	—	—	—	—	—	—	18.0	—	—
0	250	4 50	—	—	1400.0	—	—	—	—	—	—	—	—	21.0	—	—
0	300	2.70	—	—	1680 0	—	—	—	—	—	—	—	—	9.0	—	—
5	0	1.08	—	—	150.0	—	—	—	—	—	—	—	—	0	—	—
0	20	1 00	—	—	100.0	—	—	—	—	—	—	—	—	0	—	—
0	0	1 00	—	—	100.0	—	—	—	—	—	—	—	—	0	—	—
5	150	2 70	—	—	1770.0	—	—	—	—	—	—	—	—	16 8	—	—
5	100	5 40	—	—	1030.0	—	—	—	—	—	—	—	—	21 0	—	—
5	100	3 60	—	—	1010.0	—	—	—	—	—	—	—	—	16 8	—	—
5	60	3.60	—	—	880.0	—	—	—	—	—	—	—	—	30.0	—	—
5	60	3 60	—	—	1290.0	—	—	—	—	—	—	—	—	13.8	—	—
0	150	3 60	—	—	1530.0	—	—	—	—	—	—	—	—	16 8	—	—
90	80	4 50	—	—	720.0	—	66 7	—	—	—	—	—	—	3.6	—	—
5	60	2.70	—	—	1375.0	—	—	—	—	—	—	—	—	13.8	—	—
5	200	7.20	—	—	1610.0	—	—	—	—	—	—	—	—	36.0	—	—
5	200	5.40	—	—	1590.0	—	—	—	—	—	—	—	—	31.8	—	—
5	150	5.40	—	—	1720.0	—	—	—	—	—	—	—	—	24 0	—	—
5	20	1.08	—	—	170.0	—	—	—	—	—	—	—	—	0	—	—
5	60	4.50	—	—	1020.0	—	—	—	—	—	—	—	—	18.0	—	—
5	20	0 72	—	—	200.0	—	—	—	—	—	—	—	—	0	—	—
0	60	6.30	—	—	920.0	—	—	—	—	—	—	—	—	18.0	—	—
0	60	4.50	—	—	900.0	—	—	—	—	—	—	—	—	13.8	—	—
5	60	2.70	—	—	1000.0	—	—	—	—	—	—	—	—	13.8	—	—
5	150	8.10	—	—	1310.0	—	—	—	—	—	—	—	—	21.0	—	—
5	60	2.70	—	—	1650.0	—	—	—	—	—	—	—	—	16.8	—	—
5	150	6.30	—	—	1070.0	—	—	—	—	—	—	—	—	13.8	—	—
5	0	0 72	—	—	140.0	—	—	—	—	—	—	—	—	0	—	—
0	80	4 50	—	—	1220.0	—	—	—	—	—	—	—	—	24.0	—	—
0	200	2.70	—	—	1780.0	—	—	—	—	—	—	—	—	6.0	—	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0.01)

Cengage Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Fast Food—*continued*													
15834	Turkey breast and ham sandwich, 6", white bread	1	item(s)	227	—	280	19.0	45.0	2.0	5.0	2.0	—	t
16376	Turkey breast sandwich, 6", white bread	1	item(s)	217	—	270	17.0	44.0	2.0	4.5	2.0	—	t
15841	Veggie Delite sandwich, 6", wheat bread	1	item(s)	167	—	230	9.0	44.0	4.0	3.0	1.0	—	—
16375	Veggie Delite, 6", white bread	1	item(s)	160	—	220	8.0	42.0	2.0	3.0	1.5	—	—
32051	White chip macadamia nut cookie	1	item(s)	45	—	220	2.0	29.0	0.5	11.0	5.0	—	—
	Taco Bell												
29906	7-Layer burrito	1	item(s)	283	—	490	17.0	65.0	9.0	18.0	7.0	—	—
744	Bean burrito	1	item(s)	198	—	340	13.0	54.0	8.0	9.0	3.5	—	—
749	Beef burrito supreme	1	item(s)	248	—	410	17.0	51.0	7.0	17.0	8.0	—	—
33417	Beef Chalupa Supreme	1	item(s)	153	—	380	14.0	30.0	3.0	23.0	7.0	—	—
34474	Beef Gordita Baja	1	item(s)	153	—	340	13.0	29.0	4.0	19.0	5.0	—	—
29910	Beef Gordita Supreme	1	item(s)	153	—	310	14.0	29.0	3.0	16.0	6.0	—	—
2014	Beef soft taco	1	item(s)	99	—	200	10.0	21.0	3.0	9.0	4.0	—	—
10860	Beef soft taco supreme	1	item(s)	135	—	250	11.0	23.0	3.0	13.0	6.0	—	—
34472	Chicken burrito supreme	1	item(s)	248	—	390	20.0	49.0	6.0	13.0	6.0	—	—
33418	Chicken Chalupa Supreme	1	item(s)	153	—	360	17.0	29.0	2.0	20.0	5.0	—	—
34475	Chicken Gordita Baja	1	item(s)	153	—	320	17.0	28.0	3.0	16.0	3.5	—	—
29909	Chicken quesadilla	1	item(s)	184	—	520	28.0	40.0	3.0	28.0	12.0	—	—
29907	Chili cheese burrito	1	item(s)	156	—	390	16.0	40.0	3.0	18.0	9.0	—	—
10794	Cinnamon twists	1	serving(s)	35	—	170	1.0	26.0	1.0	7.0	0	—	—
29911	Grilled chicken Gordita Supreme	1	item(s)	153	—	290	17.0	28.0	2.0	12.0	5.0	—	—
14463	Grilled chicken soft taco	1	item(s)	99	—	190	14.0	19.0	1.0	6.0	2.5	—	—
29912	Grilled Steak Gordita Supreme	1	item(s)	153	—	290	15.0	28.0	2.0	13.0	5.0	—	—
29904	Grilled steak soft taco	1	item(s)	128	—	270	12.0	20.0	2.0	16.0	4.5	—	—
29905	Grilled steak soft taco supreme	1	item(s)	135	—	235	13.0	21.0	1.0	11.0	6.0	—	—
2021	Mexican pizza	1	serving(s)	216	—	530	20.0	42.0	7.0	30.0	8.0	—	—
29894	Mexican rice	1	serving(s)	131	—	170	6.0	23.0	1.0	11.0	3.0	—	—
10772	Meximelt	1	serving(s)	128	—	280	15.0	22.0	3.0	14.0	7.0	—	—
2011	Nachos	1	serving(s)	99	—	330	4.0	32.0	2.0	21.0	3.5	—	—
2012	Nachos Bellgrande	1	serving(s)	308	—	770	19.0	77.0	12.0	44.0	9.0	—	—
2023	Pintos 'n cheese	1	serving(s)	128	—	150	9.0	19.0	7.0	6.0	3.0	—	—
34473	Steak burrito supreme	1	item(s)	248	—	380	18.0	49.0	6.0	14.0	7.0	—	—
33419	Steak Chalupa Supreme	1	item(s)	153	—	360	15.0	28.0	2.0	21.0	6.0	—	—
747	Taco	1	item(s)	78	—	170	8.0	13.0	3.0	10.0	3.5	—	—
2015	Taco salad with salsa, with shell	1	serving(s)	548	—	840	30.0	80.0	15.0	45.0	11.0	—	—
14459	Taco supreme	1	item(s)	113	—	210	9.0	15.0	3.0	13.0	6.0	—	—
748	Tostada	1	item(s)	170	—	230	11.0	27.0	7.0	10.0	3.5	—	—
Convenience Meals													
	Banquet												
29961	Barbeque chicken meal	1	item(s)	281	—	330	16.0	37.0	2.0	13.0	3.0	—	—
14788	Boneless white fried chicken meal	1	item(s)	286	—	310	10.0	21.0	4.0	20.0	5.0	—	—
29960	Fish sticks meal	1	item(s)	207	—	470	13.0	58.0	1.0	20.0	3.5	—	—
29957	Lasagna with meat sauce meal	1	item(s)	312	—	320	15.0	46.0	7.0	9.0	4.0	—	—
14777	Macaroni and cheese meal	1	item(s)	340	—	420	15.0	57.0	5.0	14.0	8.0	—	—
1741	Meatloaf meal	1	item(s)	269	—	240	14.0	20.0	4.0	11.0	4.0	—	—
39418	Pepperoni pizza meal	1	item(s)	191	—	480	11.0	56.0	5.0	23.0	8.0	—	—
33759	Roasted white turkey meal	1	item(s)	255	—	230	14.0	30.0	5.0	6.0	2.0	—	—
1743	Salisbury steak meal	1	item(s)	269	196.9	380	12.0	28.0	3.0	24.0	12.0	—	—
	Budget Gourmet												
1914	Cheese manicotti with meat sauce entrée	1	item(s)	284	194.0	420	18.0	38.0	4.0	22.0	11.0	6.0	1.3
1915	Chicken with fettucini entrée	1	item(s)	284	—	380	20.0	33.0	3.0	19.0	10.0	—	—
3986	Light beef stroganoff entrée	1	item(s)	248	177.0	290	20.0	32.0	3.0	7.0	4.0	—	—
3996	Light sirloin of beef in herb sauce entrée	1	item(s)	269	214.0	260	19.0	30.0	5.0	7.0	4.0	2.3	0.3
3987	Light vegetable lasagna entrée	1	item(s)	298	227.0	290	15.0	36.0	4.8	9.0	1.8	0.9	0.6

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
5	60	2.70	—	—	1210.0	—	—	—	—	—	—	—	—	13.8	—	—
0	60	2.70	—	—	1000.0	—	—	—	—	—	—	—	—	13.8	—	—
	60	4.50	—	—	520.0	—	—	—	—	—	—	—	—	18.0	—	—
	60	2.70	—	—	500.0	—	—	—	—	—	—	—	—	13.8	—	—
5	20	0.72	—	—	160.0	—	—	—	—	—	—	—	—	0	—	—
5	250	5.40	—	—	1350.0	—	—	—	—	—	—	—	—	15.0	—	—
5	200	4.50	—	—	1190 0	—	5.9	—	—	—	—	—	—	4.8	—	—
0	200	4.50	—	—	1340.0	—	9.9	—	—	—	—	—	—	6.0	—	—
0	150	2.70	—	—	620 0	—	—	—	—	—	—	—	—	3.6	—	—
5	100	2.70	—	—	780 0	—	—	—	—	—	—	—	—	2.4	—	—
0	150	2.70	—	—	620.0	—	—	—	—	—	—	—	—	3.6	—	—
5	100	1.80	—	—	630 0	—	—	—	—	—	—	—	—	1.2	—	—
0	150	2.70	—	—	650.0	—	—	—	—	—	—	—	—	3.6	—	—
5	200	4 50	—	—	1360 0	—	—	—	—	—	—	—	—	9.0	—	—
5	100	2.70	—	—	650.0	—	—	—	—	—	—	—	—	4.8	—	—
0	100	1.80	—	—	800 0	—	—	—	—	—	—	—	—	3.6	—	—
5	450	3.60	—	—	1420.0	—	—	—	—	—	—	—	—	1.2	—	—
0	300	1.80	—	—	1080.0	—	—	—	—	—	—	—	—	0	—	—
0	0	0.37	—	—	200.0	—	0	—	—	—	—	—	—	0	—	—
5	150	1.80	—	—	650 0	—	—	—	—	—	—	—	—	4.8	—	—
0	100	1 08	—	—	550 0	—	14.6	—	—	—	—	—	—	1.2	—	—
0	100	2.70	—	—	530.0	—	—	—	—	—	—	—	—	3.6	—	—
5	100	2 70	—	—	660 0	—	—	—	—	—	—	—	—	3.6	—	—
5	120	1.44	—	—	565.0	—	29.2	—	—	—	—	—	—	3.6	—	—
0	350	3.60	—	—	1000 0	—	—	—	—	—	—	—	—	4.8	—	—
5	100	1.44	—	—	790 0	—	—	—	—	—	—	—	—	3.6	—	—
0	250	2.70	—	—	880 0	—	—	—	—	—	—	—	—	2.4	—	—
3	80	0.71	—	—	530.0	—	0	—	—	—	—	—	—	0	—	—
5	200	3.60	—	—	1280 0	—	—	—	—	—	—	—	—	4.8	—	—
5	150	1.44	—	—	670.0	—	—	—	—	—	—	—	—	3.6	—	—
5	200	4.50	—	—	1250.0	—	9.9	—	—	—	—	—	—	9.0	—	—
0	100	2.70	—	—	530 0	—	—	—	—	—	—	—	—	3.6	—	—
5	80	1.08	—	—	350 0	—	—	—	—	—	—	—	—	1.2	—	—
5	450	7.20	—	—	1780.0	—	—	—	—	—	—	—	—	12.0	—	—
0	100	1.08	—	—	370.0	—	—	—	—	—	—	—	—	3.6	—	—
5	200	1.80	—	—	730.0	—	—	—	—	—	—	—	—	4.8	—	—
																—
0	40	1.08	—	—	1210.0	—	0	—	—	—	—	—	—	4.8	—	—
5	80	1.44	—	—	1200.0	—	—	—	—	—	—	—	—	18.0	—	—
5	20	1.44	—	—	710 0	—	—	—	—	—	—	—	—	0	—	—
0	100	2.70	—	—	1170.0	—	—	—	—	—	—	—	—	0	—	—
0	150	1.44	—	—	1330.0	—	0	—	—	—	—	—	—	0	—	—
0	0	1.80	—	—	1040.0	—	0	—	—	—	—	—	—	0	—	—
5	150	1 80	—	—	870.0	—	0	—	—	—	—	—	—	0	—	—
5	60	1 80	—	—	1070.0	—	—	—	—	—	—	—	—	3.6	—	—
0	40	1 44	—	—	1140.0	—	0	—	—	—	—	—	—	0	—	—
5	300	2.70	45.4	484.0	810.0	2.29	—	0.45	—	0.51	4.00	0.22	30.7	0	0.7	—
5	100	2.70	—	—	810.0	—	—	0.15	—	0.42	6.00	—	—	0	—	—
5	40	1.80	38.9	280.0	580.0	4.71	—	0.17	—	0.36	4.28	0.27	18.9	2.4	2.5	—
0	40	1.80	57.7	540.0	850.0	4.81	—	0.15	—	0.29	5.53	0.37	38.4	6.0	1.6	—
5	283	3.03	78.5	420.0	780.0	1.39	—	0.22	—	0.45	3.13	0.32	74.8	59.1	0.2	—

TABLE H-1 Table of Food Composition (*continued*) (Computer code is for Cengage Diet Analysis program) (For purposes of calculations, use "0" for t, <1, <0.1, 0 01)

NDB Code	Food Description	Quantity	Measure	Wt (g)	H_2O (g)	Ener (kcal)	Prot (g)	Carb (g)	Fiber (g)	Fat (g)	Fat Breakdown (g)		
											Sat	Mono	Poly
Convenience Meals—*continued*													
	Healthy Choice												
9425	Cheese French bread pizza	1	item(s)	170	—	340	22.0	51.0	5.0	5.0	1.5	—	—
9306	Chicken enchilada suprema meal	1	item(s)	320	251.5	360	13.0	59.0	8.0	7.0	3.0	2.0	2.0
3821	Familiar Favorites lasagna bake with meat sauce entrée	1	item(s)	255	—	270	13.0	38.0	4.0	7.0	2.5	—	—
13744	Familiar Favorites sesame chicken with vegetables and rice entrée	1	item(s)	255	—	260	17.0	34.0	4.0	6.0	2.0	2.0	2.0
9316	Lemon pepper fish meal	1	item(s)	303	—	280	11.0	49.0	5.0	5.0	2.0	1.0	2.0
9322	Traditional salisbury steak meal	1	item(s)	354	250.3	360	23.0	45.0	5.0	9.0	3.5	4.0	1.0
9359	Traditional turkey breasts meal	1	item(s)	298	—	330	21.0	50.0	4.0	5.0	2.0	1.5	1.5
	Stouffers												
2313	Cheese French bread pizza	1	serving(s)	294	—	380	15.0	43.0	3.0	16.0	6 0	—	—
11138	Cheese manicotti with tomato sauce entrée	1	item(s)	255	—	360	18.0	41.0	2.0	14.0	6.0	—	—
2366	Chicken pot pie entrée	1	item(s)	284	—	740	23.0	56.0	4.0	47.0	18.0	12.4	10.5
11116	Homestyle baked chicken breast with mashed potatoes and gravy entrée	1	item(s)	252	—	270	21.0	21.0	2.0	11.0	3.5	—	—
11146	Homestyle beef pot roast and potatoes entrée	1	item(s)	252	—	260	16.0	24.0	3.0	11.0	4.0	—	—
11152	Homestyle roast turkey breast with stuffing and mashed potatoes entrée	1	item(s)	273	—	290	16.0	30.0	2.0	12.0	3.5	—	—
11043	Lean Cuisine Comfort Classics baked chicken and whipped potatoes and stuffing entrée	1	item(s)	245	—	240	15.0	34.0	3.0	4.5	1.0	2.0	1.0
11046	Lean Cuisine Comfort Classics honey mustard chicken with rice pilaf entrée	1	item(s)	227	—	250	17.0	37.0	1.0	4.0	1.0	1.0	1.0
9479	Lean Cuisine Deluxe French bread pizza	1	item(s)	174	—	310	16.0	44.0	3.0	9.0	3.5	0.5	0.5
360	Lean Cuisine One Dish Favorites chicken chow mein with rice	1	item(s)	255	—	190	13.0	29.0	2.0	2.5	0.5	1.0	0.5
11054	Lean Cuisine One Dish Favorites chicken enchilada Suiza with Mexican-style rice	1	serving(s)	255	—	270	10.0	47.0	3.0	4.5	2.0	1.5	1.0
9467	Lean Cuisine One Dish Favorites fettucini alfredo entrée	1	item(s)	262	—	270	13.0	39.0	2.0	7.0	3.5	2.0	1.0
11055	Lean Cuisine One Dish Favorites lasagna with meat sauce entrée	1	item(s)	298	—	320	19.0	44.0	4.0	7.0	3.0	2.0	0.5
	Weight Watchers												
11164	Smart Ones chicken enchiladas suiza entrée	1	item(s)	255	—	340	12.0	38.0	3.0	10.0	4.5	—	—
39763	Smart Ones chicken oriental entrée	1	item(s)	255	—	230	15.0	34.0	3.0	4.5	1.0	—	—
11187	Smart Ones pepperoni pizza	1	item(s)	198	—	400	22.0	58.0	4.0	9.0	3.0	—	—
39765	Smart Ones spaghetti bolognese entrée	1	item(s)	326	—	280	17.0	43.0	5.0	5.0	2.0	—	—
31512	Smart Ones spicy szechuan style vegetables and chicken	1	item(s)	255	—	220	11.0	34.0	4.0	5.0	1.0	—	—
Baby Foods													
787	Apple juice	4	fluid ounce(s)	127	111.6	60	0	14.8	0.1	0.1	0	0	0
778	Applesauce, strained	4	tablespoon(s)	64	56.7	26	0.1	6.9	1.1	0.1	0	0	0
779	Bananas with tapioca, strained	4	tablespoon(s)	60	50.4	34	0.2	9.2	1.0	0	0	0	0
604	Carrots, strained	4	tablespoon(s)	56	51.7	15	0.4	3.4	1.0	0.1	0	0	0
770	Chicken noodle dinner, strained	4	tablespoon(s)	64	54.8	42	1.7	5.8	1.3	1.3	0.4	0.5	0.3
801	Green beans, strained	4	tablespoon(s)	60	55.1	16	0.7	3.8	1.3	0.1	0	0	0
910	Human milk, mature	2	fluid ounce(s)	62	53.9	43	0.6	4.2	0	2.7	1.2	1.0	0.3
760	Mixed cereal, prepared with whole milk	4	ounce(s)	113	84.6	128	5.4	18.0	1.5	4.0	2.2	1.2	0.4
772	Mixed vegetable dinner, strained	2	ounce(s)	57	50.3	23	0.7	5.4	0.8	0	—	—	0
762	Rice cereal, prepared with whole milk	4	ounce(s)	113	84.6	130	4.4	18.9	0.1	4.1	2.6	1.0	0.2
758	Teething biscuits	1	item(s)	11	0.7	44	1.0	8.6	0.2	0.6	0.2	0.2	0.1

	Calc (mg)	Iron (mg)	Magn (mg)	Pota (mg)	Sodi (mg)	Zinc (mg)	Vit A (µg)	Thia (mg)	Vit E (mg α)	Ribo (mg)	Niac (mg)	Vit B_6 (mg)	Fola (µg)	Vit C (mg)	Vit B_{12} (µg)	Sele (µg)
	350	3.60	—	—	600.0	—	—	—	—	—	—	—	—	0	—	—
	40	1.44	—	—	580.0	—	—	—	—	—	—	—	—	3.6	—	—
	100	1.80	—	—	600.0	—	—	—	—	—	—	—	—	0	—	—
	18	0.72	—	—	580.0	—	—	—	—	—	—	—	—	12.0	—	—
	20	0.36	—	—	580.0	—	—	—	—	—	—	—	—	30.0	—	—
	80	2.70	—	—	580 0	—	—	—	—	—	—	—	—	21.0	—	—
	40	1.80	—	—	600.0	—	—	—	—	—	—	—	—	0	—	—
	200	1.80	—	230.0	660.0	—	—	—	—	—	—	—	—	2.4	—	—
	250	1.44	—	550.0	920.0	—	—	—	—	—	—	—	—	6.0	—	—
	150	2.70	—	—	1170 0	—	—	—	—	—	—	—	—	2.4	—	—
	20	0.72	—	490.0	770.0	—	0	—	—	—	—	—	—	0	—	—
	20	1.80	—	800.0	960.0	—	—	—	—	—	—	—	—	6.0	—	—
	40	1.08	—	490.0	970.0	—	—	—	—	—	—	—	—	3.6	—	—
	40	1.16	—	500.0	650.0	—	—	—	—	—	—	—	—	3.6	—	—
	64	0.38	—	370.0	650.0	—	—	—	—	—	—	—	—	0	—	—
	150	2.70	—	300.0	700.0	—	—	—	—	—	—	—	—	15.0	—	—
	40	0.72	—	380.0	650.0	—	—	—	—	—	—	—	—	2.4	—	—
	150	0.72	—	350.0	510.0	—	—	—	—	—	—	—	—	2.4	—	—
	200	0.72	—	290.0	690.0	—	0	—	—	—	—	—	—	0	—	—
	250	1.47	—	610.0	690 0	—	—	—	—	—	—	—	—	2 4	—	—
	200	0 72	—	—	800.0	—	—	—	—	—	—	—	—	2.4	—	—
	40	0 72	—	—	790.0	—	—	—	—	—	—	—	—	6 0	—	—
	200	1.08	—	401 0	700 0	—	69 1	—	—	—	—	—	—	4 8	—	—
	150	3.60	—	—	670.0	—	—	—	—	—	—	—	—	9.0	—	—
	40	1.44	—	—	890.0	—	—	—	—	—	—	—	—	0	—	—
	5	0.72	3.8	115.4	3.8	0.03	1.3	0.01	0.76	0.02	0.10	0.03	0	73.4	0	0.1
	3	0 12	1.9	45.4	1.3	0.01	0.6	0.01	0.36	0.02	0.04	0.02	1.3	24.5	0	0.2
	3	0.12	6.0	52.8	5.4	0.04	1.2	0.01	0.36	0.02	0.08	0.04	3.6	10.0	0	0.4
	12	0.20	5.0	109.8	20.7	0.08	320.9	0.01	0.29	0.02	0.25	0.04	8.4	3.2	0	0.1
	17	0.40	9.0	89.0	14.7	0 32	70.4	0 03	0.12	0.04	0.44	0.04	7.0	0	0	2.4
	23	0.40	12.0	87.6	3.0	0.12	10.8	0.02	0.04	0.04	0.20	0.02	14.4	0.2	0	0
	20	0.02	1.8	31.4	10.5	0.10	37.6	0.01	0.04	0.02	0.10	0.01	3.1	3.1	0	1.1
	249	11.82	30.6	225.7	53.3	0.80	28.4	0.49	—	0.65	6.54	0.07	12.5	1.4	0.3	
	12	0.18	6.2	68.6	4.5	0.08	77.1	0.01	—	0.02	0.28	0.04	4.5	1.6	0	0.4
	271	13.82	51.0	215.5	52.2	0.72	24.9	0.52	—	0.56	5.90	0.12	9.1	1.4	0.3	4.0
	11	0.39	3.9	35.5	28.4	0.10	3.1	0.02	0.02	0.05	0.47	0.01	5.4	1.0	0	2.6

Appendix I WHO Nutrition Recommendations

The World Health Organization (WHO) has assessed the relationships between diet and the development of chronic diseases. This appendix presents its nutrition recommendations:

- Energy: sufficient to support growth, physical activity, and a healthy body weight (BMI between 18.5 and 24.9) and to avoid weight gain greater than 11 pounds (5 kilograms) during adult life
- Total fat: 15 to 30 percent of total energy
- Saturated fatty acids: <10 percent of total energy
- Polyunsaturated fatty acids: 6 to 10 percent of total energy
- Omega-6 polyunsaturated fatty acids: 5 to 8 percent of total energy
- Omega-3 polyunsaturated fatty acids: 1 to 2 percent of total energy
- *Trans*-fatty acids: <1 percent of total energy
- Total carbohydrate: 55 to 75 percent of total energy
- Sugars: <10 percent of total energy
- Protein: 10 to 15 percent of total energy
- Cholesterol: <300 mg per day
- Salt (sodium): <5 g salt per day (<2 g sodium per day), appropriately iodized
- Fruits and vegetables: ≥400 g per day (about 1 pound)
- Total dietary fiber: >25 g per day from foods
- Physical activity: one hour of moderate-intensity activity, such as walking, on most days of the week

Appendix J Healthy People 2020

Table 1-4 (p. 25) lists the objectives from the Nutrition and Weight Status section of the Healthy People 2020 initiative. Table J-1 presents additional nutrition-related objectives from other topic areas.

TABLE J-1 Nutrition-Related Objectives from Other Topic Areas

Access to Health Services

- Increase the proportion of persons who receive appropriate evidence-based clinical preventive services.

Adolescent Health

- Increase the proportion of schools with a school breakfast program.

Arthritis, Osteoporosis, and Chronic Back Conditions

- Reduce hip fractures among older adults.
- Reduce the proportion of adults with osteoporosis.

Cancer

- Reduce the cancer death rate.
- Increase the mental and physical health-related quality of life of cancer survivors.

Diabetes

- Reduce the annual number of new cases of diagnosed diabetes in the population.
- Reduce the death rate among the population with diabetes.
- Reduce the diabetes death rate.
- Improve glycemic control among the population with diagnosed diabetes.
- Improve lipid control among persons with diagnosed diabetes.
- Increase the proportion of the population with diagnosed diabetes whose blood pressure is under control.
- Increase the proportion of persons with diagnosed diabetes who receive formal diabetes education.
- Increase prevention behaviors in persons at high risk for diabetes with prediabetes.

Early and Middle Childhood

- Increase the proportion of elementary, middle, and senior high schools that require school health education.

Educational and Community-Based Programs

- Increase the proportion of preschool Early Head Start and Head Start programs that provide health education to prevent health problems in the following areas: unintentional injury; violence; tobacco use and addiction; alcohol and drug use, unhealthy dietary patterns; and inadequate physical activity, dental health, and safety.
- Increase the proportion of elementary, middle, and senior high schools that provide comprehensive school health education to prevent health problems in the following areas: unintentional injury; violence; suicide; tobacco use and addiction; alcohol or other drug use; unintended pregnancy, HIV/AIDS, and STD infection; unhealthy dietary patterns; and inadequate physical activity.
- Increase the proportion of college and university students who receive information from their institution on each of the priority health risk behavior areas (all priority areas; unintentional injury; violence; suicide; tobacco use and addiction; alcohol and other drug use; unintended pregnancy, HIV/AIDS, and STD infection; unhealthy dietary patterns; and inadequate physical activity).
- Increase the proportion of worksites that offer an employee health promotion program to their employees.
- Increase the number of community-based organizations (including local health departments, tribal health services, nongovernmental organizations, and state agencies) providing population-based primary prevention services.

Environmental Health

- Reduce blood lead levels in children.
- Reduce the number of US homes that are found to have lead-based paint or related hazards.

(continued)

TABLE J-1 Nutrition-Related Objectives from Other Topic Areas (*continued*)

Food Safety

- Reduce infections caused by key pathogens transmitted commonly through food.
- Reduce the number of outbreak-associated infections due to Shiga toxin-producing *E. coli* 0157, or *Campylobacter, Listeria,* or *Salmonella* species associated with food commodity groups.
- Reduce severe allergic reactions to food among adults with a food allergy diagnosis.
- Increase the proportion of consumers who follow key food safety practices.
- Improve food safety practices associated with foodborne illness in foodservice and retail establishments.

Heart Disease and Stroke

- Increase overall cardiovascular health in the US population.
- Reduce coronary heart disease deaths.
- Reduce stroke deaths.
- Reduce the proportion of persons in the population with hypertension.
- Reduce the proportion of adults with high total blood cholesterol levels.
- Reduce the mean total blood cholesterol levels among adults.
- Increase the proportion of adults with prehypertension who meet the recommended guidelines.
- Increase the proportion of adults with hypertension who meet the recommended guidelines.
- Increase the proportion of adults with elevated LDL cholesterol who have been advised by a health-care provider regarding cholesterol-lowering management including lifestyle changes and, if indicated, medication.
- Increase the proportion of adults with elevated LDL-cholesterol who adhere to the prescribed LDL cholesterol–lowering management lifestyle changes and, if indicated, medication.

Maternal, Infant, and Child Health

- Reduce low birth weight (LBW) and very low birth weight (VLBW).
- Reduce preterm births.
- Increase the proportion of pregnant women who receive early and adequate prenatal care.
- Increase the proportion of mothers who achieve a recommended weight gain during their pregnancies.
- Increase the proportion of women of childbearing potential with intake of at least 400 micrograms of folic acid from fortified foods or dietary supplements.
- Reduce the proportion of women of childbearing potential who have low red blood cell folate concentrations.
- Increase the proportion of women delivering a live birth who received preconception care services and practiced key recommended preconception health behaviors.
- Increase the proportion of infants who are breastfed.
- Increase the proportion of employers that have worksite lactation support programs.
- Reduce the proportion of breastfed newborns who receive formula supplementation within the first 2 days of life.
- Reduce the occurrence of fetal alcohol syndrome (FAS).
- Reduce occurrence of neural tube defects.

Mental Health and Mental Disorders

- Reduce the proportion of adolescents who engage in disordered eating behaviors in an attempt to control their weight.

Older Adults

- Increase the proportion of the health-care workforce (including dietitians) with geriatric certification.

Oral Health

- Increase the proportion of the US population served by community water systems with optimally fluoridated water.

Physical Activity

- Reduce the proportion of adults who engage in no leisure-time physical activity.
- Increase the proportion of adolescents and adults who meet current federal physical activity guidelines for aerobic physical activity and for muscle-strengthening activity.
- Increase the proportion of the nation's public and private schools that require daily physical education for all students.
- Increase the proportion of adolescents who participate in daily school physical education.
- Increase regularly scheduled elementary school recess in the United States.
- Increase the proportion of children and adolescents who do not exceed recommended limits for screen time.

SOURCE: Adapted from Healthy people 2020: www.healthypeople.gov.

Appendix K Aids to Calculation

Many mathematical problems have been worked out in the "How To" features of the text. This appendix offers additional help and examples.

Conversions

A conversion factor is a fraction that converts a measurement expressed in one unit to another unit—for example, from pounds to kilograms or from feet to meters. To create a conversion factor, an equality (such as 1 kilogram = 2.2 pounds) is expressed as a fraction:

$$\frac{1 \text{ kg}}{2.2 \text{ lb}} \text{ and } \frac{2.2 \text{ lb}}{1 \text{ kg}}$$

To convert the units of a measurement, use the fraction with the desired unit in the numerator.

Example 1 Convert a weight of 130 pounds to kilograms.
Multiply 130 pounds by the conversion factor that includes both pounds and kilograms, with the desired unit (kilograms) in the numerator:

$$130 \text{ lb} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} = \frac{130 \text{ kg}}{2.2} = 59 \text{ kg}$$

Alternatively, to convert a measurement from one unit of measure to another, multiply the given measurement by the appropriate equivalent found on the next page of weights and measures.

Example 2 Convert 64 fluid ounces to liters.
Locate the equivalent measure from the volume section on the next page (1 ounce = 0.03 liter) and multiply the number of ounces by 0.03:

$$64 \text{ oz} \times 0.03 \text{ oz/L} = 1.9 \text{ L}$$

Percentages

A percentage is a fraction whose denominator is 100. For example:

$$50\% = \frac{50}{100}$$

Like other fractions, percentages are used to express a portion of a quantity. Fractions whose denominators are numbers other than 100 can be converted to percentages by first dividing the numerator by the denominator and then multiplying the result by 100.

Example 3 Express 5/8 as a percent.

$$\frac{5}{8} = 5 \div 8 = 0.625$$
$$0.625 \times 100 = 62.5\%$$

The following examples show how to calculate specific percentages.

Example 4 Suppose your energy intake for the day is 2000 kcalories (kcal) and your recommended energy intake is 2400 kcalories. What percent of the recommended energy intake did you consume?

Divide your intake by the recommended intake.
2000 kcal (intake) ÷ 2400 kcal (recommended) = 0.83
Multiply by 100 to express the decimal as a percent.
0.83 × 100 = 83%

Example 5 Suppose a man's intake of vitamin C is 120 milligrams and his RDA is 90 milligrams. What percent of the RDA for vitamin C did he consume?

Divide the intake by the recommended intake.
120 mg (intake) ÷ 90 mg (RDA) = 1.33
Multiply by 100 to express the decimal as a percent.
1.33 × 100 = 133%

Example 6 Dietary recommendations suggest that carbohydrates provide 45 to 65 percent of the day's energy intake. If your energy intake is 2000 kcalories, how much carbohydrate should you eat?

Because this question has a range of acceptable answers, work the problem twice. First, use 45% to find the least amount you should eat.

Divide 45 by 100 to convert to a decimal.
45 ÷ 100 = 0.45
Multiply kcalories by 0.45.
2000 kcal × 0.45 = 900 kcal
Divide kcalories by 4 to convert carbohydrate kcal to grams.
900 kcal ÷ 4 kcal/g = 225 g

Now repeat the process using 65% to find the maximum number of grams of carbohydrates you should eat.

Divide 65 by 100 to convert it to a decimal.
65 ÷ 100 = 0.65
Multiply kcalories by 0.65.
2000 kcal × 0.65 = 1300 kcal
Divide kcalories by 4 to convert carbohydrate kcal to grams.
1300 kcal ÷ 4 kcal/g = 325 g

If you plan for between 45% and 65% of your 2000-kcalorie intake to be from carbohydrates, you should eat between 225 grams and 325 grams of carbohydrates.

Weights and Measures

Length

1 centimeter (cm) = 0.39 inches (in)
1 foot (ft) = 30 centimeters (cm)
1 inch (in) = 2.54 centimeters (cm)
1 meter (m) = 39.37 inches (in)

Weight

1 gram (g) = 0.001 kilograms (kg)
= 1000 milligrams (mg)
= 0.035 ounces (oz)
1 kilogram (kg) = 1000 grams (g)
= 2.2 pounds (lb)
1 microgram (μg) = 0.001 milligrams (mg)
1 milligram (mg) = 0.001 grams (g)
= 1000 micrograms (μg)
1 ounce (oz) = 28 grams (g)
= 0.03 kilograms (kg)
= 1/16 or 0.0625 pound (lb)
1 pound (lb) = 454 grams (g)
= 0.45 kilograms (kg)
= 16 ounces (oz)

Volume

1 cup = 16 tablespoons (tbs or T)
= 0.25 liters (L)
= 236 milliliters (mL, commonly rounded to 250 mL)
= 8 ounces (oz)
1 liter (L) = 33.8 fluid ounces (fl oz)
= 0.26 gallons (gal)
= 2.1 pints (pt)
= 1.06 quarts (qt)
= 1000 milliliters (mL)
1 milliliter (mL) = 0.001 liters (L)
= 0.03 fluid ounces (fl oz)
= 1/5 teaspoon (tsp)
1 ounce (oz) = 0.03 liters (L)
= 30 milliliters (mL)
= 2 tablespoons (tbs)
1 pint (pt) = 2 cups (c)
= 0.47 liters (L)
= 16 ounces (oz)
= 0.5 quarts (qt)
1 quart (qt) = 4 cups (c)
= 0.95 liters (L)
= 32 ounces (oz)
= 1/4 or 0.25 gallon (gal)
= 2 pints (pt)
1 tablespoon (tbs or T) = 3 teaspoons (tsp)
= 15 milliliters (mL)
1 teaspoon (tsp) = 5 milliliters (mL)
1 gallon (gal) = 16 cups (c)
= 3.8 liters (L)
= 128 ounces (oz)
= 8 pints (pt)
= 4 quarts (qt)
1 cup (c) = 8 ounces (oz)
= 16 tablespoons (tbs)
= 250 milliliters (mL)

Energy

1 megajoule (MJ) = 240 kcalories (kcal)
1 kilojoule (kJ) = 0.24 kcalories (kcal)
1 kcalorie (kcal) = 4.2 kilojoule (kJ)
1 g alcohol = 7 kcal = 29 kJ
1 g carbohydrate = 4 kcal = 17 kJ
1 g fat = 9 kcal = 37 kJ
1 g protein = 4 kcal = 17 kJ

Temperature

To change from Fahrenheit (°F) to Celsius (°C), subtract 32 from the Fahrenheit measure and then multiply that result by 0.56.

To change from Celsius (°C) to Fahrenheit (°F), multiply the Celsius measure by 1.8 and add 32 to that result.

A comparison of some useful temperatures is given below.

	Celsius	Fahrenheit
Boiling point	100°C	212°F
Body temperature	37°C	98.6°F
Freezing point	0°C	32°F

APPENDIX K

Glossary

Many medical terms have their origins in Latin or Greek. By learning a few common derivations, you can glean the meaning of words you have never heard of before. For example, once you know that "hyper" means above normal, "glyc" means glucose, and "emia" means blood, you can easily determine that "hyperglycemia" means high blood glucose. The derivations below will help you to learn many terms presented in this glossary.

General

a- or **an-** = not or without
ana- = up
ant- or **anti-** = against
ante- or **pre-** or **pro-** = before
bi- or **di-** = two, twice
cata- = down
co- = with or together
dys- or **mal-** = bad, difficult, painful
endo- = inner or within
epi- = upon
exo- = outside of or without
extra- = outside of, beyond, or in addition
gen- or **-gen** = gives rise to, producing
homeo- = like, similar, constant unchanging state
hyper- = over, above, excessive
hypo- = below, under, beneath
in- = not
inter- = between, in the midst
intra- = within
-itis = infection or inflammation
-lysis = break
macro- = large or long
micro- = small
mono- = one, single
neo- = new, recent
oligo- = few or small
-osis or **-asis** = condition
para- = near
peri- = around, about
poly- = many or much
semi- = half
-stat or **-stasis-** = stationary
tri- = three

Body

angi- or **vaso-** = vessel
arterio- = artery
cardiac or **cardio-** = heart
-cyte = cell
enteron = intestine
gastro- = stomach
hema- or **-emia** = blood
hepatic = liver
myo- or **sarco-** = muscle
nephr- or **renal** = kidney
neuro- = nerve
osteo- = bone
pulmo- = lung
ure- or **-uria** = urine
vena = vein

Chemistry

-al = aldehyde
-ase = enzyme
-ate = salt
glyc- or **gluc-** = sweet (glucose)
hydro- or **hydrate** = water
lipo- = lipid
-ol = alcohol
-ose = carbohydrate
saccha- = sugar

24-hour recall: a record of foods eaten by a person for one 24-hour period.

A

absorption: the uptake of nutrients by the cells of the small intestine for transport into either the blood or the lymph.

Academy of Nutrition and Dietetics: the professional organization of dietitians in the United States; formerly the American Dietetic Association. The Canadian equivalent is Dietitians of Canada, which operates similarly.

Acceptable Daily Intake (ADI): the estimated amount of a sweetener that individuals can safely consume each day over the course of a lifetime without adverse effect.

Acceptable Macronutrient Distribution Ranges (AMDR): ranges of intakes for the energy nutrients that provide adequate energy and nutrients and reduce the risk of chronic diseases.

accredited: approved; in the case of medical centers or universities, certified by an agency recognized by the US Department of Education.

acesulfame (AY-sul-fame) **potassium:** an artificial sweetener composed of an organic potassium salt that has been approved for use in both the United States and Canada; also known as *acesulfame-K* because K is the chemical symbol for potassium.

acetaldehyde (ass-et-AL-duh-hide): an intermediate in alcohol metabolism.

acetyl CoA (ASS-eh-teel, or ah-SEET-il, coh-AY): a 2-carbon compound (*acetate,* or *acetic acid*) to which a molecule of CoA is attached.

acid controllers: medications used to prevent or relieve indigestion by suppressing production of acid in the stomach; also called *H2 blockers.*

acid-base balance: the equilibrium in the body between acid and base concentrations.

acidosis (assi-DOE-sis): above-normal acidity in the blood and body fluids.

acids: compounds that release hydrogen ions in a solution.

acne: a chronic inflammation of the skin's follicles and oil-producing glands, which leads to an accumulation of oils inside the ducts that surround hairs; usually associated with the maturation of young adults.

acupuncture (AK-you-PUNK-cher): a technique that involves piercing the skin with long thin needles at specific anatomical points to relieve pain or illness. Acupuncture sometimes uses heat, pressure, friction, suction, or electromagnetic energy to stimulate the points.

acute malnutrition: malnutrition caused by recent severe food restriction; characterized in children by underweight for height (*wasting*).

adaptive thermogenesis: adjustments in energy expenditure related to changes in environment such as extreme cold and to physiological events such as overfeeding, trauma, and changes in hormone status.

added sugars: sugars and other kcaloric sweeteners that are added to foods during processing, preparation, or at the table. Added sugars do not include the naturally occurring sugars found in fruits and milk products.

additives: substances not normally consumed as foods but added to food either intentionally or by accident.

adequacy (dietary): providing all the essential nutrients, fiber, and energy in amounts sufficient to maintain health.

Adequate Intake (AI): the average daily amount of a nutrient that appears sufficient to maintain a specified criterion; a value used as a guide for nutrient intake when an RDA cannot be determined.

adipokines (ADD-ih-poe-kines): proteins synthesized and secreted by adipose cells.

adiponectin: a protein produced by the fat cells that inhibits inflammation and protects against insulin resistance, type 2 diabetes, and cardiovascular disease.

adipose (ADD-ih-poce) **tissue:** the body's fat tissue; consists of masses of triglyceride-storing cells.

adolescence: the period from the beginning of puberty until maturity.

adrenal glands: glands adjacent to, and just above, each kidney.

adrenocorticotropin (ad-REE-noh-KORE-tee-koh-TROP-in) **or ATCH:** a hormone, so named because it stimulates *(trope)* the adrenal cortex. The adrenal gland, like the pituitary, has two parts, in this case the outer portion *(cortex)* and an inner core *(medulla)*. The release of ACTH is mediated by *corticotropin-releasing hormone (CRH)*.

adverse reactions: unusual responses to food (including intolerances and allergies).

aerobic (air-ROE-bic): requiring oxygen.

aerobic physical activity: activity in which the body's large muscles move in a rhythmic manner for a sustained period of time. Aerobic activity, also called *endurance activity*, improves cardiorespiratory fitness. Brisk walking, running, swimming, and bicycling are examples.

AIDS (acquired immune deficiency syndrome): the late stage of HIV infection, in which severe complications of opportunistic infections and cancers develop.

alcohol: a class of organic compounds containing hydroxyl (OH) groups.

alcohol abuse: a pattern of drinking that includes failure to fulfill work, school, or home responsibilities; drinking in situations that are physically dangerous (as in driving while intoxicated); recurring alcohol-related legal problems (as in aggravated assault charges); or continued drinking despite ongoing social problems that are caused by or worsened by alcohol.

alcohol dehydrogenase (dee-high-DROJ-eh-nayz): an enzyme active in the stomach and the liver that converts ethanol to acetaldehyde.

alcoholism: a pattern of drinking that includes a strong craving for alcohol, a loss of control and an inability to stop drinking once begun, withdrawal symptoms (nausea, sweating, shakiness, and anxiety) after heavy drinking, and the need for increasing amounts of alcohol to feel "high."

alcohol-related birth defects (ARBD): malformations in the skeletal and organ systems (heart, kidneys, eyes, ears) associated with prenatal alcohol exposure.

alcohol-related neurodevelopmental disorder (ARND): abnormalities in the central nervous system and cognitive development associated with prenatal alcohol exposure.

aldosterone (al-DOS-ter-own): a hormone secreted by the adrenal glands that regulates blood pressure by increasing the reabsorption of sodium by the kidneys. Aldosterone also regulates chloride and potassium concentrations.

alkalosis (alka-LOE-sis): above-normal alkalinity (base) in the blood and body fluids.

alpha-lactalbumin (lact-AL-byoo-min): a major protein in human breast milk, as opposed to *casein* (CAY-seen), a major protein in cow's milk.

alpha-tocopherol: the active vitamin E compound.

Alzheimer's disease: a degenerative disease of the brain involving memory loss and major structural changes in neuron networks; also known as *senile dementia of the Alzheimer's type (SDAT)*, *primary degenerative dementia of senile onset*, or *chronic brain syndrome*.

amenorrhea (ay-MEN-oh-REE-ah): the absence of or cessation of menstruation. *Primary amenorrhea* is menarche delayed beyond 16 years of age. *Secondary amenorrhea* is the absence of three to six consecutive menstrual cycles.

amino (a-MEEN-oh) **acids:** building blocks of proteins. Each contains an amino group, an acid group, a hydrogen atom, and a distinctive side group, all attached to a central carbon atom.

amino acid pool: the supply of amino acids derived from either food proteins or body proteins that collect in the cells and circulating blood and stand ready to be incorporated in proteins and other compounds or used for energy.

amino acid scoring: a measure of protein quality assessed by comparing a protein's amino acid pattern with that of a reference protein; sometimes called *chemical scoring*.

ammonia: a compound with the chemical formula NH_3, produced during the deamination of amino acids.

amniotic (am-nee-OTT-ic) **sac:** the "bag of waters" in the uterus, in which the fetus floats.

amylase (AM-ih-lace): an enzyme that hydrolyzes amylose (a form of starch). Amylase is a *carbohydrase*, an enzyme that breaks down carbohydrates.

anabolic steroids: drugs related to the male sex hormone, testosterone, that stimulate the development of lean body mass.

anabolism (an-AB-o-lism): reactions in which small molecules are put together to build larger ones. Anabolic reactions require energy.

anaerobic (AN-air-ROE-bic): not requiring oxygen.

anaphylactic (ana- fill-LAC-tic) **shock:** a life-threatening, whole-body allergic reaction to an offending substance.

androstenedione: hormones made in the adrenal glands that serve as precursors to the male hormone testosterone; falsely promoted as burning fat, building muscle, and slowing aging.

anecdote: a personal account of an experience or event; not reliable scientific information.

anemia (ah-NEE-me-ah): literally, "too little blood." Anemia is any condition in which too few red blood cells are present, or the red blood cells are immature (and therefore large) or too small or contain too little hemoglobin to carry the normal amount of oxygen to the tissues. Anemia is not a disease itself but can be a symptom of many different disease conditions, including many nutrient deficiencies, bleeding, excessive red blood cell destruction, and defective red blood cell formation.

anencephaly (AN-en-SEF-a-lee): an uncommon and always fatal type of neural tube defect characterized by the absence of a brain.

aneurysm (AN-you-rizm): an abnormal enlargement or bulging of a blood vessel (usually an artery) caused by damage to or weakness in the blood vessel wall.

angina (an-JYE-nah or AN-ji-nah): a painful feeling of tightness or pressure in and around the heart, often radiating to the back, neck, and arms; caused by a lack of oxygen to an area of heart muscle.

angiotensin I (AN-gee-oh-TEN-sin): an inactive precursor that is converted by an enzyme to yield active angiotensin II.

angiotensin II: a hormone involved in blood pressure regulation.

angiotensinogen: a precursor protein that is hydrolyzed to angiotensin I by renin.

anions (AN-eye-uns): negatively charged ions.

anorexia (an-oh-RECK-see-ah) **nervosa:** an eating disorder characterized by a refusal to maintain a minimally normal body weight and a distortion in perception of body shape and weight.

antacids: medications used to relieve indigestion by neutralizing acid in the stomach.

antagonist: a competing factor that counteracts the action of another factor. When a drug displaces a vitamin from its site of action, the drug renders the vitamin ineffective and thus acts as a vitamin antagonist.

anthropometric (AN-throw-poe-MET-rick): relating to measurement of the physical characteristics of the body, such as height and weight.

antibodies: large proteins of the blood and body fluids, produced by the immune system in response to the invasion of the body by foreign molecules (usually proteins called *antigens*). Antibodies combine with and inactivate the foreign invaders, thus protecting the body.

antidiuretic hormone (ADH): a hormone produced by the pituitary gland in response to dehydration (or a high sodium concentration in the blood) that stimulates the kidneys to reabsorb more water and therefore to excrete less. In addition to its antidiuretic effect, ADH elevates blood pressure and so is also called *vasopressin* (VAS-oh-PRES-in).

antigens: substances that elicit the formation of antibodies or an inflammation reaction from the immune system. A bacterium, a virus, a toxin, and a protein in food that causes allergy are all examples of antigens.

antioxidants: in the body, substances that significantly decrease the adverse effects of free radicals on normal physiological functions.

antioxidants: as a food additive, preservatives that delay or prevent rancidity of fats in foods and other damage to food caused by oxygen.

antipromoters: factors that oppose the development of cancer.

antiscorbutic (AN-tee-skor-BUE-tik) **factor:** the original name for vitamin C.

anus (AY-nus): the terminal outlet of the GI tract.

aorta (ay-OR-tuh): the large, primary artery that conducts blood from the heart to the body's smaller arteries.

apoptosis: cell death.

appendix: a narrow blind sac extending from the beginning of the colon that contains bacteria and lymph cells.

appetite: the integrated response to the sight, smell, thought, or taste of food that initiates or delays eating.

aquaculture: the practice of fish farming.

arachidonic (a-RACK-ih-DON-ic) **acid:** an omega-6 polyunsaturated fatty acid with 20 carbons and four double bonds; present in small amounts in meat and other animal products and synthesized in the body from linoleic acid.

ariboflavinosis (ay-RYE-boh-FLAY-vin-oh-sis): riboflavin deficiency.

aroma therapy: a technique that uses oil extracts from plants and flowers (usually applied by massage or baths) to enhance physical, psychological, and spiritual health.

arteries: vessels that carry blood from the heart to the tissues.

artesian water: water drawn from a well that taps a confined aquifer in which the water is under pressure.

arthritis: inflammation of a joint, usually accompanied by pain, swelling, and structural changes.

artificial fats: zero-energy fat replacers that are chemically synthesized to mimic the sensory and cooking qualities of naturally occurring fats but are totally or partially resistant to digestion.

artificial sweeteners: sugar substitutes that provide negligible, if any, energy; sometimes called *nonnutritive sweeteners*.

ascorbic acid: one of the two active forms of vitamin C. Many people refer to vitamin C by this name.

-ase (ACE): a word ending denoting an enzyme. The word beginning often identifies the compounds the enzyme works on.

aspartame (ah-SPAR-tame or ASS-par-tame): an artificial sweetener composed of two amino acids (phenylalanine and aspartic acid); approved for use in both the United States and Canada.

atherosclerosis (ATH-er-oh-scler-OH-sis): a type of artery disease characterized by plaques (accumulations of lipid-containing material) on the inner walls of the arteries.

atoms: the smallest components of an element that have all of the properties of the element.

ATP or **adenosine** (ah-DEN-oh-seen) **triphosphate** (try-FOS-fate): a common high-energy compound composed of a purine (adenine), a sugar (ribose), and three phosphate groups.

atrophic (a-TRO-fik) **gastritis** (gas-TRY-tis): chronic inflammation of the stomach accompanied by a diminished size and functioning of the mucous membrane and glands. This condition is also characterized by inadequate hydrochloric acid and intrinsic factor—two substances needed for vitamin B_{12} absorption.

atrophy (AT-ro-fee): becoming smaller; with regard to muscles, a decrease in size (and strength) because of disuse, undernutrition, or wasting diseases.

autoimmune disorder: a condition in which the body develops antibodies to its own proteins and then proceeds to destroy cells containing these proteins. In type 1 diabetes, the body develops antibodies to its insulin and destroys the pancreatic cells that produce the insulin, creating an insulin deficiency.

autonomic nervous system: the division of the nervous system that controls the body's automatic responses. Its two branches are the *sympathetic* branch, which helps the body respond to stressors from the outside environment, and the *parasympathetic* branch, which regulates normal body activities between stressful times.

avidin (AV-eh-din): the protein in egg whites that binds biotin.

ayurveda (AH-your-VAY-dah): a traditional Hindu system of improving health by using herbs, diet, meditation, massage, and yoga to stimulate the body, mind, and spirit to prevent and treat disease.

B

bacteriophages (bak-TIR-ee-oh-fayjz): viruses that infect bacteria.

balance (dietary): providing foods in proportion to one another and in proportion to the body's needs.

bariatrics: the field of medicine that specializes in treating obesity.

basal metabolic rate (BMR): the rate of energy use for metabolism under specified conditions: after a 12-hour fast and restful sleep, without any physical activity or emotional excitement, and in a comfortable setting. It is usually expressed as kcalories per kilogram body weight per hour.

basal metabolism: the energy needed to maintain life when a body is at complete digestive, physical, and emotional rest.

bases: compounds that accept hydrogen ions in a solution.

B-cells: lymphocytes that produce antibodies. *B* stands for *bone marrow*, where the B-cells develop and mature.

beer: an alcoholic beverage traditionally brewed by fermenting malted barley and adding hops for flavor.

behavior modification: the changing of behavior by the manipulation of antecedents (cues or environmental factors that trigger behavior), the behavior itself, and consequences (the penalties or rewards attached to the behavior).

belching: the release of air or gas from the stomach through the mouth.

benign: an abnormal mass of cells that is noncancerous.

beriberi: the thiamin-deficiency disease.

beta-carotene (BAY-tah KARE-oh-teen): one of the carotenoids; an orange pigment and vitamin A precursor found in plants.

beta-hydroxymethylbutryate (HMB): a metabolite of the amino acid leucine promoted to increase muscle mass and strength.

BHA and BHT: preservatives commonly used to slow the development of off-flavors, odors, and color changes caused by oxidation.

bicarbonate: an alkaline compound with the formula HCO_3 that is secreted from the pancreas as part of the pancreatic juice. Bicarbonate is also produced in all cell fluids from the dissociation of carbonic acid to help maintain the body's acid-base balance.

bifidus (BIFF-id-us, by-FEED-us) **factors:** factors in colostrum and breast milk that favor the growth of the "friendly" bacterium *Lactobacillus* (lack-toh-ba-SILL-us) *bifidus* in the infant's intestinal tract, so that other, less desirable intestinal bacteria will not flourish.

bile: an emulsifier that prepares fats and oils for digestion; an exocrine secretion made by the liver, stored in the gallbladder, and released into the small intestine when needed.

binders: chemical compounds in foods that combine with nutrients (especially minerals) to form complexes the body cannot absorb. Examples include *phytates* (FYE-tates) and *oxalates* (OCK-sa-lates).

binge drinking: pattern of drinking that raises blood alcohol concentration to 0.08 percent or higher; usually corresponds to four or more drinks for women and five or more drinks for men on a single occasion, generally within hours.

binge-eating disorder: an eating disorder with criteria similar to those of bulimia nervosa, excluding purging or other compensatory behaviors.

bioaccumulation: the accumulation of contaminants in the flesh of animals high on the food chain.

bioavailability: the rate at and the extent to which a nutrient is absorbed and used.

bioelectromagnetic medical applications: the use of electrical energy, magnetic energy, or both to stimulate bone repair, wound healing, and tissue regeneration.

biofeedback: the use of special devices to convey information about heart rate, blood pressure, skin temperature, muscle relaxation, and the like to enable a person to learn how to consciously control these medically important functions.

biofield therapeutics: a manual healing method that directs a healing force from an outside source (commonly God or another supernatural being) through the practitioner and into the client's body; commonly known as "laying on of hands."

biological value (BV): a measure of protein quality assessed by measuring the amount of protein nitrogen that is retained from a given amount of protein nitrogen absorbed.

biotechnology: the use of biological systems or organisms to create or modify products. Examples include the use of bacteria to make yogurt, yeast to make beer, and cross-breeding to enhance crop production.

biotin (BY-oh-tin): a B vitamin that functions as a coenzyme in metabolism.

blastocyst (BLASS-toe-sist): the developmental stage of the zygote when it is about 5 days old and ready for implantation.

blind experiment: an experiment in which the subjects do not know whether they are members of the experimental group or the control group.

bloating: uncomfortable abdominal fullness or distention.

blood lipid profile: results of blood tests that reveal a person's total cholesterol, triglycerides, and various lipoproteins.

body composition: the proportions of muscle, bone, fat, and other tissue that make up a person's total body weight.

body mass index (BMI): an index of a person's weight in relation to height; determined by dividing the weight (in kilograms) by the square of the height (in meters).

bolus (BOH-lus): a portion; with respect to food, the amount swallowed at one time.

bomb calorimeter (KAL-oh-RIM-eh-ter): an instrument that measures the heat energy released when foods are burned, thus providing an estimate of the potential energy (kcalories) of the foods.

bone density: a measure of bone strength. When minerals fill the bone matrix (making it dense), they give it strength.

bone meal: crushed or ground bone preparations intended to supply calcium to the diet. Calcium from bone is not well absorbed and is often contaminated with toxic minerals such as arsenic, mercury, lead, and cadmium.

bottled water: drinking water sold in bottles.

botulism (BOT-chew-lism): an often fatal foodborne illness caused by the ingestion of foods containing a toxin produced by bacteria that grow without oxygen.

bovine growth hormone (BGH): a hormone produced naturally in the pituitary gland of a cow that promotes growth and milk production; now produced for agricultural use by bacteria.

bran: the protective coating around the kernel of grain, rich in nutrients and fiber.

branched-chain amino acids: the essential amino acids leucine, isoleucine, and valine, which are present in large amounts in skeletal muscle tissue; falsely promoted as fuel for exercising muscles.

breast milk bank: a service that collects, screens, processes, and distributes donated human milk.

brown adipose tissue: masses of specialized fat cells packed with pigmented mitochondria that produce heat instead of ATP.

brown sugar: refined white sugar crystals to which manufacturers have added molasses syrup with natural flavor and color; 91 to 96 percent pure sucrose.

buffers: compounds that keep a solution's pH constant when acids or bases are added.

bulimia (byoo-LEEM-ee-ah) **nervosa:** an eating disorder characterized by repeated episodes of binge eating usually followed by self-induced vomiting, misuse of laxatives or diuretics, fasting, or excessive exercise.

C

caffeine: a natural stimulant found in many common foods and beverages, including coffee, tea, and chocolate; may enhance endurance by stimulating fatty acid release. High doses cause headaches, trembling, rapid heart rate, and other undesirable side effects.

calbindin: a calcium-binding transport protein that requires vitamin D for its synthesis.

calcidiol: vitamin D found in the blood that is made from the hydroxylation of calciol in the liver; also called *25-hydroxyvitamin D.*

calciferol (kal-SIF-er-ol): vitamin D.

calciol: vitamin D derived from animals in the diet or made in the skin from 7-dehydrocholesterol, a precursor of cholesterol, with the help of sunlight; also called *cholecalciferol* or *vitamin* D_3.

calcitonin (KAL-seh-TOE-nin): a hormone secreted by the thyroid gland that regulates blood calcium by lowering it when levels rise too high.

calcitriol: vitamin D that is made from the hydroxylation of calcidiol in the kidneys; the biologically active hormone; also called *1,25-dihydroxyvitamin D* or *active vitamin D.*

calcium: the most abundant mineral in the body; found primarily in the body's bones and teeth.

calcium rigor: hardness or stiffness of the muscles caused by high blood calcium concentrations.

calcium tetany (TET-ah-nee): intermittent spasm of the extremities due to nervous and muscular excitability caused by low blood calcium concentrations.

calcium-binding protein: a protein in the intestinal cells, made with the help of vitamin D, that facilitates calcium absorption.

calmodulin (cal-MOD-you-lin): a calcium-binding protein that regulates such cell activities as muscle contractions.

calories: units by which energy is measured. Food energy is measured in kilocalories (1000 calories equal 1 kilocalorie), abbreviated **kcalories** or **kcal**. One kcalorie is the amount of heat necessary to raise the temperature of 1 kilogram (kg) of water 1°C. The scientific use of the term *kcalorie* is the same as the popular use of the term *calorie*.

cancers: malignant growths or tumors that result from abnormal and uncontrolled cell division.

capillaries (CAP-ill-aries): small vessels that branch from an artery. Capillaries connect arteries to veins. Exchange of oxygen, nutrients, and waste materials takes place across capillary walls.

carbohydrase (KAR-boe-HIGH-drase): an enzyme that hydrolyzes carbohydrates.

carbohydrate loading: a regimen of moderate exercise followed by the consumption of a high-carbohydrate diet that enables muscles to store glycogen beyond their normal capacities; also called *glycogen loading* or *glycogen super compensation*.

carbohydrates: compounds composed of carbon, oxygen, and hydrogen arranged as monosaccharides or multiples of monosaccharides. Most, but not all, carbohydrates have a ratio of one carbon molecule to one water molecule: $(CH_2O)_n$.

carbonated water: water that contains carbon dioxide gas, either naturally occurring or added, that causes bubbles to form in it; also called *bubbling* or *sparkling water*. The FDA defines seltzer, soda, and tonic waters as soft drinks; they are not regulated as water.

carbonic acid: a compound with the formula H_2CO_3 that results from the combination of carbon dioxide (CO_2) and water (H_2O); of particular importance in maintaining the body's acid-base balance.

carcinogenesis (CAR-sin-oh-JEN-eh-sis): the process of cancer development.

carcinogens (CAR-sin-oh-jenz or car-SIN-oh-jenz): substances that can cause cancer; the adjective is *carcinogenic*.

cardiac output: the volume of blood discharged by the heart each minute; determined by multiplying the stroke volume by the heart rate. The stroke volume is the amount of oxygenated blood the heart ejects toward the tissues at each beat. Cardiac output (volume/minute) = stroke volume (volume/beat) × heart rate (beats/minute).

cardiorespiratory conditioning: improvements in heart and lung function and increased blood volume, brought about by aerobic training.

cardiorespiratory endurance: the ability to perform large-muscle, dynamic exercise of moderate to high intensity for prolonged periods.

cardiovascular disease (CVD): a general term for all diseases of the heart and blood vessels. Atherosclerosis is the main cause of CVD. When the arteries that carry blood to the heart muscle become blocked, the heart suffers damage known as *coronary heart disease (CHD)*.

carnitine (CAR-neh-teen): a nonessential, nonprotein amino acid made in the body from lysine that helps transport fatty acids across the mitochondrial membrane. As a supplement, carnitine supposedly "burns" fat and spares glycogen during endurance events, but in reality it does neither.

carotenoids (kah-ROT-eh-noyds): pigments commonly found in plants and animals, some of which have vitamin A activity. The carotenoid with the greatest vitamin A activity is beta-carotene.

cartilage therapy: the use of cleaned and powdered connective tissue, such as collagen, to improve health.

catabolism (ca-TAB-o-lism): reactions in which large molecules are broken down to smaller ones. Catabolic reactions release energy.

catalyst (CAT-uh-list): a compound that facilitates chemical reactions without itself being changed in the process.

cataracts (KAT-ah-rakts): clouding of the eye lenses that impairs vision and can lead to blindness.

cathartic (ka-THAR-tik): a strong laxative.

cations (CAT-eye-uns): positively charged ions.

CDC (Centers for Disease Control): a branch of the Department of Health and Human Services that is responsible for, among other things, monitoring foodborne diseases.

celiac disease: an intestinal disorder in which the inability to absorb the protein portion of gluten results in an immune response that damages intestinal cells; also called *celiac sprue* or *gluten-sensitive enteropathy*.

cell: the basic structural unit of all living things.

cell differentiation (DIF-er-EN-she-AY-shun): the process by which immature cells develop specific functions different from those of the original that are characteristic of their mature cell type.

cell membrane: the thin layer of tissue that surrounds the cell and encloses its contents; made primarily of lipid and protein.

central nervous system: the central part of the nervous system; the brain and spinal cord.

central obesity: excess fat around the trunk of the body; also called *abdominal fat* or *upper-body fat*.

cerebral thrombosis: a clot that blocks blood flow through an artery that feeds the brain.

certification: the process in which a private laboratory inspects shipments of a product for selected chemicals and then, if the product is found to be within acceptable levels of those chemicals, issues a guarantee to that effect.

certified lactation consultants: health-care providers who specialize in helping new mothers establish a healthy breastfeeding relationship with their newborn. These consultants are often registered nurses with specialized training in breast and infant anatomy and physiology.

certified nutritionist or **certified nutritional consultant** or **certified nutrition therapist:** a person who has been granted a document declaring his or her authority as a nutrition professional.

cesarean section: a surgically assisted birth involving removal of the fetus by an incision into the uterus, usually by way of the abdominal wall.

chaff: the outer inedible part of a grain; also called the *husk*.

CHD risk equivalents: disorders that raise the risk of heart attacks, strokes, and other complications associated with cardiovascular disease to the same degree as existing CHD. These disorders include symptomatic carotid artery disease, peripheral arterial disease, abdominal aortic aneurysm, and diabetes mellitus.

cheilosis (kye-LOH-sis or kee-LOH-sis): a condition of reddened lips with cracks at the corners of the mouth.

chelate (KEY-late): a substance that can grasp the positive ions of a mineral.

chelation (kee-LAY-shun) **therapy:** the use of ethylene diamine tetraacetic acid (EDTA) to bind with metallic ions, thus healing the body by removing toxic metals.

chiropractic (KYE-roh-PRAK-tik): a manual healing method of manipulating the spine to restore health.

chloride (KLO-ride): the major anion in the extracellular fluids of the body. Chloride is the ionic form of chlorine, Cl^-.

chlorophyll (KLO-row-fil): the green pigment of plants, which absorbs light and transfers the energy to other molecules, thereby initiating photosynthesis.

cholecalciferol (KO-lee-kal-SIF-er-ol): vitamin D derived from animals in the diet and made in the skin from 7-dehydrocholesterol, a precursor of cholesterol, with the help of sunlight; also called *vitamin D_3*.

cholecystokinin (COAL-ee-SIS-toe-KINE-in), or **CCK:** a hormone produced by cells of the intestinal wall. Target organ: the gallbladder. Response: release of bile and slowing of GI motility.

cholesterol (koh-LESS-ter-ol): one of the sterols containing a four-ring carbon structure with a carbon side chain.

cholesterol-free: less than 2 milligrams cholesterol per serving and 2 grams or less saturated fat and *trans* fat combined per serving.

choline (KOH-leen): a nitrogen-containing compound found in foods and made in the body from the amino acid methionine. Choline is part of the phospholipid lecithin and the neurotransmitter acetylcholine.

chromium: an essential trace mineral that enhances the activity of insulin.

chromium picolinate (CROW-mee-um pick-oh-LYNate): a trace mineral supplement; falsely promoted as building muscle, enhancing energy, and burning fat. *Picolinate* is a derivative of the amino acid tryptophan, which seems to enhance chromium absorption.

chromosomes: structures within the nucleus of a cell made of DNA and associated proteins. Human beings have 46 chromosomes in 23 pairs. Each chromosome has many genes.

chronic diseases: diseases characterized by a slow progression and long duration. Examples include heart disease, cancer, and diabetes.

chronic malnutrition: malnutrition caused by long-term food deprivation; characterized in children by short height for age (*stunting*).

chronological age: a person's age in years from his or her date of birth.

chylomicrons (kye-lo-MY-cronz): the class of lipoproteins that transport lipids from the intestinal cells to the rest of the body.

chyme (KIME): the semiliquid mass of partly digested food expelled by the stomach into the duodenum.

cirrhosis (seer-OH-sis): advanced liver disease in which liver cells turn orange, die, and harden, permanently losing their function; often associated with alcoholism.

cis: on the near side of; refers to a chemical configuration in which the hydrogen atoms are located on the same side of a double bond.

citric acid cycle: a series of metabolic reactions that break down molecules of acetyl CoA to carbon dioxide and hydrogen atoms; also called the *TCA cycle, tricarboxylic acid cycle,* or the *Kreb's cycle.*

clinically severe obesity: a BMI of 40 or greater or a BMI of 35 or greater with additional medical problems. A less preferred term used to describe the same condition is *morbid obesity.*

clone: a genetic copy of an animal, similar to identical twins but born at different times.

CoA (coh-AY): coenzyme A; the coenzyme derived from the B vitamin pantothenic acid and central to energy metabolism.

coenzymes: complex organic molecules that work with enzymes to facilitate the enzymes' activity. Many coenzymes have B vitamins as part of their structures.

cofactor: a small, inorganic or organic substance that facilitates the action of an enzyme.

colitis (ko-LYE-tis): inflammation of the colon.

collagen (KOL-ah-jen): the structural protein from which connective tissues such as scars, tendons, ligaments, and the foundations of bones and teeth are made.

colonic irrigation: the popular, but potentially harmful practice of "washing" the large intestine with a powerful enema machine.

colostrum (ko-LAHS-trum): a milklike secretion from the breast, present during the first few days after delivery before milk appears; rich in protective factors.

complementary and alternative medicine (CAM): diverse medical and health-care systems, practices, and products that are not currently considered part of conventional medicine; also called *adjunctive, unconventional,* or *unorthodox therapies.*

complementary proteins: two or more dietary proteins whose amino acid assortments complement each other in such a way that the essential amino acids missing from one are supplied by the other.

complex carbohydrates: polysaccharides (starches and fibers).

compound: a substance composed of two or more different atoms—for example, water (H_2O).

conception: the union of the male sperm and the female ovum; fertilization.

condensation: a chemical reaction in which water is released as two molecules combine to form one larger product.

conditionally essential amino acid: an amino acid that is normally nonessential, but must be supplied by the diet in special circumstances when the need for it exceeds the body's ability to produce it.

conditionally essential nutrient: a nutrient that is normally nonessential, but must be supplied by the diet in special circumstances when the need for it exceeds the body's ability to produce it.

conditioning: the physical effect of training; improved flexibility, strength, and endurance.

confectioners' sugar: finely powdered sucrose, 99.9 percent pure.

congregate meals: nutrition programs that provide food for the elderly in conveniently located settings such as community centers.

conjugated linoleic acid: several fatty acids that have the same chemical formula as linoleic acid (18 carbons, two double bonds) but with different configurations (the double bonds occur on adjacent carbons).

constipation: the condition of having infrequent or difficult bowel movements.

contaminants: substances that make a food impure and unsuitable for ingestion.

contamination iron: iron found in foods as the result of contamination by inorganic iron salts from iron cookware, iron-containing soils, and the like.

control group: a group of individuals similar in all possible respects to the experimental group except for the treatment. Ideally, the control group receives a placebo while the experimental group receives a real treatment.

convenient dietary supplements: liquid mean replacers, energy drinks, energy bars, and energy gels that athletes and active people use to replenish energy and nutrients when time is limited.

conventional medicine: diagnosis and treatment of diseases as practiced by medical doctors (M.D.), doctors of osteopathy (D.O.), and allied health professionals such as physical therapists and registered nurses; also called *allopathy; Western, mainstream, orthodox,* or *regular medicine;* and *biomedicine.*

cool-down: 5 to 10 minutes of light activity, such as walking or stretching, following a vigorous workout to gradually return the body's core to near-normal temperature.

copper: an essential trace mineral that is part of many enzymes.

Cori cycle: the pathway in which glucose is metabolized to lactate (by anaerobic glycolysis) in the muscle, lactate is converted back to glucose in the liver, then glucose is returned to the muscle; named after the scientist who elucidated this pathway.

corn sweeteners: corn syrup and sugars derived from corn.

corn syrup: a syrup made from cornstarch that has been treated with acid, high temperatures, and enzymes to produce glucose, maltose, and dextrins. It may be dried and used as corn syrup solids. See also *high-fructose corn syrup (HFCS).*

cornea (KOR-nee-uh): the transparent membrane covering the outside of the eye.

coronary arteries: blood vessels that supply blood to the heart.

coronary heart disease (CHD): the damage that occurs when the blood vessels carrying blood to the heart (the *coronary arteries*) become narrow and occluded.

coronary thrombosis: a clot that blocks blood flow through an artery that feeds the heart muscle.

correlation (CORE-ee-LAY-shun): the simultaneous increase, decrease, or change in two variables. If A increases as B increases, or if A decreases as B decreases, the correlation is positive. (This does not mean that A causes B or vice versa.) If A increases as B decreases, or if A decreases as B increases, the correlation is negative. (This does not mean that A prevents B or vice versa.) Some third factor may account for both A and B.

cortical bone: the very dense bone tissue that forms the outer shell surrounding trabecular bone and comprises the shaft of a long bone.

coupled reactions: pairs of chemical reactions in which some of the energy released from the breakdown of one compound is used to create a bond in the formation of another compound.

covert (KOH-vert) hidden, as if under covers.

CP, or creatine phosphate: a high-energy compound in muscle cells that acts as a reservoir of energy that can maintain a steady supply of ATP. CP provides the energy for short bursts of activity; also called *phosphocreatine*.

C-reactive protein (CRP): a protein released during the acute phase of infection or inflammation that enhances immunity by promoting phagocytosis and activating platelets. Its presence may be used to assess a person's risk of an impending heart attack or stroke.

creatine (KREE-ah-tin): a nitrogen-containing compound that combines with phosphate to form the high-energy compound creatine phosphate (or phosphocreatine) in muscles.

cretinism (CREE-tin-ism): a congenital disease characterized by mental and physical retardation and commonly caused by maternal iodine deficiency during pregnancy.

critical periods: finite periods during development in which certain events occur that will have irreversible effects on later developmental stages; usually a period of rapid cell division.

cross-contamination: the contamination of food by bacteria that occurs when the food comes into contact with surfaces previously touched by raw meat, poultry, or seafood.

cruciferous vegetables: vegetables of the cabbage family, including cauliflower, broccoli, and brussels sprouts.

crypts (KRIPTS): tubular glands that lie between the intestinal villi and secrete intestinal juices into the small intestine.

cultural competence: having an awareness and acceptance of cultures and the ability to interact effectively with people of diverse cultures.

cyclamate (SIGH-kla-mate): an artificial sweetener composed of a sodium or calcium salt of cyclamic acid that is being considered for approval in the United States and is available in Canada as a tabletop sweetener, but not as an additive.

cytokines (SIGH-toe-kines): special proteins that direct immune and inflammatory responses.

cytoplasm (SIGH-toh-plazm): the cell contents, except for the nucleus.

cytosol: the fluid of cytoplasm that contains water, ions, nutrients, and enzymes.

D

Daily Values (DV): reference values developed by the FDA specifically for use on food labels.

deamination (dee-AM-ih-NAY-shun): removal of the amino (NH_2) group from a compound such as an amino acid.

defecate (DEF-uh-cate): to move the bowels and eliminate waste.

deficient: inadequate; a nutrient amount that fails to meet the body's needs and eventually results in deficiency symptoms.

dehydration: the condition in which body water output exceeds water input. Symptoms include thirst, dry skin and mucous membranes, rapid heartbeat, low blood pressure, and weakness.

Delaney Clause: a clause in the Food Additive Amendment to the Food, Drug, and Cosmetic Act that states that no substance that is known to cause cancer in animals or human beings at any dose level shall be added to foods.

***de minimus* rule:** a guideline that defines risk as a cancer rate of less than one cancer per million people exposed to a contaminant over a 70-year lifetime.

denaturation (dee-NAY-chur-AY-shun): the change in a protein's shape and consequent loss of its function brought about by heat, agitation, acid, base, alcohol, heavy metals, or other agents.

dental caries: decay of teeth.

dental plaque: a gummy mass of bacteria that grows on teeth and can lead to dental caries and gum disease.

dextrose: the name food manufacturers use for the sugar that is chemically the same as glucose.

DHEA (dehydroepiandrosterone) and androstenedione: hormones made in the adrenal glands that serve as precursors to the male hormone testosterone; falsely promoted as burning fat, building muscle, and slowing aging.

DHF (dihydrofolate): a coenzyme form of folate.

diabetes (DYE-uh-BEET-eez): chronic disorders of carbohydrate metabolism, usually characterized by hyperglycemia resulting from insufficient or ineffective insulin; clinically called *diabetes mellitus* (MELL-ih-tus or MELL-eye-tus).

diarrhea: the frequent passage of watery bowel movements.

diet: the foods and beverages a person eats and drinks.

diet history: a record of eating behaviors and the foods a person eats.

dietary fibers: in plant foods, the *nonstarch polysaccharides* that are not digested by human digestive enzymes, although some are digested by GI tract bacteria.

dietary folate equivalents (DFE): the amount of folate available to the body from naturally occurring sources, fortified foods, and supplements, accounting for differences in the bioavailability from each source.

Dietary Reference Intakes (DRI): a set of nutrient intake values for healthy people in the United States and Canada. These values are used for planning and assessing diets and include: Estimated Average Requirements (EAR), Recommended Dietary Allowances (RDA), Adequate Intakes (AI), and Tolerable Upper Intake Levels (UL).

dietary supplement: any pill, capsule, tablet, liquid, or powder that contains vitamins, minerals, herbs, or amino acids; intended to increase dietary intake of these substances.

dietetic technician: a person who has completed a minimum of an associate's degree from an accredited university or college and an approved dietetic technician program that includes a supervised practice experience. See also *dietetic technician, registered (DTR)*.

dietetic technician, registered (DTR): a dietetic technician who has passed a national examination and maintains registration through continuing professional education.

dietitian: a person trained in nutrition, food science, and diet planning. See also *registered dietitian*.

digestion: the process by which food is broken down into absorbable units.

digestive enzymes: proteins found in digestive juices that act on food substances, causing them to break down into simpler compounds.

digestive system: all the organs and glands associated with the ingestion and digestion of food.

dioxins (dye-OCK-sins): a class of chemical pollutants created as by-products of chemical manufacturing, incineration, chlorine bleaching of paper pulp, and other industrial processes. Dioxins persist in the environment and accumulate in the food chain.

dipeptide (dye-PEP-tide): two amino acids bonded together.

diploma mills: entities without valid accreditation that provide worthless degrees.

direct calorimetry: a means of estimating energy expenditure by measuring the amount of heat released.

disaccharides (dye-SACK-uh-rides): pairs of monosaccharides linked together. See Appendix C for the chemical structures of the disaccharides.

discretionary kcalories: the kcalories remaining in a person's energy allowance after consuming enough nutrient-dense foods to meet all nutrient needs for a day.

disordered eating: eating behaviors that are neither normal nor healthy, including restrained eating, fasting, binge eating, and purging.

dispensable amino acids: nonessential amino acids.

dissociates (dis-SO-see-aites): physically separates.

distilled water: water that has been vaporized and recondensed, leaving it free of dissolved minerals.

diverticula (dye-ver-TIC-you-la): sacs or pouches that develop in the weakened areas of the intestinal wall (like bulges in an inner tube where the tire wall is weak).

diverticulitis (DYE-ver-tic-you-LYE-tis): infected or inflamed diverticula.

diverticulosis (DYE-ver-tic-you-LOH-sis): the condition of having diverticula.

DNA (deoxyribonucleic acid): the double helix molecules of which genes are made.

docosahexaenoic (DOE-cossa-HEXA-ee-NO-ick) **acid (DHA):** an omega-3 polyunsaturated fatty acid with 22 carbons and six double bonds; present in fatty fish and synthesized in limited amounts in the body from linolenic acid.

dolomite: a compound of minerals (calcium magnesium carbonate) found in limestone and marble. Dolomite is powdered and is sold as a calcium-magnesium supplement. However, it may be contaminated with toxic minerals, is not well absorbed, and interferes with absorption of other essential minerals.

double-blind experiment: an experiment in which neither the subjects nor the researchers know which subjects are members of the experimental group and which are serving as control subjects, until after the experiment is over.

Down syndrome: a genetic abnormality that causes mental retardation, short stature, and flattened facial features.

drink: a dose of any alcoholic beverage that delivers ½ ounce of pure ethanol: 5 ounces of wine, 10 ounces of wine cooler, 12 ounces of beer, or 1½ ounces of liquor.

drug: a substance that can modify one or more of the body's functions.

drug history: a record of all the drugs, over-the-counter and prescribed, that a person takes routinely.

DTR: see *dietetic technician, registered.*

duodenum (doo-oh-DEEN-um, doo-ODD-num): the top portion of the small intestine (about "12 fingers' breadth" long in ancient terminology).

duration: length of time (for example, the time spent in each activity session).

dysentery (DISS-en-terry): an infection of the digestive tract that causes diarrhea.

dysphagia (dis-FAY-jah): difficulty swallowing.

E

eating disorders: disturbances in eating behavior that jeopardize a person's physical or psychological health.

eating pattern: customary intake of foods and beverages over time.

eclampsia (eh-KLAMP-see-ah): a condition characterized by extremely high blood pressure, elevated protein in the urine, seizures, and possibly coma.

edema (eh-DEEM-uh): the swelling of body tissue caused by excessive amounts of fluid in the interstitial spaces; seen in protein deficiency (among other conditions).

edentulous (ee-DENT-you-lus): lack of teeth.

eicosanoids (eye-COSS-uh-noyds): derivatives of 20-carbon fatty acids; biologically active compounds that help to regulate blood pressure, blood clotting, and other body functions. They include *prostaglandins* (PROS-tah-GLAND-ins), *thromboxanes* (throm-BOX-ains), and *leukotrienes* (LOO-ko-TRY-eens).

eicosapentaenoic (EYE-cossa-PENTA-ee-NO-ick) **acid (EPA):** an omega-3 polyunsaturated fatty acid with 20 carbons and five double bonds; present in fatty fish and synthesized in limited amounts in the body from linolenic acid.

electrolyte solutions: solutions that can conduct electricity.

electrolytes: salts that dissolve in water and dissociate into charged particles called ions.

electron transport chain: the final pathway in energy metabolism that transports electrons from hydrogen to oxygen and captures the energy released in the bonds of ATP; also called the *respiratory chain.*

element: a substance composed of atoms that are alike—for example, iron (Fe).

embolism (EM-boh-lizm): the obstruction of a blood vessel by an *embolus* (EM-boh-luss), or traveling clot, causing sudden tissue death.

embryo (EM-bree-oh): the developing infant from 2 to 8 weeks after conception.

emergency shelters: facilities that are used to provide temporary housing.

emerging risk factors: recently identified factors that enhance the ability to predict disease risk in an individual.

emetic (em-ETT-ic): an agent that causes vomiting.

empty-kcalorie foods: a popular term used to denote foods that contribute energy but lack protein, vitamins, and minerals.

emulsifier (ee-MUL-sih-fire): substances with both water-soluble and fat-soluble portions that promotes the mixing of oils and fats in a watery solution.

endogenous (en-DODGE-eh-nus): from within the body.

endoplasmic reticulum (en-doh-PLAZ-mic reh-TIC-you-lum): a complex network of intracellular membranes. The *rough endoplasmic reticulum* is dotted with ribosomes, where protein synthesis takes place. The *smooth endoplasmic reticulum* bears no ribosomes.

endosperm: the inner edible part of a kernel of grain, rich in starch and proteins.

enema: solution inserted into the rectum and colon to stimulate a bowel movement and empty the lower large intestine.

energy: the capacity to do work. The energy in food is chemical energy. The body can convert this chemical energy to mechanical, electrical, or heat energy.

energy balance: the energy (kcalories) consumed from foods and beverages compared with the energy expended through metabolic processes and physical activities.

energy density: a measure of the energy a food provides relative to the amount of food (kcalories per gram).

energy-yielding nutrients: the nutrients that break down to yield energy the body can use (carbohydrate, fat, and protein).

enhanced water: water that is fortified with ingredients such as vitamins, minerals, protein, oxygen, or herbs. Enhanced water is marketed as *vitamin water, sports water, oxygenated water,* and *protein water.*

enriched: the addition to a food of nutrients that were lost during processing so that the food will meet a specified standard.

enteropancreatic (EN-ter-oh-PAN-kree-AT-ik) **circulation:** the circulatory route from the pancreas to the intestine and back to the pancreas.

enzymes: proteins that facilitate chemical reactions without being changed in the process; protein catalysts.

EPA (Environmental Protection Agency): a federal agency that is responsible for, among other things, regulating pesticides and establishing water quality standards.

epidemic (ep-ih-DEM-ick): the appearance of a disease (usually infectious) or condition that attacks many people at the same time in the same region.

epigenetics: the study of heritable changes in gene function that occur without a change in the DNA sequence.

epiglottis (epp-ih-GLOTT-iss): cartilage in the throat that guards the entrance to the trachea and prevents fluid or food from entering it when a person swallows.

epinephrine (EP-ih-NEFF-rin): a hormone of the adrenal gland that modulates the stress response; formerly called *adrenaline*. When administered by injection, epinephrine counteracts anaphylactic shock by opening the airways and maintaining heartbeat and blood pressure.

epithelial (ep-i-THEE-lee-ul) **cells:** cells on the surface of the skin and mucous membranes.

epithelial tissue: the layer of the body that serves as a selective barrier between the body's interior and the environment. Examples are the cornea of the eyes, the skin, the respiratory lining of the lungs, and the lining of the digestive tract.

ergocalciferol (ER-go-kal-SIF-er-ol): vitamin D derived from plants in the diet; also called *vitamin* D_2.

ergogenic (ER-go-JEN-ick) **aids:** substances or techniques used in an attempt to enhance physical performance.

erythrocyte (eh-RITH-ro-cite) **hemolysis** (he-MOLL-uh-sis): the breaking open of red blood cells (erythrocytes); a symptom of vitamin E–deficiency disease in human beings.

erythrocyte protoporphyrin (PRO-toe-PORE-fe-rin): a precursor to hemoglobin.

erythropoietin (eh-RITH-ro-POY-eh-tin): a hormone that stimulates red blood cell production.

esophageal (ee-SOF-ah-GEE-al) **sphincter:** a sphincter muscle at the upper or lower end of the esophagus. The lower esophageal sphincter is also called the *cardiac sphincter*.

esophagus (ee-SOFF-ah-gus): the food pipe; the conduit from the mouth to the stomach.

essential amino acids: amino acids that the body cannot synthesize in amounts sufficient to meet physiological needs.

essential fatty acids: fatty acids that the body cannot synthesize in amounts sufficient to meet physiological needs.

essential nutrients: nutrients a person must obtain from food because the body cannot synthesize them in amounts sufficient to meet physiological needs; also called *indispensable nutrients*. About 40 nutrients are currently known to be essential for human beings.

Estimated Average Requirement (EAR): the average daily amount of a nutrient that will maintain a specific biochemical or physiological function in half the healthy people of a given age and gender group.

Estimated Energy Requirement (EER): the average dietary energy intake that maintains energy balance and good health in a person of a given age, gender, weight, height, and level of physical activity.

estrogens: hormones responsible for the menstrual cycle and other female characteristics.

ethanol: a particular type of alcohol found in beer, wine, and liquor; also called *ethyl alcohol*.

ethnic foods: foods associated with particular cultural groups.

excessive drinking: heavy drinking, binge drinking, or both.

exchange lists: diet-planning tools that organize foods by their proportions of carbohydrate, fat, and protein. Foods on any single list can be used interchangeably.

exercise: planned, structured, and repetitive body movements that promote or maintain physical fitness.

exogenous (eks-ODGE-eh-nus): from outside the body, usually from foods.

experimental group: a group of individuals similar in all possible respects to the control group except for the treatment. The experimental group receives the real treatment.

extra lean: less than 5 grams of fat, 2 grams of saturated fat and *trans* fat combined, and 95 milligrams cholesterol per serving and per 100 grams of meat, poultry, and seafood.

extracellular fluid: fluid outside the cells. Extracellular fluid includes two main components—the interstitial fluid between cells and the intravascular fluid of plasma. Extracellular fluid accounts for approximately one-third of the body's water.

F

FAD (flavin adenine dinucleotide): a coenzyme form of riboflavin.

fad diets: popular eating plans that promise quick weight loss. Most fad diets severely limit certain foods or overemphasize others (for example, never eat potatoes or pasta or eat cabbage soup daily).

faith healing: healing by invoking divine intervention without the use of medical, surgical, or other traditional therapy.

false negative: a test result indicating that a condition is not present (negative) when in fact it is present (therefore false).

false positive: a test result indicating that a condition is present (positive) when in fact it is not (therefore false).

famine: widespread and extreme scarcity of food in an area that causes starvation and death in a large portion of the population.

FAO (Food and Agriculture Organization): an international agency (part of the United Nations) that has adopted standards to regulate pesticide use among other responsibilities.

fat replacers: ingredients that replace some or all of the functions of fat and may or may not provide energy.

fat-free: less than 0.5 gram of fat per serving (and no added fat or oil); synonyms include *zero-fat, no fat,* and *nonfat*.

fats: lipids that are solid at room temperature (77°F or 25°C).

fatty acid: an organic compound composed of a carbon chain with hydrogens attached and an acid group (COOH) at one end and a methyl group (CH_3) at the other end.

fatty acid oxidation: the metabolic breakdown of fatty acids to acetyl CoA; also called *beta oxidation*.

fatty liver: an early stage of liver deterioration seen in several diseases, including kwashiorkor and alcoholic liver disease. Fatty liver is characterized by an accumulation of fat in the liver cells.

fatty streaks: accumulations of cholesterol and other lipids along the walls of the arteries.

FDA (Food and Drug Administration): a part of the Department of Health and Human Services' Public Health Service that is responsible for ensuring the safety and wholesomeness of all dietary supplements and food processed and sold in interstate commerce except meat, poultry, and eggs (which are under the jurisdiction of the USDA); inspecting food plants and imported foods; and setting standards for food composition and product labeling.

female athlete triad: a potentially fatal combination of three medical problems—disordered eating, amenorrhea, and osteoporosis.

fermentable: the extent to which bacteria in the GI tract can break down fibers to fragments that the body can use.

ferritin (FAIR-ih-tin): the iron storage protein.

fertility: the capacity of a woman to produce a normal ovum periodically and of a man to produce normal sperm; the ability to reproduce.

fetal alcohol spectrum disorder: a range of physical, behavioral, and cognitive abnormalities caused by prenatal alcohol exposure.

fetal alcohol syndrome (FAS): a cluster of physical, behavioral, and cognitive abnormalities associated with prenatal alcohol exposure, including facial malformations, growth retardation, and central nervous disorders.

fetal programming: the influence of substances during fetal growth on the development of diseases in later life.

fetus (FEET-us): the developing infant from 8 weeks after conception until term.

fibrocystic (FYE-bro-SIS-tik) **breast disease:** a harmless condition in which the breasts develop lumps, sometimes associated with caffeine consumption. In some, it responds to abstinence from caffeine; in others, it can be treated with vitamin E.

fibrosis (fye-BROH-sis): an intermediate stage of liver deterioration seen in several diseases, including viral hepatitis and alcoholic liver disease. In fibrosis, the liver cells lose their function and assume the characteristics of connective tissue cells (fibers).

field gleaning: collecting crops from fields that either have already been harvested or are not profitable to harvest.

filtered water: water treated by filtration, usually through *activated carbon filters* that reduce the lead in tap water, or by *reverse osmosis* units that force pressurized water across a membrane removing lead, arsenic, and some microorganisms from tap water.

fitness: the characteristics that enable the body to perform physical activity; more broadly, the ability to meet routine physical demands with enough reserve energy to rise to a physical challenge; or the body's ability to withstand stress of all kinds.

flatulence: passage of excessive amounts of intestinal gas.

flavonoids (FLAY-von-oyds): yellow pigments in foods; phytochemicals that may exert physiological effects on the body.

flaxseeds: the small brown seeds of the flax plant; valued in nutrition as a source of fiber, lignans, and omega-3 fatty acids.

flexibility: the capacity of the joints to move through a full range of motion; the ability to bend and recover without injury.

flora: bacteria in the intestines.

fluid balance: maintenance of the proper types and amounts of fluid in each compartment of the body fluids.

fluorapatite (floor-APP-uh-tite): the stabilized form of bone and tooth crystal, in which fluoride has replaced the hydroxyl groups of hydroxyapatite.

fluoride: an essential trace mineral that makes teeth stronger and more resistant to decay.

fluorosis (floor-OH-sis): discoloration and pitting of tooth enamel caused by excess fluoride during tooth development.

FMN (flavin mononucleotide): a coenzyme form of riboflavin.

folate (FOLE-ate): a B vitamin; also known as folic acid, folacin, or pteroylglutamic (tare-o-EEL-glue-TAM-ick) acid (PGA). The coenzyme forms are *DHF (dihydrofolate)* and *THF (tetrahydrofolate)*.

follicle-stimulating hormone (FSH): a hormone that stimulates maturation of the ovarian follicles in females and the production of sperm in males. (The ovarian follicles are part of the female reproductive system where the eggs are produced.) The release of FSH is mediated by *follicle-stimulating hormone releasing hormone (FSH–RH)*.

food allergy: an adverse reaction to food that involves an immune response; also called *food-hypersensitivity reaction*.

food aversions: strong desires to avoid particular foods.

food bank: a facility that collects and distributes food donations to authorized organizations feeding the hungry.

food chain: the sequence in which living things depend on other living things for food.

food cravings: strong desires to eat particular foods.

food crisis: a sharp rise in the rates of hunger and malnutrition, usually set off by a shock to either the supply of, or demand for, food and a sudden spike in food prices.

food deserts: neighborhoods and communities characterized by limited access to nutritious and affordable foods.

food frequency questionnaire: a checklist of foods on which a person can record the frequency with which he or she eats each food.

food group plans: diet-planning tools that sort foods into groups based on nutrient content and then specify that people should eat certain amounts of foods from each group.

food insecurity: limited or uncertain access to foods of sufficient quality or quantity to sustain a healthy and active life.

food insufficiency: an inadequate amount of food due to a lack of resources.

food intolerances: adverse reactions to foods that do not involve the immune system.

food pantries: programs that provide groceries to be prepared and eaten at home.

food poverty: hunger resulting from inadequate access to available food for various reasons, including inadequate resources, political obstacles, social disruptions, poor weather conditions, and lack of transportation.

food record: an extensive, accurate log of all foods eaten over a period of several days or weeks. A food record that includes associated information such as when, where, and with whom each food is eaten is sometimes called a *food diary*.

food recovery: collecting wholesome food for distribution to low-income people who are hungry.

food security: access to enough food to sustain a healthy and active life.

food substitutes: foods that are designed to replace other foods.

foodborne illness: illness transmitted to human beings through food and water, caused by either an infectious agent (foodborne infection) or a poisonous substance (food intoxication); commonly known as *food poisoning*.

foods: products derived from plants or animals that can be taken into the body to yield energy and nutrients for the maintenance of life and the growth and repair of tissues.

fortified: the addition to a food of nutrients that were either not originally present or present in insignificant amounts. Fortification can be used to correct or prevent a widespread nutrient deficiency or to balance the total nutrient profile of a food.

fossil fuels: coal, oil, and natural gas.

fraudulent: the promotion, for financial gain, of devices, treatments, services, plans, or products (including diets and supplements) that alter or claim to alter a human condition without proof of safety or effectiveness.

free: "nutritionally trivial" and unlikely to have a physiological consequence; synonyms include *without, no,* and *zero*. A food that does not contain a nutrient naturally may make such a claim, but only as it applies to all similar foods (for example, "applesauce, a fat-free food").

free radical: an unstable molecule with one or more unpaired electrons.

frequency: the number of occurrences per unit of time (for example, the number of activity sessions per week).

fructose (FRUK-tose or FROOK-tose): a monosaccharide; sometimes known as *fruit sugar* or *levulose*. Fructose is found abundantly in fruits, honey, and saps.

fuel: compounds that cells can use for energy. The major fuels include glucose, fatty acids, and amino acids; other fuels include ketone bodies, lactate, glycerol, and alcohol.

full term: between the thirty-eighth and forty-second week of pregnancy.

functional foods: whole, fortified, or modified foods that contain physiologically active compounds that provide health benefits beyond their nutrient contributions; sometimes called *designer foods* or *nutraceuticals*.

G

g: grams; a unit of weight equivalent to about 0.03 ounces.

galactose (ga-LAK-tose): a monosaccharide; part of the disaccharide lactose.

gallbladder: the organ that stores and concentrates bile. When it receives the signal that fat is present in the duodenum, the gallbladder contracts and squirts bile through the bile duct into the duodenum.

gangrene (GANG-green): death of tissue, usually due to insufficient blood supply.

gastric glands: exocrine glands in the stomach wall that secrete gastric juice into the stomach.

gastric juice: the digestive secretion of the gastric glands of the stomach.

gastrin: a hormone secreted by cells in the stomach wall. Target organ: the glands of the stomach. Response: secretion of gastric acid.

gastroesophageal reflux: the backflow of stomach acid into the esophagus, causing damage to the cells of the esophagus and the sensation of heartburn; commonly known as *heartburn* or *acid indigestion*.

gastroesophageal reflux disease (GERD): a condition characterized by the backflow of stomach acid into the esophagus two or more times a week.

gastrointestinal (GI) tract: the digestive tract. The principal organs are the stomach and intestines.

gatekeepers: with respect to nutrition, key people who control other people's access to foods and thereby exert profound impacts on their nutrition. Examples are the spouse who buys and cooks the food, the parent who feeds the children, and the caregiver in a day-care center.

gene expression: the process by which a cell converts the genetic code into RNA and protein.

gene pool: all the genetic information of a population at a given time.

generally recognized as safe (GRAS): food additives that have long been in use and are believed to be safe. First established by the FDA in 1958, the GRAS list is subject to revision as new facts become known.

genes: sections of chromosomes that contain the instructions needed to make one or more proteins.

genetic engineering: the use of biotechnology to modify the genetic material of living cells so that they will produce new substances or perform new functions. Foods produced via this technology are called *genetically modified (GM)* or *genetically engineered (GE) foods*.

genetics: the study of genes and inheritance.

genome (GEE-nome): the complete set of genetic material (DNA) in an organism or a cell. The study of genomes is called *genomics*.

genomics: the study of all the genes in an organism and their interactions with environmental factors.

genotoxicant: a substance that mutates or damages genetic material.

geophagia: the specific craving for nonfood items such as clay, baby powder, chalk, ash, ceramics, paper, paint chips, charcoal, or dirt.

germ: the seed that grows into a mature plant, especially rich in vitamins and minerals.

gestation (jes-TAY-shun): the period from conception to birth. For human beings, the average length of a healthy gestation is 40 weeks. Pregnancy is often divided into 3-month periods, called *trimesters*.

gestational diabetes: glucose intolerance with onset or first recognition during pregnancy.

gestational hypertension: high blood pressure that develops in the second half of pregnancy and resolves after childbirth, usually without affecting the outcome of the pregnancy.

ghrelin (GRELL-in): a protein produced by the stomach cells that enhances appetite and decreases energy expenditure.

glands: cells or groups of cells that secrete materials for special uses in the body. Glands may be *exocrine* (EKS-oh-crin) *glands*, secreting their materials "out" (into the digestive tract or onto the surface of the skin), or *endocrine* (EN-doe-crin) *glands*, secreting their materials "in" (into the blood).

glossitis (gloss-EYE-tis): an inflammation of the tongue.

glucagon (GLOO-ka-gon): a hormone secreted by special cells in the pancreas in response to low blood glucose concentration. Glucagon elicits its release of glucose from liver glycogen stores.

glucocorticoids: hormones from the adrenal cortex that affect the body's management of glucose.

glucogenic amino acids: amino acids that can make glucose via either pyruvate or TCA cycle intermediates.

gluconeogenesis (gloo-ko-nee-oh-JEN-ih-sis): the making of glucose from a noncarbohydrate source such as amino acids or glycerol.

glucose (GLOO-kose): a monosaccharide; sometimes known as *blood sugar* in the body or *dextrose* in foods.

glucose polymers: compounds that supply glucose, not as single molecules, but linked in chains somewhat like starch. The objective is to attract less water from the body into the digestive tract (osmotic attraction depends on the number, not the size, of particles).

glucose tolerance factors (GTF): small organic compounds that enhance insulin's actions.

glycemic (gly-SEEM-ic) **index:** a method of classifying foods according to their potential for raising blood glucose.

glycemic response: the extent to which a food raises the blood glucose concentration and elicits an insulin response.

glycerol (GLISS-er-ol): an alcohol composed of a three-carbon chain, which can serve as the backbone for a triglyceride.

glycogen (GLY-ko-jen): an animal polysaccharide composed of glucose; a storage form of glucose manufactured and stored in the liver and muscles. Glycogen is not a significant food source of carbohydrate and is not counted as a dietary carbohydrate in foods.

glycolysis (gly-COLL-ih-sis): the metabolic breakdown of glucose to pyruvate. Glycolysis does not require oxygen (anaerobic).

goblet cells: cells of the GI tract (and lungs) that secrete mucus.

goiter (GOY-ter): an enlargement of the thyroid gland due to an iodine deficiency, malfunction of the gland, or overconsumption of a goitrogen. Goiter caused by iodine deficiency is *simple goiter*.

goitrogen (GOY-troh-jen): a substance that enlarges the thyroid gland and causes *toxic goiter*. Goitrogens occur naturally in such foods as cabbage, kale, brussels sprouts, cauliflower, broccoli, and kohlrabi.

Golgi (GOAL-gee) **apparatus:** a set of membranes within the cell where secretory materials are packaged for export.

good source of: the product provides between 10 and 19 percent of the Daily Value for a given nutrient per serving.

gout (GOWT): a common form of arthritis characterized by deposits of uric acid crystals in the joints.

growth hormone (GH): a hormone secreted by the pituitary that regulates the cell division and protein synthesis needed for normal growth; also called *somatotropin*. The release of GH is mediated by *GH-releasing hormone (GHRH)* and *GH-inhibiting hormone*.

hard water: water with a high calcium and magnesium content.

Hazard Analysis Critical Control Points (HACCP): a systematic plan to identify and correct potential microbial hazards in the manufacturing, distribution, and commercial use of food products; commonly referred to as "HASS-ip."

hazard: a source of danger; used to refer to circumstances in which harm is possible under normal conditions of use.

HDL (high-density lipoprotein): the type of lipoprotein that transports cholesterol back to the liver from the cells; composed primarily of protein.

health claims: statements that characterize the relationship between a nutrient or other substance in a food and a disease or health-related condition.

health history: an account of a client's current and past health status and disease risks.

healthy: on food labels, a food that is low in fat, saturated fat, cholesterol, and sodium and that contains at least 10 percent of the Daily Values for vitamin A, vitamin C, iron, calcium, protein, or fiber.

Healthy Eating Index: a measure that assesses how well a diet meets the recommendations of the *Dietary Guidelines for Americans* and MyPlate.

Healthy People: a national public health initiative under the jurisdiction of the US Department of Health and Human Services (DHHS) that identifies the most significant preventable threats to health and focuses efforts toward eliminating them.

heart attack: sudden tissue death caused by blockages of vessels that feed the heart muscle; also called *myocardial* (my-oh-KAR-dee-al) *infarction* (in-FARK-shun) or *cardiac arrest.*

heartburn: a burning sensation in the chest area caused by backflow of stomach acid into the esophagus; medically known as *gastroesophageal reflux.*

heat stroke: a dangerous accumulation of body heat with accompanying loss of body fluid.

heavy drinking: consuming an average of more than one drink per day for women and more than two drinks per day for men.

heavy metals: mineral ions such as mercury and lead, so called because they are of relatively high atomic weight. Many heavy metals are poisonous.

Heimlich (HIME-lick) **maneuver (abdominal thrusts):** a technique for dislodging an object from the trachea of a choking person; named for the physician who developed it.

hematocrit (hee-MAT-oh-krit): the percentage of total blood volume that consists of red blood cells.

heme (HEEM) **iron:** the iron in foods that is bound to the hemoglobin and myoglobin proteins; found only in meat, fish, and poultry.

hemochromatosis (HE-moh-KRO-ma-toe-sis): a genetically determined failure to prevent absorption of unneeded dietary iron that is characterized by iron overload and tissue damage.

hemoglobin (HE-moh-GLO-bin): the oxygen-carrying protein of the red blood cells that transports oxygen from the lungs to tissues throughout the body; hemoglobin accounts for 80 percent of the body's iron.

hemolytic (HE-moh-LIT-ick) **anemia:** the condition of having too few red blood cells as a result of erythrocyte hemolysis.

hemophilia (HE-moh-FEEL-ee-ah): a hereditary disease in which the blood is unable to clot because it lacks the ability to synthesize certain clotting factors.

hemorrhagic (hem-oh-RAJ-ik) **disease:** a disease characterized by excessive bleeding.

hemorrhoids (HEM-oh-royds): painful swelling of the veins surrounding the rectum.

hemosiderin (heem-oh-SID-er-in): an iron-storage protein primarily made in times of iron overload.

hepatic portal vein: the vein that collects blood from the GI tract and conducts it to the liver.

hepatic vein: the vein that collects blood from the liver and returns it to the heart.

hepcidin: a hormone produced by the liver that regulates iron balance.

herbal (ERB-al) **medicine:** the use of plants to treat disease or improve health; also known as *botanical medicine* or *phytotherapy.*

hGH (human growth hormone): a hormone produced by the brain's pituitary gland that regulates normal growth and development; also called *somatotropin.*

high: on food labels, 20 percent or more of the Daily Value for a given nutrient per serving; synonyms include *rich in* or *excellent source.*

high fiber: 5 grams or more of fiber per serving. A high-fiber claim made on a food that contains more than 3 grams of fat per serving and per 100 grams of food must also declare total fat.

high food security: no indications of food-access problems or limitations.

high potency: One hundred percent or more of the Daily Value for the nutrient in a single supplement and for at least two-thirds of the nutrients in a multinutrient supplement.

high-fructose corn syrup (HFCS): a syrup made from cornstarch that has been treated with an enzyme that converts some of the glucose to the sweeter fructose; made especially for use in processed foods and beverages, where it is the predominant sweetener.

high-quality proteins: dietary proteins containing all the essential amino acids in relatively the same amounts that human beings require. They may also contain nonessential amino acids.

high-risk pregnancy: a pregnancy characterized by indicators that make it likely the birth will be surrounded by problems such as premature delivery, difficult birth, restricted growth, birth defects, and early infant death.

histamine (HISS-tah-mean or HISS-tah-men): a substance produced by cells of the immune system as part of a local immune reaction to an antigen.

HIV (human immunodeficiency virus): the virus that destroys lymphocytes and impairs immunity, eventually causing AIDS.

HMB (beta-hydroxybetamethylbutyrate): a metabolite of the branched-chain amino acid leucine promoted to increase muscle mass and strength.

homeopathy (hoh-me-OP-ah-thee): a practice based on the theory that "like cures like," that is, that substances that cause symptoms in healthy people can cure those symptoms when given in very dilute amounts.

homeostasis (HOME-ee-oh-STAY-sis): the maintenance of constant internal conditions (such as blood chemistry, temperature, and blood pressure) by the body's control systems. A homeostatic system is constantly reacting to external forces to maintain limits set by the body's needs.

honey: sugar (mostly sucrose) formed from nectar gathered by bees. Composition and flavor vary, but honey always contains a mixture of sucrose, fructose, and glucose.

hormones: chemical messengers. Hormones are secreted by a variety of glands in response to altered conditions in the body. Each hormone travels to one or more specific target tissues or organs, where it elicits a specific response to maintain homeostasis.

hormone-sensitive lipase: an enzyme inside adipose cells that responds to the body's need for fuel by hydrolyzing triglycerides so that their parts (glycerol and fatty acids) enter the general circulation and thus become available to other cells for fuel. The signals to which this enzyme responds include epinephrine and glucagon, which oppose insulin.

hourly sweat rate: the amount of weight lost plus fluid consumed during exercise per hour. One pound equals roughly 2 cups (500 milliliters) of fluid.

human carrying capacity: the maximum number of people the earth can support over time.

human genome (GEE-nome): the complete set of genetic material (DNA) in a human being.

hunger: the painful sensation caused by a lack of food that initiates food-seeking behavior; a consequence of food insecurity that, because of prolonged, involuntary lack of food, results in discomfort, illness, weakness, or pain that goes beyond the usual uneasy sensation.

husk: the outer inedible part of a grain; also called the *chaff*.

hydrochloric acid: an acid composed of hydrogen and chloride atoms (HCl) that is normally produced by the gastric glands.

hydrogenation (HIGH-dro-jen-AY-shun or high-DROJ-eh-NAY-shun): a chemical process by which hydrogens are added to monounsaturated or polyunsaturated fatty acids to reduce the number of double bonds, making the fats more saturated (solid) and more resistant to oxidation (protecting against rancidity). Hydrogenation produces *trans*-fatty acids.

hydrolysis (high-DROL-ih-sis): a chemical reaction in which one molecule is split into two molecules, with hydrogen (H) added to one and a hydroxyl group (OH) added to the other (from water, H_2O).

hydrophilic (high-dro-FIL-ick): a term referring to water-loving, or water-soluble, substances.

hydrophobic (high-dro-FOE-bick): a term referring to water-fearing, or non-water-soluble, substances; also known as *lipophilic* (fat loving).

hydrotherapy: the use of water (in whirlpools, as douches, or packed as ice, for example) to promote relaxation and healing.

hydroxyapatite (high-drox-ee-APP-ah-tite): crystals made of calcium and phosphorus.

hyperactivity: inattentive and impulsive behavior that is more frequent and severe than is typical of others a similar age; professionally called *attention-deficit/hyperactivity disorder (ADHD)*.

hypercalcemia: high blood calcium that may develop from a variety of disorders, including vitamin D toxicity. It does *not* develop from a high calcium intake.

hyperglycemia: elevated blood glucose concentrations.

hyperplastic obesity: obesity due to an increase in the *number* of fat cells.

hypertension: consistently higher-than-normal blood pressure. Hypertension that develops without an identifiable cause is known as *essential* or *primary hypertension;* hypertension that is caused by a specific disorder such as kidney disease is known as *secondary hypertension*.

hyperthermia: an above-normal body temperature.

hypertrophic obesity: obesity due to an increase in the *size* of fat cells.

hypertrophy (high-PER-tro-fee): growing larger; with regard to muscles, an increase in size (and strength) in response to use.

hypnotherapy: a technique that uses hypnosis and the power of suggestion to improve health behaviors, relieve pain, and heal.

hypoglycemia (HIGH-po-gly-SEE-me-ah): an abnormally low blood glucose concentration.

hyponatremia (HIGH-poe-na-TREE-mee-ah): a decreased concentration of sodium in the blood.

hypothalamus (high-po-THAL-ah-mus): a brain center that controls activities such as maintenance of water balance, regulation of body temperature, and control of appetite.

hypothermia: a below-normal body temperature.

hypothesis (hi-POTH-eh-sis): an unproven statement that tentatively explains the relationships between two or more variables.

hypothyroidism: underactivity of the thyroid gland that may be caused by iodine deficiency or any number of other causes.

I

ileocecal (ill-ee-oh-SEEK-ul) **valve:** the sphincter separating the small and large intestines.

ileum (ILL-ee-um): the last segment of the small intestine.

imagery: a technique that guides clients to achieve a desired physical, emotional, or spiritual state by visualizing themselves in that state.

imitation foods: foods that substitute for and resemble another food, but are nutritionally inferior to it with respect to vitamin, mineral, or protein content. If the substitute is not inferior to the food it resembles and if its name provides an accurate description of the product, it need not be labeled "imitation."

immune response: the body's reaction to foreign antigens, which neutralizes or eliminates them, thus preventing damage.

immune system: the body's natural defense against foreign materials that have penetrated the skin or mucous membranes.

immunity: the body's ability to defend itself against diseases.

immunoglobulins (IM-you-noh-GLOB-you-linz): proteins capable of acting as antibodies.

implantation (IM-plan-TAY-shun): the embedding of the blastocyst in the inner lining of the uterus.

indigestion: incomplete or uncomfortable digestion, usually accompanied by pain, nausea, vomiting, heartburn, intestinal gas, or belching.

indirect calorimetry: a means of estimating energy expenditure by measuring the amount of oxygen consumed.

indirect or **incidental additives:** substances that can get into food as a result of contact during growing, processing, packaging, storing, cooking, or some other stage before the foods are consumed; sometimes called *accidental additives*.

indispensable amino acids: essential amino acids.

indispensable nutrients: nutrients a person must obtain from food because the body cannot synthesize them in amounts sufficient to meet physiological needs; also called *essential nutrients*.

infectious diseases: diseases caused by bacteria, viruses, parasites, or other microorganisms that can be transmitted from one person to another through air, water, or food; by contact; or through vector organisms such as mosquitoes.

inflammation: an immunological response to cellular injury characterized by an increase in white blood cells.

initiators: factors that cause mutations that give rise to cancer, such as radiation and carcinogens.

inorganic: not containing carbon or pertaining to living things.

inositol (in-OSS-ih-tall): a nonessential nutrient that can be made in the body from glucose. Inositol is a part of cell membrane structures.

insoluble fibers: nonstarch polysaccharides that do not dissolve in water. Examples include the tough, fibrous structures found in the strings of celery and the skins of corn kernels.

insulin (IN-suh-lin): a hormone secreted by special cells in the pancreas in response to (among other things) elevated blood glucose concentration. Insulin controls the transport of glucose from the bloodstream into the muscle and fat cells.

insulin resistance: the condition in which a normal amount of insulin produces a subnormal effect in muscle, adipose, and liver cells, resulting in an elevated fasting glucose; a metabolic consequence of obesity that precedes type 2 diabetes.

integrative medicine: care that combines conventional and complementary therapies for which there is some high-quality scientific evidence of safety and effectiveness. Integrative medicine emphasizes the importance of the relationship between the practitioner and the patient and focuses on wellness, healing, and the whole person.

intensity: the degree of exertion while exercising (for example, the amount of weight lifted or the speed of running).

intentional food additives: additives intentionally added to foods, such as nutrients, colors, and preservatives.

intermittent claudication (klaw-dih-KAY-shun): severe calf pain caused by inadequate blood supply. It occurs when walking and subsides during rest.

Internet (the Net): a worldwide network of millions of computers linked together to share information.

interstitial (IN-ter-STISH-al) **fluid:** fluid between the cells (intercellular), usually high in sodium and chloride. Interstitial fluid is a large component of extracellular fluid.

intestinal ischemia (is-KEY-me-ah): a diminished blood flow to the intestines that is characterized by abdominal pain, forceful bowel movements, and blood in the stool.

intra-abdominal fat: fat stored within the abdominal cavity in association with the internal abdominal organs, as opposed to the fat stored directly under the skin (subcutaneous fat); also called *visceral fat.*

intracellular fluid: fluid within the cells, usually high in potassium and phosphate. Intracellular fluid accounts for approximately two-thirds of the body's water.

intrinsic factor: a glycoprotein (a protein with short polysaccharide chains attached) secreted by the stomach cells that binds with vitamin B_{12} in the small intestine to aid in the absorption of vitamin B_{12}.

invert sugar: a mixture of glucose and fructose formed by the hydrolysis of sucrose in a chemical process; sold only in liquid form and sweeter than sucrose. Invert sugar is used as a food additive to help preserve freshness and prevent shrinkage.

iodide: the ion form of iodine.

iodine: an essential trace mineral that is needed for the synthesis of thyroid hormones.

ions (EYE-uns): atoms or molecules that have gained or lost electrons and therefore have electrical charges. Examples include the positively charged sodium ion (Na^+) and the negatively charged chloride ion (Cl^-).

iridology: the study of changes in the iris of the eye and their relationships to disease.

iron: an essential trace mineral that is needed for the transport of oxygen and the metabolism of energy nutrients.

iron deficiency: the state of having depleted iron stores.

iron overload: toxicity from excess iron.

iron-deficiency anemia: severe depletion of iron stores that results in low hemoglobin and small, pale red blood cells. Anemias that impair hemoglobin synthesis are *microcytic* (small cell).

irradiation: sterilizing a food by exposure to energy waves, similar to ultraviolet light and microwaves; sometimes called *ionizing radiation.*

irritable bowel syndrome: an intestinal disorder of unknown cause. Symptoms include abdominal discomfort and cramping, diarrhea, constipation, or alternating diarrhea and constipation.

IU: international units; a measure of vitamin activity used before direct chemical analysis was available.Many fortified foods and supplements use IU on their labels.

J

jejunum (je-JOON-um): the first two-fifths of the small intestine beyond the duodenum.

joule: a measure of *work* energy; the amount of energy expended when 1 kilogram is moved 1 meter by a force of 1 newton.

K

kcal: abbreviation of kcalories; a unit by which energy is measured.

kcalorie: a unit by which energy is measured. One kcalorie is the amount of heat necessary to raise the temperature of 1 kilogram (kg) of water 1°C. The scientific use of the term *kcalorie* is the same as the popular use of the term *calorie.*

kcalorie (energy) control: management of food energy intake.

kcalorie-free: fewer than 5 kcalories per serving.

kefir (keh-FUR): a fermented milk created by adding *Lactobacillus acidophilus* and other bacteria that break down lactose to glucose and galactose, producing a sweet, lactose-free product.

keratin (KARE-uh-tin): a water-insoluble protein; the normal protein of hair and nails.

keratinization: accumulation of keratin in a tissue; a sign of vitamin A deficiency.

keratomalacia (KARE-ah-toe-ma-LAY-shuh): softening of the cornea that leads to irreversible blindness; a sign of severe vitamin A deficiency.

Keshan (KESH-an or ka-SHAWN) **disease:** the heart disease associated with selenium deficiency; named for one of the provinces of China where it was first studied. Keshan disease is characterized by heart enlargement and insufficiency; fibrous tissue replaces the muscle tissue that normally composes the middle layer of the walls of the heart.

keto (KEY-toe) **acid:** an organic acid that contains a carbonyl group (C=O).

ketogenic amino acids: amino acids that are degraded to acetyl CoA.

ketone (KEE-tone) **bodies:** compounds produced during the incomplete breakdown of fat when glucose is not available in the cells.

ketosis (kee-TOE-sis): an undesirably high concentration of ketone bodies in the blood and urine.

Kreb's cycle: named after the scientist who elucidated this biochemistry, a series of metabolic reactions that break down molecules of acetyl CoA to carbon dioxide and hydrogen atoms; also called the *citric acid cycle* or the *TCA cycle.*

kwashiorkor (kwash-ee-OR-core or kwash-ee-or-CORE): severe malnutrition characterized by failure to grow and develop, edema, changes in the pigmentation of hair and skin, fatty liver, anemia, and apathy.

L

lactadherin (lack-tad-HAIR-in): a protein in breast milk that attacks diarrhea-causing viruses.

lactase deficiency: a lack of the enzyme required to digest the disaccharide lactose into its component monosaccharides (glucose and galactose).

lactase: an enzyme that hydrolyzes lactose.

lactate: a 3-carbon compound produced from pyruvate during anaerobic metabolism.

lactation: production and secretion of breast milk for the purpose of nourishing an infant.

lacteals (LACK-tee-als): the lymphatic vessels of the intestine that take up nutrients and pass them to the lymph circulation.

lactoferrin (lack-toh-FERR-in): a protein in breast milk that binds iron and keeps it from supporting the growth of the infant's intestinal bacteria.

lacto-ovo-vegetarians: people who include milk, milk products, and eggs, but exclude meat, poultry, and seafood from their diets.

lactose (LAK-tose): a disaccharide composed of glucose and galactose; commonly known as *milk sugar.*

lactose intolerance: a condition that results from the inability to digest the milk sugar lactose; characterized by bloating, gas, abdominal discomfort, and diarrhea. Lactose intolerance differs from milk allergy, which is caused by an immune reaction to the protein in milk.

lactovegetarians: people who include milk and milk products, but exclude meat, poultry, seafood, and eggs from their diets.

large intestine or colon (COAL-un): the lower portion of intestine that completes the digestive process. Its segments are the *ascending colon*, the *transverse colon*, the *descending colon*, and the *sigmoid colon*.

larynx: the upper part of the air passageway that contains the vocal cords; also called the *voice box*.

laxatives: substances that loosen the bowels and thereby prevent or treat constipation.

LDL (low-density lipoprotein): the type of lipoprotein derived from very-low-density lipoproteins (VLDL) as triglycerides are removed and broken down; composed primarily of cholesterol.

lean: less than 10 grams of fat, 4.5 grams of saturated fat and *trans* fat combined, and 95 milligrams of cholesterol per serving and per 100 grams of meat, poultry, and seafood.

lean body mass: the body minus its fat.

lecithin (LESS-uh-thin): one of the phospholipids. Both nature and the food industry use lecithin as an emulsifier to combine water-soluble and fat-soluble ingredients that do not ordinarily mix, such as water and oil.

legumes (lay-GYOOMS or LEG-yooms): plants of the bean and pea family, with seeds that are rich in protein compared with other plant-derived foods.

leptin: a protein produced by fat cells under direction of the *ob* gene that decreases appetite and increases energy expenditure.

less: on food labels, at least 25 percent less of a given nutrient or kcalories than the comparison food; synonyms include *fewer* and *reduced*.

less cholesterol: 25 percent or less cholesterol than the comparison food (reflecting a reduction of at least 20 milligrams per serving), and 2 grams or less saturated fat and *trans* fat combined per serving.

less fat: 25 percent or less fat than the comparison food.

less saturated fat: 25 percent or less saturated fat and *trans* fat combined than the comparison food.

let-down reflex: the reflex that forces milk to the front of the breast when the infant begins to nurse.

levulose: an older name for fructose.

license to practice: permission under state or federal law, granted on meeting specified criteria, to use a certain title (such as dietitian) and offer certain services. Licensed dietitians may use the initials LD after their names.

life expectancy: the average number of years lived by people in a given society.

life span: the maximum number of years of life attainable by a member of a species.

light or lite: one-third fewer kcalories than the comparison food; 50 percent or less of the fat or sodium than the comparison food; any use of the term other than as defined must specify what it is referring to (for example, "light in color" or "light in texture").

lignans: phytochemicals present in flaxseed that are converted to phytosterols by intestinal bacteria and are under study as possible anticancer agents.

limiting amino acid: the essential amino acid found in the shortest supply relative to the amounts needed for protein synthesis in the body. Four amino acids are most likely to be limiting: lysine, methionine, threonine, and tryptophan.

lingual: pertaining to the tongue.

linoleic (lin-oh-LAY-ick) **acid:** an essential fatty acid with 18 carbons and two double bonds.

linolenic (lin-oh-LEN-ick) **acid:** an essential fatty acid with 18 carbons and three double bonds.

lipase (LYE-pase): an enzyme that hydrolyzes lipids (fats). *Lingual lipase* refers to the fat-digesting enzyme secreted from the salivary gland at the base of the tongue.

lipids: a family of compounds that includes triglycerides, phospholipids, and sterols. Lipids are characterized by their insolubility in water. (Lipids also include the fat-soluble vitamins, described in Chapter 11.)

lipoprotein lipase (LPL): an enzyme that hydrolyzes triglycerides passing by in the bloodstream and directs their parts into the cells, where they can be metabolized for energy or reassembled for storage.

lipoprotein-associated phospholipase A(2) or **Lp-PLA(2):** a lipoprotein-bound enzyme that generates potent proinflammatory and proatherogenic products such as oxidized free fatty acids and lysophosphatidylcholine. Lp-PLA(2) is a specific marker of plaque inflammation.

lipoproteins (LIP-oh-PRO-teenz): clusters of lipids associated with proteins that serve as transport vehicles for lipids in the lymph and blood.

lipotoxicity: the adverse effects of fat in nonadipose tissues.

liquor or distilled spirits: an alcoholic beverage traditionally made by fermenting and distilling a carbohydrate source such as molasses, potatoes, rye, beets, barley, or corn.

listeriosis: an infection caused by eating food contaminated with the bacterium *Listeria monocytogenes*, which can be killed by pasteurization and cooking but can survive at refrigerated temperatures; certain ready-to-eat foods, such as hot dogs and deli meats, may become contaminated after cooking or processing, but before packaging.

liver: the organ that manufactures bile. (The liver's many other functions are described in Chapter 7.)

longevity: long duration of life.

low: on food labels, an amount that would allow frequent consumption of a food without exceeding the Daily Value for the nutrient. A food that is naturally low in a nutrient may make such a claim, but only as it applies to all similar foods (for example, "fresh cauliflower, a low-sodium food"); synonyms include *little, few,* and *low source of.*

low birthweight (LBW): a birthweight of 5½ pounds (2500 grams) or less; indicates probable poor health in the newborn and poor nutrition status in the mother during pregnancy, before pregnancy, or both. Optimal birthweight for a full-term baby is 6.8 to 7.9 pounds (about 3100 to 3600 grams).

low cholesterol: 20 milligrams or less cholesterol per serving and 2 grams or less saturated fat and *trans* fat combined per serving.

low fat: 3 grams or less fat per serving.

low food security: reduced quality of life with little or no indication of reduced food intake; formerly known as *food insecurity without hunger.*

low kcalorie: 40 kcalories or less per serving.

low saturated fat: 1 gram or less saturated fat and less than 0.5 gram of *trans* fat per serving.

low sodium: 140 milligrams or less per serving.

low-risk pregnancy: a pregnancy characterized by factors that make it likely the birth will be normal and the infant healthy.

lumen (LOO-men): the space within a vessel, such as the intestine.

lutein (LOO-teen): a plant pigment of yellow hue; a phytochemical believed to play roles in eye functioning and health.

luteinizing (LOO-tee-in-EYE-zing) **hormone (LH):** a hormone that stimulates ovulation and the development of the corpus luteum (the small tissue that develops from a ruptured ovarian follicle and secretes hormones); so called because the follicle turns yellow as it matures. In men, LH stimulates testosterone secretion. The release of LH is mediated by *luteinizing hormone–releasing hormone (LH–RH).*

lycopene (LYE-koh-peen): a pigment responsible for the red color of tomatoes and other red-hued vegetables; a phytochemical that may act as an antioxidant in the body.

lymph (LIMF): a clear yellowish fluid that is similar to blood except that it contains no red blood cells or platelets. Lymph from the GI tract transports fat and fat-soluble vitamins to the bloodstream via lymphatic vessels.

lymphatic (lim-FAT-ic) **system:** a loosely organized system of vessels and ducts that convey fluids toward the heart. The GI part of the lymphatic system carries the products of fat digestion into the bloodstream.

lymphocytes (LIM-foh-sites): white blood cells that participate in acquired immunity; B-cells and T-cells.

lysosomes (LYE-so-zomes): cellular organelles; membrane-enclosed sacs of degradative enzymes.

M

macrobiotic diet: a philosophical approach of eating mostly plant-based foods such as whole grains, legumes, and vegetables, with small amounts of fish, fruits, nuts, and seeds.

macrocytic: abnormally large blood cells.

macronutrients: carbohydrate, fat, and protein; the nutrients the body requires in relatively large amounts (many grams daily).

macrophages (MAK-roe-fay-jez): large phagocytic cells that serve as scavengers of the blood, cleaning it of old or abnormal cells, cellular debris, and antigens.

macrosomia (mak-roh-SO-me-ah): abnormally large body size. In the case of infants, a birthweight at the 90th percentile or higher for gestational age (roughly 9 lb—or 4000 g—or more); macrosomia results from prepregnancy obesity, excessive weight gain during pregnancy, or uncontrolled gestational diabetes.

macular (MACK-you-lar) **degeneration:** deterioration of the macular area of the eye that can lead to loss of central vision and eventual blindness. The *macula* is a small, oval, yellowish region in the center of the retina that provides the sharp, straight-ahead vision so critical to reading and driving.

magnesium: a cation within the body's cells, active in many enzyme systems.

major minerals: essential mineral nutrients the human body requires in relatively large amounts (greater than 100 milligrams per day); sometimes called *macrominerals.*

malignant (ma-LIG-nant): describes a cancerous cell or tumor, which can injure healthy tissue and spread cancer to other regions of the body.

malnutrition: any condition caused by excess or deficient food energy or nutrient intake or by an imbalance of nutrients.

maltase: an enzyme that hydrolyzes maltose.

maltose (MAWL-tose): a disaccharide composed of two glucose units; sometimes known as *malt sugar.*

mammary glands: glands of the female breast that secrete milk.

manganese: an essential trace mineral that acts as a cofactor for many enzymes.

maple sugar: a sugar (mostly sucrose) purified from the concentrated sap of the sugar maple tree.

marasmus (ma-RAZ-mus): severe malnutrition characterized by poor growth, dramatic weight loss, loss of body fat and muscle, and apathy.

margin of safety: when speaking of food additives, a zone between the concentration normally used and that at which a hazard exists. For common table salt, for example, the margin of safety is 1/5 (five times the amount normally used would be hazardous).

marginal food security: one or two indications of food-access problems but with little or no change in food intake.

massage therapy: a healing method in which the therapist manually kneads muscles to reduce tension, increase blood circulation, improve joint mobility, and promote healing of injuries.

mastication: the process of chewing.

matrix (MAY-tricks): the basic substance that gives form to a developing structure; in the body, the formative cells from which teeth and bones grow.

matter: anything that takes up space and has mass.

Meals on Wheels: a nutrition program that delivers food for the elderly to their homes.

meat replacements: products formulated to look and taste like meat, fish, or poultry; usually made of textured vegetable protein.

meditation: a self-directed technique of relaxing the body and calming the mind.

megaloblastic: abnormally large blood cells.

menadione (men-uh-DYE-own): the synthetic form of vitamin K.

Menkes disease: a genetic disorder of copper transport that creates a copper deficiency and results in mental retardation, poor muscle tone, seizures, brittle kinky hair, and failure to thrive.

MEOS or **microsomal** (my-krow-SO-mal) **ethanol oxidizing system:** a system of enzymes in the liver that oxidize not only alcohol but also several classes of drugs.

metabolic syndrome: a combination of risk factors—insulin resistance, hypertension, abnormal blood lipids, and abdominal obesity—that greatly increase a person's risk of developing coronary heart disease; also called *Syndrome X, insulin resistance syndrome,* or *dysmetabolic syndrome.*

metabolic water: water generated during metabolism.

metabolism: the sum total of all the chemical reactions that go on in living cells. *Energy metabolism* includes all the reactions by which the body obtains and expends the energy from food.

metalloenzymes (meh-TAL-oh-EN-zimes): enzymes that contain one or more minerals as part of their structures.

metallothionein (meh-TAL-oh-THIGH-oh-neen): a sulfur-rich protein that avidly binds with and transports metals such as zinc.

metastasize (me-TAS-tah-size): the spread of cancer from one part of the body to another.

methylation: the addition of a methyl group (CH_3).

MFP factor: a peptide released during the digestion of meat, fish, and poultry that enhances nonheme iron absorption.

mg NE: milligrams niacin equivalents; a measure of niacin activity.

mg: milligrams; one-thousandth of a gram.

micelles (MY-cells): tiny spherical complexes of emulsified fat that arise during digestion; most contain bile salts and the products of lipid digestion, including fatty acids, monoglycerides, and cholesterol.

microangiopathies: disorders of the small blood vessels.

microarray technology: research tools that analyze the expression of thousands of genes simultaneously and search for particular gene changes associated with a disease. DNA microarrays are also called *DNA chips.*

microcytic (my-cro-SIT-ic) **hypochromic** (high-po-KROME-ic) **anemia:** small, pale red blood cells that develop in iron-deficiency anemia.

microgram (µg): one-millionth of a gram.

microgram DFE (µg DFE): micrograms dietary folate equivalents; a measure of folate activity.

microgram (µg RAE): micrograms retinol activity equivalents; a measure of vitamin A activity.

micronutrients: vitamins and minerals; the nutrients the body requires in relatively small amounts (milligrams or micrograms daily).

microvilli (MY-cro-VILL-ee or MY-cro-VILL-eye): tiny, hairlike projections on each cell of every villus that can trap nutrient particles and transport them into the cells; singular *microvillus.*

milk anemia: iron-deficiency anemia that develops when an excessive milk intake displaces iron-rich foods from the diet.

milliequivalents per liter (mEq/L): the concentration of electrolytes in a volume of solution. Milliequivalents are a useful measure when considering ions because the number of charges reveals characteristics about the solution that are not evident when the concentration is expressed in terms of weight.

mineral oil: a purified liquid derived from petroleum and used to treat constipation.

mineral water: water from a spring or well that naturally contains at least 250 to 500 parts per million (ppm) of minerals. Minerals give water a distinctive flavor. Many mineral waters are high in sodium.

mineralization: the process in which calcium, phosphorus, and other minerals crystallize on the collagen matrix of a growing bone, hardening the bone.

minerals: inorganic elements. Some minerals are essential nutrients required in small amounts by the body for health.

misinformation: false or misleading information.

mitochondria (my-toh-KON-dree-uh): the cellular organelles made of membranes (lipid and protein) with enzymes mounted on them that are responsible for producing ATP aerobically; the singular is *mitochondrion*.

mmol: millimoles; one-thousandth of a mole, the molecular weight of a substance. To convert mmol to mg, multiply by the atomic weight of the substance.

moderate-intensity physical activity: physical activity that requires some increase in breathing and/or heart rate and expends 3.5 to 7 kcalories per minute. Walking at a speed of 3 to 4.5 miles per hour (about 15 to 20 minutes to walk 1 mile) is an example.

moderation (alcohol): up to one drink per day for women with no more than three drinks on any single day and up to two drinks per day for men with no more than four drinks on any single day.

moderation (dietary): providing enough but not too much of a substance.

molasses: the thick brown syrup produced during sugar refining. Molasses retains residual sugar and other by-products and a few minerals; blackstrap molasses contains significant amounts of calcium and iron.

molecule: two or more atoms of the same or different elements joined by chemical bonds. Examples are molecules of the element oxygen, composed of two oxygen atoms (O_2), and molecules of the compound water, composed of two hydrogen atoms and one oxygen atom (H_2O).

molybdenum (mo-LIB-duh-num): an essential trace mineral that acts as a cofactor for many enzymes.

monoglycerides: molecules of glycerol with one fatty acid attached. A molecule of glycerol with two fatty acids attached is a *diglyceride*.

monosaccharides (mon-oh-SACK-uh-rides): carbohydrates of the general formula $C_nH_{2n}O_n$ that typically form a single ring. The monosaccharides important in nutrition are *hexoses*, sugars with six atoms of carbon and the formula $C_6H_{12}O_6$.

monosodium glutamate (MSG): a sodium salt of the amino acid glutamic acid commonly used as a flavor enhancer. The FDA classifies MSG as a "generally recognized as safe" ingredient.

monounsaturated fatty acid (MUFA): a fatty acid that lacks two hydrogen atoms and has one double bond between carbons—for example, oleic acid. A *monounsaturated fat* is composed of triglycerides in which most of the fatty acids are monounsaturated.

more: on food labels, at least 10 percent more of the Daily Value for a given nutrient than the comparison food; synonyms include *added* and *extra*.

motility: the ability of the GI tract muscles to move.

mouth: the oral cavity containing the tongue and teeth.

MSG symptom complex: an acute, temporary intolerance reaction that may occur after the ingestion of the additive MSG (monosodium glutamate). Symptoms include burning sensations, chest and facial flushing and pain, and throbbing headaches.

mucous (MYOO-kus) **membranes:** the membranes, composed of mucus-secreting cells, that line the surfaces of body tissues.

mucus (MYOO-kus): a slippery substance secreted by cells of the GI lining (and other body linings) that protects the cells from exposure to digestive juices (and other destructive agents). The lining of the GI tract with its coat of mucus is a *mucous membrane*. (The noun is *mucus;* the adjective is *mucous*.)

muscle dysmorphia (dis-MORE-fee-ah): a psychiatric disorder characterized by a preoccupation with building body mass.

muscle endurance: the ability of a muscle to contract repeatedly without becoming exhausted.

muscle power: the product of force generation (strength) and movement velocity (speed); the speed at which a given amount of exertion is completed.

muscle strength: the ability of muscles to work against resistance.

mutations: permanent changes in the DNA that can be inherited.

myoglobin: the oxygen-holding protein of the muscle cells.

N

NAD (nicotinamide adenine dinucleotide): the main coenzyme form of the vitamin niacin. Its reduced form is NADH.

NADP (the phosphate form of NAD): a coenzyme form of niacin.

nanoceuticals: substances with extremely small particles that have been manufactured by nanotechnology.

nanotechnology: a manufacturing technology that manipulates atoms to change the structure of matter.

narcotic (nar-KOT-ic): a drug that dulls the senses, induces sleep, and becomes addictive with prolonged use.

natural water: water obtained from a spring or well that is certified to be safe and sanitary. The mineral content may not be changed, but the water may be treated in other ways such as with ozone or by filtration.

naturopathic (nay-chur-oh-PATH-ick) **medicine:** a system that taps the natural healing forces within the body by integrating several practices, including traditional medicine, herbal medicine, clinical nutrition, homeopathy, acupuncture, East Asian medicine, hydrotherapy, and manipulative therapy.

neotame (NEE-oh-tame): an artificial sweetener composed of two amino acids (phenylalanine and aspartic acid); approved for use in the United States.

net protein utilization (NPU): a measure of protein quality assessed by measuring the amount of protein nitrogen that is retained from a given amount of protein nitrogen eaten.

neural tube: the embryonic tissue that forms the brain and spinal cord. The two main types of neural tube defects are *spina bifida* (literally "split spine") and *anencephaly* ("no brain").

neural tube defects: malformations of the brain, spinal cord, or both during embryonic development that often result in lifelong disability or death.

neurofibrillary tangles: snarls of the threadlike strands that extend from the nerve cells, commonly found in the brains of people with Alzheimer's dementia.

neurons: nerve cells; the structural and functional units of the nervous system. Neurons initiate and conduct nerve impulse transmissions.

neuropeptide Y: a chemical produced in the brain that stimulates appetite, diminishes energy expenditure, and increases fat storage.

neurotransmitters: chemicals that are released at the end of a nerve cell when a nerve impulse arrives there. They diffuse across the gap to the next cell and alter the membrane of that second cell to either inhibit or excite it.

neutrophils (NEW-tro-fills): the most common of white blood cell. Neutrophils destroy antigens by phagocytosis.

niacin (NIGH-a-sin): a B vitamin. The coenzyme forms are *NAD (nicotinamide adenine dinucleotide)* and *NADP (the phosphate form of NAD)*. Niacin can be eaten preformed or made in the body from its precursor, tryptophan, an essential amino acid.

niacin equivalents (NE): the amount of niacin present in food, including the niacin that can theoretically be made from its precursor, tryptophan.

niacin flush: a temporary burning, tingling, and itching sensation that occurs when a person takes a large dose of nicotinic acid; often accompanied by a headache and reddened face, arms, and chest.

night blindness: slow recovery of vision after flashes of bright light at night or an inability to see in dim light; an early symptom of vitamin A deficiency.

nitrites (NYE-trites): salts added to food to prevent botulism. One example is sodium nitrite, which is used to preserve meats.

nitrogen balance: the amount of nitrogen consumed (N in) as compared with the amount of nitrogen excreted (N out) in a given period of time.

nitrosamines (nye-TROHS-uh-meens): derivatives of nitrites that may be formed in the stomach when nitrites combine with amines. Nitrosamines are carcinogenic in animals.

nonessential amino acids: amino acids that the body can synthesize.

nonexercise activity thermogenesis (NEAT): energy expended in everyday spontaneous activities.

nonheme iron: the iron in foods that is not bound to proteins; found in both plant-derived and animal-derived foods.

nonnutritive sweeteners: sweeteners that yield no energy (or insignificant energy in the case of aspartame).

nonperishable food collection: collecting processed foods from wholesalers and markets.

nonpoint water pollution: water pollution caused by runoff from all over an area rather than from discrete "point" sources. An example is the pollution caused by runoff from agricultural fields.

nucleotide bases: the nitrogen-containing building blocks of DNA and RNA—cytosine (C), thymine (T), uracil (U), guanine (G), and adenine (A). In DNA, the base pairs are A–T and C–G and in RNA, the base pairs are A–U and C–G.

nucleotides: the subunits of DNA and RNA molecules, composed of a phosphate group, a 5-carbon sugar (deoxyribose for DNA and ribose for RNA), and a nitrogen-containing base.

nucleus: a major membrane-enclosed body within cells, which contains the cell's genetic material (DNA), embedded in chromosomes.

nursing bottle tooth decay: extensive tooth decay due to prolonged tooth contact with formula, milk, fruit juice, or other carbohydrate-rich liquid offered to an infant in a bottle.

nutrient claims: statements that characterize the quantity of a nutrient in a food.

nutrient density: a measure of the nutrients a food provides relative to the energy it provides. The more nutrients and the fewer kcalories, the higher the nutrient density.

nutrient profiling: ranking foods based on their nutrient composition.

nutrients: chemical substances obtained from food and used in the body to provide energy, structural materials, and regulating agents to support growth, maintenance, and repair of the body's tissues. Nutrients may also reduce the risks of some diseases.

nutrigenetics: the science of how genes affect the activities of nutrients.

nutrigenomics: the science of how nutrients affect the activities of genes.

nutrition: the science of foods and the nutrients and other substances they contain, and of their actions within the body (including ingestion, digestion, absorption, transport, metabolism, and excretion). A broader definition includes the social, economic, cultural, and psychological implications of food and eating.

nutrition assessment: a comprehensive analysis of a person's nutrition status that uses health, socioeconomic, drug, and diet histories; anthropometric measurements; physical examinations; and laboratory tests.

nutrition screening: the use of preliminary nutrition assessment techniques to identify people who are malnourished or are at risk for malnutrition.

nutritional genomics: the science of how nutrients affect the activities of genes *(nutrigenomics)* and how genes affect the activities of nutrients *(nutrigenetics)*.

nutritionist: a person who specializes in the study of nutrition. Note that this definition does not specify qualifications and may apply not only to registered dietitians but also to self-described experts whose training is questionable. Most states have licensing laws that define the scope of practice for those calling themselves nutritionists.

nutritive sweeteners: sweeteners that yield energy, including both sugars and sugar alcohols.

O

obese: overweight with adverse health effects; BMI 30 or more.

obesogenic (oh-BES-oh-JEN-ick) **environment:** all the factors surrounding a person that promote weight gain, such as increased food intake, especially of unhealthy choices, and decreased physical activity.

obligatory (ah-BLIG-ah-TORE-ee) **water excretion:** the amount of water the body has to excrete each day to dispose of its wastes—about 500 milliliters (about 2 cups, or 1 pint).

oils: lipids that are liquid at room temperature (77°F or 25°C).

olestra: a synthetic fat made from sucrose and fatty acids that provides 0 kcalories per gram; also known as *sucrose polyester.*

oligopeptide (OL-ee-go-PEP-tide): string of four to nine amino acids.

omega: the last letter of the Greek alphabet (ω), used by chemists to refer to the position of the closest double bond to the methyl (CH_3) end of a fatty acid.

omega-3 fatty acid: a polyunsaturated fatty acid in which the closest double bond to the methyl (CH_3) end of the carbon chain is three carbons away.

omega-6 fatty acid: a polyunsaturated fatty acid in which the closest double bond to the methyl (CH_3) end of the carbon chain is six carbons away.

omnivorous: an eating pattern that includes foods derived from both animals and plants.

opsin (OP-sin): the protein portion of visual pigment molecules.

oral rehydration therapy (ORT): the administration of a simple solution of sugar, salt, and water, taken by mouth, to treat dehydration caused by diarrhea.

organelles: subcellular structures such as ribosomes, mitochondria, and lysosomes.

organic: in agriculture, crops grown and processed according to USDA regulations defining the use of fertilizers, herbicides, insecticides, fungicides, preservatives, and other chemical ingredients.

organic: in chemistry, a substance or molecule containing carbon-carbon bonds or carbon-hydrogen bonds. This definition excludes coal, diamonds, and a few carbon-containing compounds that contain only a single carbon and no hydrogen, such as carbon dioxide (CO_2), calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), and sodium cyanide (NaCN).

organic: on food labels, that at least 95 percent of the product's ingredients have been grown and processed according to USDA regulations defining the use of fertilizers, herbicides, insecticides, fungicides, preservatives, and other chemical ingredients.

organic halogens: an organic compound containing one or more atoms of a halogen—fluorine, chlorine, iodine, or bromine.

orlistat (OR-leh-stat): a drug used in the treatment of obesity that inhibits pancreatic lipase activity in the GI tract, thus blocking digestion and absorption of dietary fat and limiting energy intake.

orthomolecular medicine: the use of large doses of vitamins to treat chronic disease.

osmosis: the movement of water across a membrane *toward* the side where the solutes are more concentrated.

osmotic pressure: the amount of pressure needed to prevent the movement of water across a membrane.

osteoarthritis: a painful, degenerative disease of the joints that occurs when the cartilage in a joint deteriorates; joint structure is damaged, with loss of function; also called *degenerative arthritis.*

osteoblasts: cells that build bone during growth.

osteocalcin (os-teo-KAL-sen): a calcium-binding protein in bones, essential for normal mineralization.

osteoclasts: cells that destroy bone during growth.

osteomalacia (OS-tee-oh-ma-LAY-shuh): a bone disease characterized by softening of the bones. Symptoms include bending of the spine and bowing of the legs. The disease occurs most often in adult women.

osteoporosis (OS-tee-oh-pore-OH-sis): a disease in which the bones become porous and fragile due to a loss of minerals; also called *adult bone loss.*

outbreaks: two or more cases of a similar illness resulting from the ingestion of a common food.

overnutrition: excess energy or nutrients.

overt (oh-VERT): out in the open and easy to observe.

overweight: body weight greater than the weight range that is considered healthy; BMI 25 to 29.9.

ovum (OH-vum): the female reproductive cell, capable of developing into a new organism upon fertilization; commonly referred to as an egg.

oxaloacetate (OKS-ah-low-AS-eh-tate): a carbohydrate intermediate of the TCA cycle.

oxidants (OKS-ih-dants): compounds (such as oxygen itself) that oxidize other compounds. Compounds that prevent oxidation are called *antioxidants,* whereas those that promote it are called *prooxidants.*

oxidation (OKS-ee-day-shun): the process of a substance combining with oxygen; oxidation reactions involve the loss of electrons.

oxidative stress: a condition in which the production of oxidants and free radicals exceeds the body's ability to handle them and prevent damage.

oxytocin (OCK-see-TOH-sin): a hormone that stimulates the mammary glands to eject milk during lactation and the uterus to contract during childbirth.

oyster shell: a product made from the powdered shells of oysters that is sold as a calcium supplement, but it is not well absorbed by the digestive system.

ozone therapy: the use of ozone gas to enhance the body's immune system.

P

pancreas: a gland that secretes digestive enzymes and juices into the duodenum. (The pancreas also secretes hormones into the blood that help to maintain glucose homeostasis.)

pancreatic (pank-ree-AT-ic) **juice:** the exocrine secretion of the pancreas that contains enzymes for the digestion of carbohydrate, fat, and protein as well as bicarbonate, a neutralizing agent. The juice flows from the pancreas into the small intestine through the pancreatic duct. (The pancreas also has an endocrine function, the secretion of insulin and other hormones.)

pantothenic (PAN-toe-THEN-ick) **acid:** a B vitamin. The principal active form is part of coenzyme A, called "CoA" throughout Chapter 7.

parathyroid hormone: a hormone from the parathyroid glands that regulates blood calcium by raising it when levels fall too low; also known as *parathormone* (PAIR-ah-THOR-moan).

pasteurization: heat processing of food that inactivates some, but not all, microorganisms in the food; not a sterilization process. Bacteria that cause spoilage are still present.

pathogens (PATH-oh-jenz): microorganisms capable of producing disease.

PBB (polybrominated biphenyl) and **PCB (polychlorinated biphenyl):** toxic organic halogens used in pesticides, paints, and flame retardants.

PDCAAS (protein digestibility–corrected amino acid score): a measure of protein quality assessed by comparing the amino acid score of a food protein with the amino acid requirements of preschool-age children and then correcting for the true digestibility of the protein; recommended by the FAO/WHO and used to establish protein quality of foods for Daily Value percentages on food labels.

peak bone mass: the highest attainable bone density for an individual, developed during the first three decades of life.

peer review: a process in which a panel of scientists rigorously evaluates a research study to assure that the scientific method was followed.

pellagra (pell-AY-gra): the niacin-deficiency disease.

pepsin: a gastric enzyme that hydrolyzes protein. Pepsin is secreted in an inactive form, *pepsinogen,* which is activated by hydrochloric acid in the stomach.

pepsinogen: an inactive compound that is activated by hydrochloric acid in the stomach to form pepsin.

peptic ulcer: a lesion in the mucous membrane of either the stomach (a *gastric ulcer*) or the duodenum (a *duodenal ulcer*).

peptidase: a digestive enzyme that hydrolyzes peptide bonds. *Tripeptidases* cleave tripeptides; *dipeptidases* cleave dipeptides. *Endopeptidases* cleave peptide bonds within the chain to create smaller fragments, whereas *exopeptidases* cleave bonds at the ends to release free amino acids.

peptide bond: a bond that connects the acid end of one amino acid with the amino end of another, forming a link in a protein chain.

percent Daily Value (%DV): the percentage of a Daily Value recommendation found in a specified serving of food for key nutrients based on a 2000-kcalorie diet.

percent fat-free: may be used only if the product meets the definition of *low fat* or *fat-free* and must reflect the amount of fat in 100 grams (for example, a food that contains 2.5 grams of fat per 50 grams can claim to be "95 percent fat-free").

perinatal: referring to the time between the twenty-eighth week of gestation and 1 month after birth.

peripheral (puh-RIFF-er-ul) **nervous system:** the peripheral (outermost) part of the nervous system; the vast complex of wiring that extends from the central nervous system to the body's outermost areas. It contains both *somatic* and *autonomic* components.

peripheral resistance: the resistance to pumped blood in the small arterial branches (arterioles) that carry blood to the tissues.

perishable food rescue or **salvage:** collecting perishable produce from wholesalers and markets.

peristalsis (per-ih-STALL-sis): wavelike muscular contractions of the GI tract that push its contents along.

pernicious (per-NISH-us) **anemia:** a blood disorder that reflects a vitamin B_{12} deficiency caused by lack of intrinsic factor and characterized by abnormally large and immature red blood cells. Other symptoms include muscle weakness and irreversible neurological damage.

persistence: stubborn or enduring continuance; with respect to food contaminants, the quality of persisting, rather than breaking down, in the bodies of animals and human beings.

pesticides: chemicals used to control insects, weeds, fungi, and other pests on plants, vegetables, fruits, and animals. Used broadly, the term

includes herbicides (to kill weeds), insecticides (to kill insects), and fungicides (to kill fungi).

pH: the unit of measure expressing a substance's acidity or alkalinity. The lower the pH, the higher the H^+ ion concentration and the stronger the acid. A pH above 7 is alkaline, or base (a solution in which OH^- ions predominate).

phagocytes (FAG-oh-sites): white blood cells (neutrophils and macrophages) that have the ability to ingest and destroy foreign substances.

phagocytosis (FAG-oh-sigh-TOH-sis): the process by which phagocytes engulf and destroy foreign materials.

pharmacological effect: the body's response to a large dose of a nutrient (levels commonly available only from supplements) that overwhelms some body system and acts like a drug.

pharynx (FAIR-inks): the passageway leading from the nose and mouth to the larynx and esophagus, respectively.

phenylketonuria (FEN-il-KEY-toe-NEW-ree-ah) or **PKU:** an inherited disorder characterized by failure to metabolize the amino acid phenylalanine to tyrosine.

phosphocreatine (PC): a high-energy compound in muscle cells that acts as a reservoir of energy that can maintain a steady supply of ATP and provides the energy for short bursts of activity; also called *creatine phosphate (CP).*

phospholipid (FOS-foe-LIP-id): a compound similar to a triglyceride but having a phosphate group (a phosphorus-containing salt) and choline (or another nitrogen-containing compound) in place of one of the fatty acids.

phosphorus: a major mineral found mostly in the body's bones and teeth.

photosynthesis: the process by which green plants use the sun's energy to make carbohydrates from carbon dioxide and water.

phylloquinone (FILL-oh-KWIN-own): the naturally occurring form of vitamin K.

physical activity: bodily movement produced by muscle contractions that substantially increase energy expenditure.

physiological age: a person's age as estimated from her or his body's health and probable life expectancy.

physiological effect: the body's response to a normal dose of a nutrient (levels commonly found in foods) that provides a normal blood concentration.

physiological fuel value: the number of kcalories that the body derives from a food, in contrast to the number of kcalories determined by calorimetry.

phytic (FYE-tick) **acid:** a nonnutrient component of plant seeds; also called *phytate* (FYE-tate). Phytic acid occurs in the husks of grains, legumes, and seeds and is capable of binding minerals such as zinc, iron, calcium, magnesium, and copper in insoluble complexes in the intestine, which the body excretes unused.

phytochemicals (FIE-toe-KEM-ih-cals): nonnutrient compounds found in plants that confer taste, color, and other characteristics. Some phytochemicals have biological activity in the body.

phytoestrogens: phytochemicals structurally similar to human estrogen that weakly mimic or modulate estrogen's action in the body. Phytoestrogens include the isoflavones *genistein, daidzein,* and *glycitein.*

pica (PIE-ka): the general term for eating nonfood items. The specific craving for nonfood items that come from the earth, such as clay or dirt, is known as *geophagia.*

pigment: a molecule capable of absorbing certain wavelengths of light so that it reflects only those that we perceive as a certain color.

placebo (pla-see-bo): an inert, harmless medication given to provide comfort and hope; a sham treatment used in controlled research studies.

placebo effect: a change that occurs in response to expectations in the effectiveness of a treatment that actually has no pharmaceutical effects.

placenta (plah-SEN-tuh): the organ that develops inside the uterus early in pregnancy, through which the fetus receives nutrients and oxygen and returns carbon dioxide and other waste products to be excreted.

plant-based diets: an eating pattern that derives most of its protein from plant products (although some animal products may be included).

plant-pesticides: pesticides made by the plants themselves.

plant sterols: phytochemicals that have structural similarities to cholesterol and lower blood cholesterol by interfering with cholesterol absorption. Plant sterols include *sterol esters* and *stanol esters.*

plaques (PLACKS): the accumulation of fatty deposits, smooth muscle cells, and fibrous connective tissue that develops in the artery walls in atherosclerosis.

platelets: tiny, disc-shaped bodies in the blood, important in blood clot formation.

PLP (pyridoxal phosphate): the primary active coenzyme form of vitamin B_6.

point of unsaturation: the double bond of a fatty acid, where hydrogen atoms can easily be added to the structure.

polar: characteristic of a neutral molecule, such as water, that has opposite charges spatially separated within the molecule.

polypeptide: many (10 or more) amino acids bonded together.

polysaccharides: compounds composed of many monosaccharides linked together. An intermediate string of 3 to 10 monosaccharides is an *oligosaccharide.*

polyunsaturated fatty acid (PUFA): a fatty acid that lacks four or more hydrogen atoms and has two or more double bonds between carbons—for example, linoleic acid (two double bonds) and linolenic acid (three double bonds). A *polyunsaturated fat* is composed of triglycerides in which most of the fatty acids are polyunsaturated.

portion sizes: the quantity of a food served or eaten at one meal or snack; *not* a standard amount.

post term: after the forty-second week of pregnancy.

postpartum amenorrhea: the normal temporary absence of menstrual periods immediately following childbirth.

potable (POT-ah-bul): water that is suitable for drinking.

potassium: the principal cation within the body's cells; critical to the maintenance of fluid balance, nerve impulse transmissions, and muscle contractions.

powdered bone: crushed or ground bone preparations intended to supply calcium to the diet. Calcium from bone is not well absorbed and is often contaminated with toxic minerals such as arsenic, mercury, lead, and cadmium.

prebiotics: food components (such as fibers) that are not digested by the human body but are used as food by the GI bacteria to promote their growth and activity.

precursors: substances that precede others; with regard to vitamins, compounds that can be converted into active vitamins; also known as *provitamins.*

prediabetes: condition in which blood glucose levels are higher than normal but not high enough to be diagnosed as diabetes; considered a major risk factor for future diabetes and cardiovascular diseases; formerly called *impaired glucose tolerance.*

preeclampsia (PRE-ee-KLAMP-see-ah): a condition characterized by high blood pressure and some protein in the urine.

preformed vitamin A: dietary vitamin A in its active form.

prehypertension: slightly higher-than-normal blood pressure, but not as high as hypertension.

prenatal alcohol exposure: subjecting a fetus to a pattern of excessive alcohol intake characterized by substantial regular use or heavy episodic drinking.

prepared food rescue: collecting prepared foods from commercial kitchens.

preservatives: antimicrobial agents, antioxidants, and other additives that retard spoilage or maintain desired qualities, such as softness in baked goods.

pressure ulcers: damage to the skin and underlying tissues as a result of compression and poor circulation; commonly seen in people who are bedridden or chair-bound.

preterm (premature): prior to the thirty-eighth week of pregnancy.

primary deficiency: a nutrient deficiency caused by inadequate dietary intake of a nutrient.

probiotics: living microorganisms found in foods that, when consumed in sufficient quantities, are beneficial to health.

processed foods: foods that have been treated to change their physical, chemical, microbiological, or sensory properties.

proenzyme: the inactive form of an enzyme; also called a *zymogen*.

progesterone: the hormone of gestation (pregnancy).

progressive overload principle: the training principle that a body system, in order to improve, must be worked at frequencies, durations, or intensities that gradually increase physical demands.

prolactin (pro-LAK-tin): a hormone secreted from the anterior pituitary gland that acts on the mammary glands to promote the production of milk. The release of prolactin is mediated by *prolactin-inhibiting hormone (PIH)*.

promoters: factors that favor the development of cancers once they have begun.

proof: a way of stating the percentage of alcohol in distilled liquor. Liquor that is 100 proof is 50 percent alcohol; 90 proof is 45 percent, and so forth.

prooxidants: substances that significantly induce oxidative stress.

protease (PRO-tee-ace): an enzyme that hydrolyzes proteins.

protein digestibility: a measure of the amount of amino acids absorbed from a given protein intake.

protein efficiency ratio (PER): a measure of protein quality assessed by determining how well a given protein supports weight gain in growing rats; used to establish the protein quality for infant formulas and baby foods.

protein turnover: the degradation and synthesis of protein.

proteins: compounds composed of carbon, hydrogen, oxygen, and nitrogen atoms, arranged into amino acids linked in a chain. Some amino acids also contain sulfur atoms.

protein-sparing action: the action of carbohydrate (and fat) in providing energy that allows protein to be used for other purposes.

proteome: all proteins in a cell. The study of all proteins produced by a species is called *proteomics*.

proteomics: the study of the all proteins produced by a species.

puberty: the period in life in which a person becomes physically capable of reproduction.

public health dietitians: dietitians who specialize in providing nutrition services through organized community efforts.

public water: water from a municipal or county water system that has been treated and disinfected.

purified water: water that has been treated by distillation or other physical or chemical processes that remove dissolved solids. Because purified water contains no minerals or contaminants, it is useful for medical and research purposes.

purines: compounds of nitrogen-containing bases such as adenine, guanine, and caffeine. Purines that originate from the body are *endogenous* and those that derive from foods are *exogenous*.

pyloric (pie-LORE-ic) **sphincter:** the circular muscle that separates the stomach from the small intestine and regulates the flow of partially digested food into the small intestine; also called *pylorus* or *pyloric valve*.

pyruvate (PIE-roo-vate): a 3-carbon compound that plays a key role in energy metabolism.

Q

qi gong (chée GUNG): a Chinese system that combines movement, meditation, and breathing techniques to enhance the flow of qi (vital energy) in the body.

quality of life: a person's perceived physical and mental well-being.

R

rachitic (ra-KIT-ik) **rosary:** the poorly formed rib attachments that may develop in a vitamin D deficiency; literally, "the rosary of rickets."

radura: an international symbol used to identify retail foods that have been irradiated.

randomization (ran-dom-ih-zay-shun): a process of choosing the members of the experimental and control groups without bias.

raw sugar: the first crop of crystals harvested during sugar processing. Raw sugar cannot be sold in the United States because it contains too much filth (dirt, insect fragments, and the like). Sugar sold as "raw sugar" domestically has actually gone through more than half of the refining steps.

RD: see *registered dietitian*.

Recommended Dietary Allowance (RDA): the average daily amount of a nutrient considered adequate to meet the known nutrient needs of practically all healthy people; a goal for dietary intake by individuals.

rectum: the muscular terminal part of the intestine, extending from the sigmoid colon to the anus.

reduced kcalorie: at least 25 percent fewer kcalories per serving than the comparison food.

reference protein: a standard against which to measure the quality of other proteins.

refined: the process by which the coarse parts of a food are removed. When wheat is refined into flour, the bran, germ, and husk are removed, leaving only the endosperm.

refined flour: finely ground endosperm that is usually enriched with nutrients and bleached for whiteness; sometimes called *white flour*.

reflux: a backward flow.

registered dietitian (RD): a person who has completed a minimum of a bachelor's degree from an accredited university or college, has completed approved course work and a supervised practice program, has passed a national examination, and maintains registration through continuing professional education.

registration: listing; with respect to health professionals, listing with a professional organization that requires specific course work, experience, and passing of an examination.

relaxin: the hormone of late pregnancy.

remodeling: the dismantling and re-formation of a structure.

renin (REN-in): an enzyme from the kidneys that hydrolyzes the protein angiotensinogen to angiotensin I, which results in the kidneys reabsorbing sodium.

rennin: an enzyme that coagulates milk; found in the gastric juice of cows, but not human beings.

replication (REP-lih-KAY-shun): repeating an experiment and getting the same results.

requirement: the lowest continuing intake of a nutrient that will maintain a specified criterion of adequacy.

residues: whatever remains. In the case of pesticides, those amounts that remain on or in foods when people buy and use them.

resistance training: the use of free weights or weight machines to provide resistance for developing muscle strength, power, and endurance; also called *weight training*. A person's own body weight may also be used to provide resistance such as when a person does push-ups, pull-ups, or abdominal crunches.

resistant starches: starches that escape digestion and absorption in the small intestine of healthy people.

respiratory chain: the final pathway in energy metabolism that transports electrons from hydrogen to oxygen and captures the energy released in the bonds of ATP; also called the *electron transport chain.*

resting metabolic rate (RMR): similar to the basal metabolic rate (BMR), a measure of the energy use of a person at rest in a comfortable setting, but with less stringent criteria for recent food intake and physical activity. Consequently, the RMR is slightly higher than the BMR.

retina (RET-in-uh): the innermost membrane of the eye, composed of several layers including one that contains the rods and cones.

retinal (RET-ih-nal): the aldehyde form of vitamin A.

retinoic (RET-ih-NO-ick) **acid:** the acid form of vitamin A.

retinoids (RET-ih-noyds): chemically related compounds with biological activity similar to that of retinol; metabolites of retinol.

retinol (RET-ih-nol): the alcohol form of vitamin A.

retinol activity equivalents (RAE): a measure of vitamin A activity; the amount of retinol that the body will derive from a food containing preformed retinol or its precursor beta-carotene.

retinol-binding protein (RBP): the specific protein responsible for transporting retinol.

rheumatoid (ROO-ma-toyd) **arthritis:** a disease of the immune system involving painful inflammation of the joints and related structures.

rhodopsin (ro-DOP-sin): a light-sensitive pigment of the retina that contains the retinal form of vitamin A and the protein opsin.

riboflavin (RYE-boh-flay-vin): a B vitamin. The coenzyme forms are *FMN (flavin mononucleotide)* and *FAD (flavin adenine dinucleotide).*

ribose: a naturally occurring 5-carbon sugar needed for the synthesis of ATP.

ribosomes (RYE-boh-zomes): protein-making organelles in cells that are composed of RNA and protein.

rickets: the vitamin D–deficiency disease in children characterized by inadequate mineralization of bone (manifested in bowed legs or knock-knees, outward-bowed chest, and "beads" on ribs). A rare type of rickets, not caused by vitamin D deficiency, is known as *vitamin D–refractory rickets.*

risk: a measure of the probability and severity of harm.

risk factor: a condition or behavior associated with an elevated frequency of a disease but not proved to be causal. Leading risk factors for chronic diseases include obesity, cigarette smoking, high blood pressure, high blood cholesterol, physical inactivity, and a diet high in saturated fats and low in vegetables, fruits, and whole grains.

RNA (ribonucleic acid): a compound similar to DNA, but RNA is a single strand with a ribose sugar instead of a deoxyribose sugar and uracil instead of thymine as one of its bases.

S

saccharin (SAK-ah-ren): an artificial sweetener that has been approved for use in the United States. In Canada, saccharin can only be used as a tabletop sweetener, not as an additive.

safety: the condition of being free from harm or danger.

saliva: the secretion of the salivary glands. Its principal enzyme begins carbohydrate digestion.

salivary glands: exocrine glands that secrete saliva into the mouth.

salt: a compound composed of a positive ion other than H^+ and a negative ion other than OH^-. An example is sodium chloride (Na^+ Cl^-).

salt sensitivity: a characteristic of individuals who respond to a high salt intake with an increase in blood pressure or to a low salt intake with a decrease in blood pressure.

sarcopenia (SAR-koh-PEE-nee-ah): loss of skeletal muscle mass, strength, and quality.

satiating: having the power to suppress hunger and inhibit eating.

satiation (say-she-AY-shun): the feeling of satisfaction and fullness that occurs during a meal and halts eating. Satiation determines how much food is consumed during a meal.

satiety (sah-TIE-eh-tee): the feeling of fullness and satisfaction that occurs after a meal and inhibits eating until the next meal. Satiety determines how much time passes between meals.

saturated fat-free: less than 0.5 gram of saturated fat and 0.5 gram of *trans* fat per serving.

saturated fatty acid: a fatty acid carrying the maximum possible number of hydrogen atoms—for example, stearic acid. A *saturated fat* is composed of triglycerides in which most of the fatty acids are saturated.

scurvy: the vitamin C–deficiency disease.

secondary deficiency: a nutrient deficiency caused by something other than an inadequate intake such as a disease condition or drug interaction that reduces absorption, accelerates use, hastens excretion, or destroys the nutrient.

secretin (see-CREET-in): a hormone produced by cells in the duodenum wall. Target organ: the pancreas. Response: secretion of bicarbonate-rich pancreatic juice.

sedentary: physically inactive (literally, "sitting down a lot").

segmentation (SEG-men-TAY-shun): a periodic squeezing or partitioning of the intestine at intervals along its length by its circular muscles.

selenium (se-LEEN-ee-um): an essential trace mineral that is part of an antioxidant enzyme.

senile dementia: the loss of brain function beyond the normal loss of physical adeptness and memory that occurs with aging.

senile plaques: clumps of the protein fragment beta-amyloid on the nerve cells, commonly found in the brains of people with Alzheimer's dementia.

serotonin (SER-oh-TONE-in): a neurotransmitter important in sleep regulation, appetite control, and sensory perception, among other roles. Serotonin is synthesized in the body from the amino acid tryptophan with the help of vitamin B_6.

set point: the point at which controls are set (for example, on a thermostat). The set-point theory that relates to body weight proposes that the body tends to maintain a certain weight by means of its own internal controls.

serving sizes: the standardized quantity of a food; such information allows comparisons when reading food labels and consistency when following the *Dietary Guidelines.*

sickle-cell anemia: a hereditary form of anemia characterized by abnormal sickle- or crescent-shaped red blood cells. Sickled cells interfere with oxygen transport and blood flow. Symptoms are precipitated by dehydration and insufficient oxygen (as may occur at high altitudes) and include hemolytic anemia (red blood cells burst), fever, and severe pain in the joints and abdomen.

simple carbohydrates: monosaccharides and disaccharides (the sugars).

small for gestational age (SGA): term describing an infant whose birth weight is low compared with the number of weeks in utero, often reflecting growth failure.

small intestine: a 10-foot length of small-diameter intestine that is the major site of digestion of food and absorption of nutrients. Its segments are the *duodenum, jejunum,* and *ileum.*

socioeconomic history: a record of a person's social and economic background, including such factors as education, income, and ethnic identity.

sodium: the principal cation in the extracellular fluids of the body; critical to the maintenance of fluid balance, nerve impulse transmissions, and muscle contractions.

sodium bicarbonate (baking soda): a white crystalline powder that is used to buffer acid that accumulates in the muscles and blood during high-intensity exercise.

sodium-free and **salt-free:** less than 5 milligrams of sodium per serving.

soft water: water with a high sodium or potassium content.

solanine (SOH-lah-neen): a poisonous narcotic-like substance present in potato peels and sprouts.

solid fats: fats that are not usually liquid at room temperature; commonly found in most foods derived from animals and vegetable oils that have been hydrogenated. Solid fats typically contain more saturated and *trans* fats than most oils (Chapter 5 provides more details).

soluble fibers: nonstarch polysaccharides that dissolve in water to form a gel. An example is pectin from fruit, which is used to thicken jellies.

solutes (SOLL-yutes): the substances that are dissolved in a solution. The number of molecules in a given volume of fluid is the *solute concentration*.

somatic (so-MAT-ick) **nervous system:** the division of the nervous system that controls the voluntary muscles, as distinguished from the autonomic nervous system, which controls involuntary functions.

somatostatin (GHIH): a hormone that inhibits the release of growth hormone; the opposite of *somatotropin (GH)*.

soup kitchens: programs that provide prepared meals to be eaten on site.

sperm: the male reproductive cell, capable of fertilizing an ovum.

sphincter (SFINK-ter): a circular muscle surrounding, and able to close, a body opening. Sphincters are found at specific points along the GI tract and regulate the flow of food particles.

spina (SPY-nah) **bifida** (BIFF-ih-dah): one of the most common types of neural tube defects; characterized by the incomplete closure of the spinal cord and its bony encasement.

sports anemia: a transient condition of low hemoglobin in the blood, associated with the early stages of sports training or other strenuous activity.

spring water: water originating from an underground spring or well. It may be bubbly (carbonated), or "flat" or "still," meaning not carbonated. Brand names such as "Spring Pure" do not necessarily mean that the water comes from a spring.

starches: plant polysaccharides composed of many glucose molecules.

sterile: free of microorganisms, such as bacteria.

sterols (STARE-ols or STEER-ols): compounds containing a four-ring carbon structure with any of a variety of side chains attached.

stevia (STEE-vee-ah): glycosides found in the leaves of a South American shrub that are used as an herbal sweetener; sold in the United States as a dietary supplement that provides sweetness without kcalories.

stomach: a muscular, elastic, saclike portion of the digestive tract that grinds and churns swallowed food, mixing it with acid and enzymes to form chyme.

stools: waste matter discharged from the colon; also called *feces* (FEE-seez).

stress: any threat to a person's well-being; a demand placed on the body to adapt.

stress eating: eating in response to arousal.

stress fractures: bone damage or breaks caused by stress on bone surfaces during exercise.

stress response: the body's response to stress, mediated by both nerves and hormones.

stressors: environmental elements, physical or psychological, that cause stress.

stroke: an event in which the blood flow to a part of the brain is cut off; also called *cerebrovascular accident (CVA)*.

structure-function claims: statements that characterize the relationship between a nutrient or other substance in a food and its role in the body.

subclavian (sub-KLAY-vee-an) **vein:** the vein that provides passageway from the lymphatic system to the vascular system.

subclinical deficiency: a deficiency in the early stages, before the outward signs have appeared.

subcutaneous fat: fat stored directly under the skin.

subjects: the people or animals participating in a research project.

successful weight-loss maintenance: achieving a weight loss of at least 10 percent of initial body weight and maintaining the loss for at least one year.

sucralose (SUE-kra-lose): an artificial sweetener composed of sucrose with Cl atoms instead of OH groups; approved for use in the United States and Canada.

sucrase: an enzyme that hydrolyzes sucrose.

sucrose (SUE-krose): a disaccharide composed of glucose and fructose; commonly known as *table sugar, beet sugar,* or *cane sugar.* Sucrose also occurs in many fruits and some vegetables and grains.

sudden infant death syndrome (SIDS): the unexpected and unexplained death of an apparently well infant; the most common cause of death of infants between the second week and the end of the first year of life; also called *crib death*.

sugar alcohols: sugarlike compounds that can be derived from fruits or commercially produced from dextrose; also called *polyols*. Sugar alcohols are absorbed more slowly than other sugars and metabolized differently in the human body; they are not readily utilized by ordinary mouth bacteria. Examples are maltitol, mannitol, sorbitol, xylitol, isomalt, and lactitol.

sugar-free: less than 0.5 gram of sugar per serving.

sugars: simple carbohydrates composed of monosaccharides and disaccharides.

sulfate: a salt produced from the oxidation of sulfur.

sulfites: salts containing sulfur that are added to foods to prevent spoilage.

sulfur: a mineral present in the body as part of some proteins.

sushi: vinegar-flavored rice and seafood, typically wrapped in seaweed and stuffed with colorful vegetables. Some sushi is stuffed with raw fish; other varieties contain cooked seafood.

sustainable: able to continue indefinitely; using resources at such a rate that the earth can keep on replacing them and producing pollutants at a rate with which the environment and human cleanup efforts can keep pace, so that no net accumulation of pollution occurs.

sustainable agriculture: ability to produce food indefinitely, with little or no harm to the environment.

symptomatic allergy: an immune response that produces antibodies and symptoms.

synergistic (SIN-er-JIS-tick): multiple factors operating together in such a way that their combined effects are greater than the sum of their individual effects.

T

tagatose (TAG-ah-tose): a monosaccharide structurally similar to fructose that is incompletely absorbed and thus provides only 1.5 kcalories per gram; approved for use as a "generally recognized as safe" ingredient.

TCA cycle or **tricarboxylic** (try-car-box-ILL-ick) **acid cycle:** a series of metabolic reactions that break down molecules of acetyl CoA to carbon dioxide and hydrogen atoms; also called the *citric acid cycle* or the *Kreb's cycle* after the biochemist who elucidated its reactions.

T-cells: lymphocytes that attack antigens. *T* stands for the *thymus gland*, where the T-cells mature.

tempeh (TEM-pay): a fermented soybean food, rich in protein and fiber.

teratogen (ter-AT-oh-jen): a substance that causes abnormal fetal development and birth defects.

teratogenic (ter-AT-oh-jen-ik): causing abnormal fetal development and birth defects.

testosterone: a steroid hormone from the testicles, or testes. The steroids are chemically related to, and some are derived from, the lipid cholesterol.

textured vegetable protein: processed soybean protein used in vegetarian products such as soy burgers.

theory: a tentative explanation that integrates many and diverse findings to further the understanding of a defined topic.

thermic effect of food (TEF): an estimation of the energy required to process food (digest, absorb, transport, metabolize, and store ingested nutrients); also called the *specific dynamic effect (SDE) of food* or the *specific dynamic activity (SDA) of food.* The sum of the TEF and any increase in the metabolic rate due to overeating is known as *diet-induced thermogenesis (DIT).*

thermogenesis: the generation of heat; used in physiology and nutrition studies as an index of how much energy the body is expending.

THF (tetrahydrofolate): a coenzyme form of folate.

thiamin (THIGH-ah-min): a B vitamin. The coenzyme form is *TPP (thiamin pyrophosphate).*

thirst: a conscious desire to drink.

thoracic (thor-ASS-ic) **duct:** the main lymphatic vessel that collects lymph and drains into the left subclavian vein.

thrombosis (throm-BOH-sis): the formation of a *thrombus* (THROM-bus), or a blood clot, that may obstruct a blood vessel, causing gradual tissue death.

thyroid-stimulating hormone (TSH): a hormone secreted by the pituitary that stimulates the thyroid gland to secrete its hormones—thyroxin and triiodothyronine. The release of TSH is mediated by *TSH-releasing hormone (TRH).*

thyrotropin: another name for thyroid-stimulating hormone (TSH).

tocopherol (tuh-KOFF-er-ol): a general term for several chemically related compounds, one of which has vitamin E activity.

tofu (TOE-foo): a curd made from soybeans, rich in protein and often fortified with calcium; used in many Asian and vegetarian dishes in place of meat.

Tolerable Upper Intake Level (UL): the maximum daily amount of a nutrient that appears safe for most healthy people and beyond which there is an increased risk of adverse health effects.

tolerance level: the maximum amount of residue permitted in a food when a pesticide is used according to the label directions.

toxicity: the ability of a substance to harm living organisms. All substances are toxic if high enough concentrations are used.

TPP (thiamin pyrophosphate): the coenzyme form of thiamin.

trabecular (tra-BECK-you-lar) **bone:** the lacy inner structure of calcium crystals that supports the bone's structure and provides a calcium storage bank.

trace minerals: essential mineral nutrients the human body requires in relatively small amounts (less than 100 milligrams per day); sometimes called *microminerals.*

trachea (TRAKE-ee-uh): the air passageway from the larynx to the lungs; also called the *windpipe.*

training: practicing an activity regularly, which leads to conditioning. (Training is what you do; conditioning is what you get.)

trans: on the other side of; refers to a chemical configuration in which the hydrogen atoms are located on opposite sides of a double bond.

***trans* fat-free:** less than 0.5 gram of *trans* fat and less than 0.5 gram of saturated fat per serving.

transamination (TRANS-am-ih-NAY-shun): the transfer of an amino group from one amino acid to a keto acid, producing a new nonessential amino acid and a new keto acid.

transcription: the process of messenger RNA being made from a template of DNA.

***trans*-fatty acids:** fatty acids with hydrogens on opposite sides of the double bond.

transferrin (trans-FAIR-in): the iron transport protein.

transient ischemic (is-KEY-mik) **attack (TIA):** a temporary reduction in blood flow to the brain, which causes temporary symptoms that vary depending on the part of the brain affected. Common symptoms include light-headedness, visual disturbances, paralysis, staggering, numbness, and inability to swallow.

translation: the process of messenger RNA directing the sequence of amino acids and synthesis of proteins.

travelers' diarrhea: nausea, vomiting, and diarrhea caused by consuming food or water contaminated by any of several organisms, most commonly, *E. coli, Shigella, Campylobacter jejuni,* and *Salmonella.*

triglycerides (try-GLISS-er-rides): the chief form of fat in the diet and the major storage form of fat in the body; composed of a molecule of glycerol with three fatty acids attached; also called *triacylglycerols* (try-ay-seel-GLISS-er-ols).

tripeptide: three amino acids bonded together.

tumor: an abnormal tissue mass with no physiological function; also called a *neoplasm* (NEE-oh-plazm).

turbinado (ter-bih-NOD-oh) **sugar:** sugar produced using the same refining process as white sugar, but without the bleaching and anti-caking treatment. Traces of molasses give turbinado its sandy color.

type 1 diabetes: the less common type of diabetes in which the pancreas produces little to no insulin. Type 1 diabetes usually results from autoimmune destruction of pancreatic beta cells.

type 2 diabetes: the more common type of diabetes in which the cells fail to respond to insulin. Type 2 diabetes usually accompanies obesity and results from insulin resistance coupled with insufficient insulin secretion.

U

ulcer: a lesion of the skin or mucous membranes characterized by inflammation and damaged tissues.

ultrahigh temperature (UHT) treatment: sterilizing a food by brief exposure to temperatures above those normally used.

umbilical (um-BILL-ih-cul) **cord:** the ropelike structure through which the fetus's veins and arteries reach the placenta; the route of nourishment and oxygen to the fetus and the route of waste disposal from the fetus. The scar in the middle of the abdomen that marks the former attachment of the umbilical cord is the *umbilicus* (um-BILL-ih-cus), commonly known as the "belly button."

uncoupled reactions: chemical reactions in which energy is released as heat.

undernutrition: deficient energy or nutrients.

underweight: body weight lower than the weight range that is considered healthy; generally defined as BMI <18.5.

unsaturated fatty acid: a fatty acid that lacks hydrogen atoms and has at least one double bond between carbons (includes monounsaturated and polyunsaturated fatty acids). An *unsaturated fat* is composed of triglycerides in which most of the fatty acids are unsaturated.

unspecified eating disorders: eating disorders that do not meet the defined criteria for specific eating disorders.

urea (you-REE-uh): the principal nitrogen-excretion product of protein metabolism. Two ammonia fragments are combined with carbon dioxide to form urea.

USDA (US Department of Agriculture): the federal agency responsible for enforcing standards for the wholesomeness and quality of meat, poultry, and eggs produced in the United States; conducting nutrition research; and educating the public about nutrition.

uterus (YOU-ter-us): the muscular organ within which the infant develops before birth.

V

validity (va-lid-ih-tee): having the quality of being founded on fact or evidence.

variables: factors that change. A variable may depend on another variable (for example, a child's height depends on his age), or it may be

independent (for example, a child's height does not depend on the color of her eyes). Sometimes both variables correlate with a third variable (a child's height and eye color both depend on genetics).

variety (dietary): eating a wide selection of foods within and among the major food groups.

vasoconstrictor (VAS-oh-kon-STRIK-tor): a substance that constricts or narrows the blood vessels.

vasopressin (VAS-oh-PRES-in): another name for antidiuretic hormone, so called because it elevates blood pressure.

vegans (VEE-gans): people who exclude all animal-derived foods (including meat, poultry, fish, eggs, and milk and milk products) from their diets; also called *pure vegetarians, strict vegetarians,* or *total vegetarians.*

vegetarians: a general term used to describe people who exclude meat, poultry, fish, or other animal-derived foods from their diets.

veins (VANES): vessels that carry blood to the heart.

very low food security: multiple indications of disrupted eating patterns and reduced food intake; formerly known as *food insecurity with hunger.*

very low sodium: 35 milligrams or less per serving.

vigorous-intensity physical activity: physical activity that requires a large increase in breathing and/or heart rate and expends more than 7 kcalories per minute. Walking at a very brisk pace (>4.5 miles per hour) or running at a pace of at least 5 miles per hour are examples.

villi (VILL-ee, VILL-eye): fingerlike projections from the folds of the small intestine; singular *villus.*

visceral fat: fat stored within the abdominal cavity in association with the internal abdominal organs; also called *intra-abdominal fat.*

viscous: a gel-like consistency.

vitamin A: all naturally occurring compounds with the biological activity of *retinol* (RET-ih-nol), the alcohol form of vitamin A.

vitamin A activity: a term referring to both the active forms of vitamin A and the precursor forms in foods without distinguishing between them.

vitamin B_6: a family of compounds—pyridoxal, pyridoxine, and pyridoxamine. The primary active coenzyme form is *PLP (pyridoxal phosphate).*

vitamin B_{12}: a B vitamin characterized by the presence of cobalt. The active forms of coenzyme B_{12} are methylcobalamin and deoxyadenosylcobalamin.

vitamin D_2: vitamin D derived from plants in the diet; also called *ergocalciferol.*

vitamin D_3: vitamin D derived from animals in the diet and made in the skin from 7-dehydrocholesterol, a precursor of cholesterol, with the help of sunlight; also called *cholecalciferol.*

vitamins: organic, essential nutrients required in small amounts by the body for health. Vitamins regulate body processes that support growth and maintain life.

VLDL (very-low-density lipoprotein): the type of lipoprotein made primarily by liver cells to transport lipids to various tissues in the body; composed primarily of triglycerides.

VO_2max: the maximum rate of oxygen consumption by an individual at sea level.

vomiting: expulsion of the contents of the stomach up through the esophagus to the mouth.

vulnerable plaque: plaque that is susceptible to rupture because it has only a thin fibrous barrier between its lipid-rich core and the artery lining.

W

waist circumference: an anthropometric measurement used to assess a person's abdominal fat.

warm-up: 5 to 10 minutes of light activity, such as easy jogging or cycling, prior to a workout to prepare the body for more vigorous activity.

water balance: the balance between water intake and output (losses).

water intoxication: the rare condition in which body water contents are too high in all body fluid compartments.

wean: to gradually replace breast milk with infant formula or other foods appropriate to an infant's diet.

websites: Internet resources composed of text and graphic files, each with a unique URL (Uniform Resource Locator) that names the site (for example, www.usda.gov).

weight management: maintaining body weight in a healthy range by preventing gradual weight gain over time and losing weight if overweight, and by preventing weight losses and gaining weight if underweight.

well water: water drawn from ground water by tapping into an aquifer.

Wernicke-Korsakoff (VER-nee-key KORE-sah-kof) **syndrome:** a neurological disorder typically associated with chronic alcoholism and caused by a deficiency of the B vitamin thiamin; also called *alcohol-related dementia.*

wheat flour: any flour made from the endosperm of the wheat kernel.

whey protein: a by-product of cheese production; falsely promoted as increasing muscle mass. Whey is the watery part of milk that separates from the curds.

white sugar: granulated sucrose or "table sugar," produced by dissolving, concentrating, and recrystallizing raw sugar.

WHO (World Health Organization): an international agency concerned with promoting health and eradicating disease.

whole grain: a grain that maintains the same relative proportions of starchy endosperm, germ, and bran as the original (all but the husk); not refined.

whole-wheat flour: any flour made from the entire wheat kernel.

Wilson's disease: a genetic disorder of copper metabolism that creates a copper toxicity and results in neurologic symptoms such as tremors, impaired speech, inappropriate behaviors, and personality changes.

wine: an alcoholic beverage traditionally made by fermenting a sugar source such as grape juice.

without appreciable risk: practical certainty that injury will not result even after a lifetime of exposure.

X

xanthophylls (ZAN-tho-fills): pigments found in plants responsible for the color changes seen in autumn leaves.

xerophthalmia (zer-off-THAL-mee-uh): progressive blindness caused by inadequate mucus production due to severe vitamin A deficiency.

xerosis (zee-ROW-sis): abnormal drying of the skin and mucous membranes; a sign of vitamin A deficiency.

Y

yields: production per acre.

yogurt: milk product that results from the fermentation of lactic acid in milk by *Lactobacillus bulgaricus* and *Streptococcus thermophilus.*

Z

zinc: an essential trace mineral that is part of many enzymes and a constituent of insulin.

zygote (ZY-goat): the initial product of the union of ovum and sperm; a fertilized ovum.

zymogen (ZYE-mo-jen): the inactive precursor of an enzyme; sometimes called a *proenzyme.*

Index

- Page numbers in bold indicate definition of term.
- Page numbers followed by the letter "f" indicate figures or photographs.
- Page numbers followed by the letter "n" indicate footnotes.
- Page numbers followed by the letter "t" indicate tables.

A

AAP. *See* American Academy of Pediatrics
Abdominal fat, 245, 245f
Abortion, malnutrition and, 486
Absorption, 69, 76f, 77–79
  anatomy of system, 77–78
  of calcium, 386
  of calcium from supplements, 400
  of carbohydrates, 103
  hormonal and nervous systems in, 83
  of iron, 406–407, 406f, 411
  of lipids, 140–141, 141f
  of monosaccharides, 103f
  of nutrients, 576, 576t
  of proteins, 171, 172f
  of vitamin B_{12}, 315
  of zinc, 415, 415f, 416
Academy of Nutrition and Dietetics, **30**, 115, 657, 662, 674
Acceptable Daily Intake (ADI), **113**, 645
Acceptable Macronutrient Distribution Ranges (AMDR), **20**, 184
Accredited organization, 31
Accutane, 344
ACE inhibitors, for hypertension, 597
Acesulfame potassium, 114t
Acetaldehyde, **223**, 226
Acetic acid, 102n
Acetylcholine (neurotransmitter), 567
Acetyl CoA, **202**, 208f, 209f
  alcohol and, 223, 223f
  fatty acid-to-, 208f
  pantothenic acid and, 308
  paths of, 206f, 210
  pyruvate-to-, 206, 206f, 319
Acid(s), **176**, B-6. *See also* Amino acids; DNA (deoxyribonucleic acid); Fatty acids; specific types
  acetic, 102n
  amino, 168–188
  arachidonic, **145**
  ascorbic, 323, 323f, 360
  aspartic, 169f
  carbonic, 377, 377f
  conjugated linoleic, 135
  dehydroascorbic, 323f
  docosahexaenoic, 145, 509
  eicosapentaenoic, 145
  keto, 179, 217
  linoleic, 130, **131–132**, 135, 150
  linolenic, 130, 132, 145, 150
  orotic, 319
  PABA (para-aminobenzoic acid), 319
  phytic, 100, 429t
  propionic, 102n
  retinoic, 340, **340**, 341
  RNA (ribonucleic acid), 173, 190
  stearic, 130–131, 147
  TCA (tricarboxylic acid) cycle, **202–203**, 210–212, 211f, 307, C-12f
Acid (stomach), 75, 93
Acid-base balance, **106**, 376–377
  buffer regulation of, 377
  electrolytes, water, and, 376
  kidney regulation and, 377
  lung respiration and, 377
Acid controllers, **92**
Acidity, of body's fluids, 376–377
Acidosis, **176**
Acne, **344**
Acquired immune deficiency syndrome (AIDS). *See* AIDS (acquired immune deficiency syndrome)
Acrylamide, 605, 646
ACSM. *See* American College of Sports Medicine
Action without Borders (hunger relief), 675t
Activated carbon filters, 640
Active packaging, of microwave products, 646–647
Active transport, absorption by, 77, 77f
Active vitamin D (calcitriol). *See* Vitamin D (calciferol)
Activity. *See* Physical activity
Acute malnutrition. *See also* Malnutrition
  chronic malnutrition and, 668t
Adaptation
  energy conservation and, 218
  gluconeogenesis and, 217
  ketone bodies and, 217
Adaptive thermogenesis, **239**
Added sugars, **38**
Addictions, weight management and, 125
Additives, **642–648**. *See also* Bacteriophages; BHA (food additive); BHT (food additive); Delaney Clause; Generally recognized as safe; Nitrosamines; Sulfites
  antibiotics as, 648
  antimicrobials, 643–644
  antioxidants as, 644
  color, 644, 644f
  decaffeinated coffee and, 647
  dioxins as, 647
  flavor, 644–645
  hormones as, 647–648
  indirect, 646–648, 646t
  intentional, 643–646
  nitrites, 643
  nitrosamines, 643–644
  for nutrients, 645–646
  packaging additives, 646–647
  regulations governing, 642–643
Adenosine diphosphate (ADP), 201f, C-8f
Adenosine triphosphate (ATP), 201f, C-8f. *See also* ATP, Mitochondria
Adequacy (dietary), **36**. *See also* Dietary Reference Intakes
  digestion and, 86
  food record (log), 284f
  nutrient density and, 36–38, 37f
Adequate energy, protein and, 184–185
Adequate Intake (AI), **19**. *See also* Dietary Reference Intakes
  for biotin, 308
  for calcium, 386–387
  for chloride, 383
  for choline, 318
  of chromium, 423
  of fatty acids, 150
  of fluoride, 422
  of pantothenic acid, 309
  of trace minerals, 404f
  of vitamin K, 356
  for vitamins for adolescents, 537–538
  of water, 369–370
ADH. *See* Antidiuretic hormone
ADI. *See* Acceptable Daily Intake
Adipokines, **144**, 248
Adipose cell, 144f
Adipose tissue, **144**, 232n
  fat storage in, 264, 282
  weight gain and, 248
Adolescence/adolescents, **537**
  AI of vitamins for, 537–538
  beverages for, 539
  eating away from home, 539–540
  iron in, 408, 409, 519
  nutrition during, 536–540
  physical activities for, 530t
  pregnancy during, 488
  puberty and, 537
  smoking by, 548
  snacking by, 539
  weight-loss surgery for, 531
Adolescent health, 538–539
  Healthy People 2020 on, J-1t
ADP (adenosine diphosphate), 201f, C-8f
Adrenal glands, **372**
  vitamin C in, 324
Adrenocorticotropin (ACTH) hormone, A-4
Adults. *See also* Aging process; Older adults
  analysis of measures in, E-7
  body weight distribution, 243t
  diabetes among, 597, 598f
  energy-yielding nutrients for, 509f
  heart rate, respiration rate, and energy needs of, 506t
  height measurement of, E-6, E-6f
  intakes compared with infants, 508f
  nutrition for, 551–572
Adverse reactions, **526**
Aerobic physical activity, **205**, 281, 282, **439**, 445. *See also* Physical activity
  for children and adolescents, 530f
  fat and glucose use in, 447
  as heart disease defense, 593f
  sustaining, 447f, 449f
Aflatoxins, 626
Africa, crop production in, 655
African Americans, weight and, 537
Age
  CHD and, 589
  energy requirements by, 239
  of pregnant woman, 488–489
Aging process, 556–560. *See also* Older adults
  arthritis in, 564–565
  body composition in, 557
  body weight and, 557
  bone calcium and, 397–398
  brain in, 565–568
  economic changes in, 559
  GI tract in, 558
  as hypertension risk factor, 595
  immunity and inflammation in, 557–558
  muscle mass and strength in, 554
  nutrient concerns of, 563t
  physiological changes in, 557–559
  psychological changes in, 559
  sensory losses in, 558–559
  social changes in, 560
  strategies for healthful, 568t
  tooth loss in, 558
  of US population, 551–552, 552f
  vision and, 564
Agriculture. *See also* Crops; Food(s); USDA
  genetically assisted, 654
  methods compared, 674t
  sustainable, 673
AI. *See* Adequate Intake
AIDS (acquired immune deficiency syndrome), **584**
  breastfeeding and, 495
  epidemic of, 584t
Air displacement plethysmography, 246f
Alanine (amino acid), 168, 169f, C-3f

Alcohol, **220**. *See also* Alcohol abuse; Alcoholism; Cirrhosis; Ethanol; Fatty liver; Fetal alcohol syndrome; Fibrosis; Glycerol; MEOS (microsomal ethanol-oxidizing system)
in beverages, 220–222
birth defects from, 501–503
in body, 220–225
bone loss and, 397
in brain, 224–225, 224f, 225t
breastfeeding and, 496
damage from, 225–227, 228t
dehydration and, 225
diabetes and, 601
doses and blood level percentages by gender, 225t
as drug, 221
energy from, 9, 10
energy metabolism interference by, C-14f, C-14 to C-15
fluid needs and, 370
fluid replacement and, 457
food composition table for, H-48t to H-51t
food list for, G-16t
in GI tract, 222
as hypertension risk factor, 595
kcalories in, 226t
in liver, 222–224, 226
long-term effects of, 227
malnutrition and, 225–227
metabolism of, 222f, 224
myths and truths about, 228t
in older adults, 567–568
osteoporosis and, 399
pregnancy and, 489
as risk factor, 26
short-term effects of, 227
strategies for handling, 228–229
Alcohol abuse, **223**. *See also* Fetal alcohol syndrome; Wernicke-Korsakoff syndrome
health effects of, 228t
thiamin deficiency and, 301
vitamin B_6 and, 309
Alcohol dehydrogenase enzyme, 222
Alcoholism, **226**
signs of, 227t
Alcohol-related birth defects (ARBD), 501
Alcohol-related neurodevelopmental disorder (ARND), **501**
Aldosterone, **372**, A-7
sodium and, 375
Alkalosis, **176**
Alkylresorcinols, 429t
Allergens, from genetically modified crops, 654
Allergies. *See also* Food allergies; Lactose intolerance
breast milk protection from, 510
food, 177, 513–514, 524–526
Allicin, 429t
Almonds. *See* Nuts and nut butters
Aloe vera, 616f, 618t
Alpha cells, 106n
Alpha-lactalbumin, **509**
Alpha-linolenic acid, 145n
Alpha-tocopherol, **353**
Alternative medicine, 614–620
Alternative sweeteners, 113–115, 113f, 114t
Alternative therapies, nutrition-related, 616–619
Alzheimer's disease, 558, **566**, 566t
healthy brain compared with, 567f
AMDR. *See* Acceptable Macronutrient Distribution Ranges
Amenorrhea, **253**
breastfeeding and, 495
eating disorders and, 253, 254
American Academy of Pediatrics (AAP)
on breastfeeding, 507–508
childhood obesity and, 530
on dietary supplements, 519
on infant formula standards, 511
on solid foods in infant diet, 513
vitamin A recommendations by, 343
vitamin D recommendations by, 349, 509
American Cancer Society, on soy and phytoestrogens, 429
American College of Sports Medicine (ACSM), 443
physical fitness guidelines, 440t
American Dietetic Association (ADA). *See* Academy of Nutrition and Dietetics
American Heart Association
dietary guidelines for children, 547t
recommendations for fish servings, 151
American Medical Association, on food irradiation, 632
Amino acid pool, **178**
Amino acids, **168**, 169f. *See also* Alanine; Arginine; Dipeptide; Essential amino acids; Nonessential amino acids; Phenylalanine; Polypeptide; Protein entries; Tripeptide; Tryptophan
alanine as, 168, 169f
biotin and, 307
branched-chain, 187
cell composition and, 181
condensation to form dipeptide, 169f
conditionally essential, 169
deamination of, 207
degradation of, C-10
in energy pathway, 209f
essential, 168t, 169
limiting, 181
in metabolic pathways, C-11f
metabolism of, 207–213
nonessential, 168, 168t, 179f
protein and, 167–188, C-3f
roles of, 178
sequence of human insulin, 170f
sequencing of, 173
structure of, 169–170
supplements for, 186–187
vitamin C and, 324
Amino acid scoring, D-1t, **D-1** to D-2, D-2t
Ammonia, **179**. *See also* Amino acids, supplements for; Deamination
from deamination, 207
as urea, 179–180
Amniotic sac, **470–471**, 471f
Amylase, **101**, 102f
Amylin (hormone), 236
Anabolic reactions, 175, 200f
Anabolic steroids, **465**
Anabolism, **199**
Anaerobic activity, **205**, 206f, **444**, 445f
Analysis, of research findings, 15–16
Anaphylactic shock, **525**
Androstenedione, **465**
Anecdote, **12**
Anemia, **314**. *See also* Hemolytic anemia; Macrocytic anemia; Milk anemia; Pernicious anemia; Sickle-cell anemia
folate, 314–315, 321, E-21–E-22, E-21t
hemolytics, 353
iron-deficiency, 408, 409, 452, E-19 to E-21, E-20t
from lead poisoning, 522
milk, 409n, 516
nutritional, E-18 to E-19, E-19t
pernicious, 317
from pica, 411
sickle-cell, 173
sports, 409, 453
vitamin B_{12} and, 317, 321, E-21t, E-21 to E-22
Anencephaly, **472–473**
Aneurysm, **587**
Angina, **588**
Angiotensin I, **372**
Angiotensin II, **372**
Animal fats, 134f, 150
Animal foods, 678–680. *See also* specific foods
cancer risk reduction and, 606t
Animal protein. *See* Fish; Meat; Milk and milk products; Pork; Poultry; Protein (animal)
Animals. *See also* Livestock
cloning of, 654
energy restriction in, 554–555
genetic engineering of, 652
protein from, 181
Animal studies, 14f
Anions, **373**. *See also* Chloride
Anorexia nervosa, **254–256**, 257. *See also* Eating disorders
hunger pangs and, 234
osteoporosis and, 183
starvation in, 255
treatment of, 255–256
as underweight condition, 287
Antacids, **92**, 315, 396, **400**
Antagonist, **306**
reactions to supplements, 306
Anthropometric measurements, **22**, E-5t, E-5 to E-15, E-8f to E-13f
of body fat and lean tissue, E-15
Antibiotics, as additives, 648
Antibodies, **177**, **583**
Antidiuretic hormone (ADH), **225**, **371–372**, A-6
Antigens, **177**, **582**
food allergies and, 177
Antihistamines, vitamin C and, 324
Anti-inflammatory drugs, *H. pylori* and, 93
Antimicrobials, 643–644
Antioxidants, **134**, **360–363**, 556–557. *See also* Beta-carotene; Carotenoids; Free radicals; Oxidants; Oxidative stress; Vitamin C; Vitamin E
arthritis and, 565
atherosclerosis reversal and, 590
beta-carotene as, 342
cancer and, 361
in diet, 556
disease prevention and, 360–363, 363t
as food additives, 644
food sources v. supplements for, 362–363
heart disease and, 361–362, 430
selenium as, 419
vitamin C as, 323
vitamin E as, 353
Antipromoters, **604**, 605
Antiscorbutic factor, **323**
Anus, **72**, 73
Anxiety, physical activity and, 439
Aorta, **81**
Appendix, **72**, 116
Appetite, **233**. *See also* Eating disorders; Overeating; Weight entries
of children, 517
exercise and, 281
ketosis and, 217
in older adults, 557
Appetite control, weight management and, 125
Aquaculture, 671
Arachidonic acid, **145**
Arginine, C-3f
heart disease and, 183
Armed conflict, famines from, 664
Arsenic, usefulness of, 405
Arteries, **81**. *See also* Atherosclerosis; Blood cholesterol; Capillaries; Cardiovascular disease (CVD); Coronary heart disease (CHD); Hemorrhagic disease
coronary, 586
hardening of, 587
Artesian water, 371
Arthritis, 564–565. *See also* Osteoarthritis; Rheumatoid arthritis
alcohol and, 228t
glucosamine for, 565
Healthy People 2020 on, J-1t
treatment for, 565
Articles, research, 16t
Artificial fats, **155–156**
Artificial sweeteners, **113**, 113f, 645
Ascorbic acid, **323**, 323f, 360
Asian foods, 46t
Aspartame, 114t, 491, 645
Aspartic acid, 169f
Aspirin, folate and, 315
Assessments, nutrition, 22–24, E-1 to E-22
Associations, food choices and, 5
Asymptomatic allergy, 524n
Atherogenic diet, 591
Atherosclerosis, **137**, **546**, 558, **586–588**
HDL, LDL, and, 590
Athletes. *See also* Exercise; Fitness; Muscle dysmorphia; Physical activity
dietary supplements and, 452
eating disorders of, 252–254
protein for, 450–451, 451t
supplements for, 463–466
Atkins Diet, 294t
Atmosphere, eating environment and, 282

Atoms, **B-1**
bonds and, 96f, B-3 to B-4
ions and, B-5f, B-5 to B-6
nature of, B-1 to B-3
ATP (adenosine triphosphate), **199,** 200f, C-8f
capture and release of energy by, 201f, 444
magnesium and, 392
synthesis of, 212f
Atrophic gastritis, **316–317,** 558, **562**
Atrophy, **441**
Attitude, weight management and, 284–285
Autoimmune disorder, **598**
Autonomic nervous system, **A-8**
Availability, food choices and, 4

B

Baby foods. *See also* Infant formula
food composition table for, H-86t to H-87t
Back conditions, Healthy People 2020 on, J-1t
Bacteria
in colon, 76
gastrointestinal, 74, 82–83
safe cooking temperatures and, 630f
Salmonella, 626f
Bacteriophages, **644**
"Bad" cholesterol, 143
Baked goods, food composition table for, H-4t to H-9t
Balance, **36**
acid-base, 376–377
calcium, 385–386, 386f
fluid and electrolyte, 373–376
of water, 368, 370
Balanced diet, 3, **36,** 36f, 66
B vitamins in, 322
Barrett's esophagus, 92
Basal metabolic rate (BMR), **236**
energy requirements and, 239
factors affecting, 237t
uncoupling proteins and, 268
Basal metabolism, **236**
Bases, **176,** B-6
acid-base balance and, 376–377
ammonia as, 179–180
nucleotide, 190
Basic (alkaline) character, of pancreatic juice, 75
B-cells, **583**
Beans. *See* Legumes
Beef. *See also* Meat
choice cuts of, 52
food composition table for, H-42t to H-45t
ground, 52
Beer, **220,** 221f. *See also* Alcohol; Alcohol abuse
Behavior
child misbehavior and, 524
hunger and, 521
"hyper," 524
iron deficiency and, 410–411, 521
nutrient deficiencies and, 521–522
Behavior modification, **283**
weight management and, 283–285, 531
Belching, **91**
preventing or alleviating, 93t
Benefits, of complementary and alternative medicine, 615–617, 616f
Benign tumor, 602n
Beriberi (thiamin deficiency), **301–302,** 302f, 321
Beta-amyloid levels, in Alzheimer's disease, 567
Beta-blockers, for hypertension, 597
Beta-carotene, **340,** 345. *See also* Vitamin A
as antioxidant, 342
cancer prevention and, 361
disease prevention and, 363t
free radicals and, 361
vitamin A toxicity and, 344, 345f
Beta cells, 106n
Beta-hydroxymethylbutyrate (HMB), **465**
Beverages, 367. *See also* specific types
for adolescents, 539
alcohol in, 220–222
caffeine content of, H-2t to H-3t
energy drinks as, 457
fluid needs and, 370
food composition table for, H-48t to H-51t
poor choices for fluid replacement, 457
sugars in, 112
for weight gain, 288
BGH. *See* Bovine growth hormone
BHA (food additive), 644
BHT (food additive), 644
Bicarbonate, **75,** 84, **377,** 377f
Bicarbonate-carbonic acid buffer system, 377f
Bifidus factors, **510**
Bile, **75,** 138
fat emulsification by, 138
Binders, **378**
Binge drinking, **227.** *See also* Alcohol abuse
Binge eating disorder, **257,** 257f. *See also* Eating disorders
Bioaccumulation, **634**
of toxins in food chain, 635f
Bioavailability, **378, 403**
of calcium, 388, 389f
of heme iron, 407
of iron, 413, 513
of minerals, 378
of nutrients, H-1
of vitamins, **298,** 334, 562
Biochemical analyses, E-17 to E-22
of vitamin and mineral status, E-17t
Biochemical structures and pathways, C-1 to C-16
Biodiversity, **672–673**
Bioelectrical impedance measurement, 246f, E-15
Bioflavonoids, 319
Biofortification, 653
Biological value (BV), of proteins, **D-3,** D-3t
Biological weapons, 655
Biopharming, 654
Biotechnology, **652**
arguments in opposition to and support of, 656t
as defense against hunger, 655
FDA on foods produced by, 655
food, 652–657
potential problems and concerns with, 654–657
Biotin, **307–308,** C-7f
Adequate Intake, 308
deficiency and toxicity of, 308
food sources of, 307, 307f
Birth defects. *See also* Alcohol-related birth defects; Gestational diabetes; High risk pregnancy; Low birthweight infant
alcohol and, 501–503
fetal alcohol syndrome and, 228t, **501–503,** 502f, 503f
folate and, 312–313, 313f, 473
from gestational diabetes, 487
malnutrition and, 486
vitamin A and, 344
Birthweight. *See also* Low birthweight (LBW) infant
of babies of older mothers, 489
infant health and, 475
Bisphenol A, 647
Black cohosh, 618t
Blastocyst, **471**
Bleeding. *See also* Anemia; Hemophilia; Hemorrhagic disease
iron losses from, 409
vitamins for, 355
Blind experiment, **15**
Blindness. *See also* Keratomalacia; Vision; Xerophthalmia
at night, 343, 343f
vitamin A deficiency and, 343–344, 343f
Bloating, **90**
Blood. *See also* Red blood cells; Vascular system
calcium balance in, 386f
circulation of, 81
phosphorus in, 390
Blood cells, 583. *See also* Red blood cells
normal and in macrocytic anemia, 314f
normal and iron deficiency compared, 410f
vitamin B_{12}-deficiency syndrome and, 317
vitamin E and, 353
white, 583
Blood cholesterol, 137, **546–547.** *See also* Dietary cholesterol; Fatty streaks; HDL (high density lipoprotein) cholesterol; LDL (low density lipoprotein) cholesterol; Plaque
calcium and, 385
plant sterol lowering of, 430
Blood clotting, 588
process of, 355f
vitamin E and, 362
vitamin K and, 354
Blood glucose, 106–109. *See also* Diabetes; Gluconeogenesis; Glucose; Glycemic index; Glycemic response; Hyperglycemia; Hypoglycemia; Metabolic syndrome
diabetes and, 107–108
fasting, 107
homeostasis of, 106–109
Blood lipid profile, **147.** *See also* Blood cholesterol; HDL (high density lipoprotein) cholesterol; LDL (low density lipoprotein) cholesterol; Triglycerides; VLDL (very-low density lipoprotein) cholesterol
Blood lipids, 589
weight and, 248
Blood pressure. *See also* Atherosclerosis; Cardiovascular disease (CVD); Hypertension
body regulation of, 372f
in children, 547
DASH diet for lowering, 380, 596
in pregnancy, 487
salt and, 379
water and, 371–373
Blood sugar, glucose as, 97
Blood vessels. *See also* Arteries; Cardiovascular disease (CVD); Veins
diseases of large vessels, 600
diseases of small vessels, 600–601
vitamin C for, 325
Blood volume
body regulation of, 372f
water and, 371–373
Blood cells. *See also* Anemia
BMI. *See* Body mass index
BMR. *See* Basal metabolic rate
Body. *See also* Weight; specific minerals
alcohol in, 220–225
barriers to disease in, 582
elemental composition of, B-4t
energy in, 10
iron recycled in, 408f
minerals in, 377–395
nutrient composition of, 6–7
response to physical activity, 441
shapes compared, 245f
Body composition/size, **241**
BMI and, 242–243, 242f, 243t
BMR and, 239f
body weight and, 241–249
energy requirement and, 239
of healthy-weight men and women, 7f
measures of, 245, 246f
in older adults, 557
physical activity and, 281, 438
techniques for estimating, 245
waist circumference and, 244–245
Body fat. *See* Fat (body)
Body fluids, water and, 368–377
Body image. *See also* Eating disorders; Overweight; Underweight
food choices and, 5
weight and, 241
Body mass, lean, 237
Body mass index (BMI), **242–243,** E-7,Z. *See also* Obesity; Overweight
calculations of, 242f, 243t
of children, 529
mortality and, 247f
weight and, 242–243
Body weight. *See* Weight
Bolus, **72**
Bomb calorimeter, **232,** 232f
Bonding, chemical, B-3 to B-4

Bone(s). *See also* Calcium; Osteocalcin; Osteomalacia; Osteoporosis; Rickets
in adolescents, 538, 538f
aging and, 397–398
alcohol and, 397
calcium and, 385, 386
cortical, 396
development phases of, 389f
fontanel and, 352f
hormone regulation of, 398
magnesium component of, 392
maximizing mass of, 398
minimizing loss of, 398
nutrients for, 400
phosphorus in, 390
physical activity, weight, and, 399
in physical examination, E-16t
rickets and, 349
trabecular, 396
vitamin A and, 342, 344
vitamin D and, 347–348
Bone density, **396**
calcium and, 390
physical activity and, 438
resistance training and, 443
vitamin C and, 325
Bone development, in pregnancy, 482
Bone loss. *See* Osteoporosis
Bone meal, 396, **400**
Borlaug, Norman, 655
Bottled water, **370**, 650
Botulinum toxin, 626
Botulism, **515**, 625t
Bovine growth hormone (BGH), **647–648**
Bovine spongiform encephalopathy (BSE), **629**
Brain. *See also* Alzheimer's disease; Neurofibrillary tangles; Senile dementia; Senile plaques
aging process, 565–568
alcohol and, 224–225, 224f, 225t
Alzheimer's compared with healthy, 567f
childhood lead exposure and, 522
glycogen in, 105
Bran, 50f. *See also* Grain
Branched-chain amino acids, **187**
Bread
fiber and whole grain in, 49f
food composition table for, H-4t to H-9t
labels compared, 120f
nutrients in, 51f, 111t
Bread for the World, 675t
Breakfast
for adolescents, 539
children and, 521
energy density of options for, 8–9, 8f
nutrient density compared, 37f
Breakfast cereals. *See also* Cereals
as processed foods, 50–51
Breast cancer, 603, 604t
soy, phytoestrogens, and, 429
Breast disease, fibrocystic, 353
Breastfeeding, 507–508. *See also* Breast milk; Lactation
alcohol and, 489, 496
benefits of, 492t
caffeine and, 491, 497
dieting during, 491
energy and nutrient needs during, 493, 494
energy nutrients in, 509
environmental contaminants and, 490, 496–497
foodborne illness and, 490–491
food choices during, 495
frequency and duration of, 508–509
illicit drugs and, 489, 496
learned behavior aspect of, 493
maternal health during, 495–496
medicinal drugs and, 489, 496
nutrient supplements during, 494
smoking, chewing tobacco, and, 489–490, 496
sugar substitutes and, 491
tips for, 493t
vitamins and minerals during, 491, 494
water during, 494
WIC information on, 494–495
Breast milk
DHA content of, 509
immunological protection by, 510
infant growth and, 507–508
nutrients in, 509, 511f
transition to cow's milk, 512–513
Breast milk banks, **511**
Brown adipose tissue (brown fat), **268**
Brownell, K., 294
Buffers, **176**, **377**. *See also* Bicarbonate; Bicarbonate-carbonic acid buffer system
Bulimia nervosa, 90, **256–257**. *See also* Eating disorders
treatment of, 257
Butter. *See also* Fats; Oils
fats in, 154
Butyric acid, 102n
B vitamins, 298, 300–322. *See also* Biotin; Folate; Niacin; Pantothenic acid; Riboflavin; Thiamin; specific B vitamins under Vitamin(s)
alcohol use and, 226
choline and, 318
deficiencies of, 319–322, 321f
food sources for, 322
interactions among, 319–322
metabolic pathways of, 319, 320f
roles of, 319
toxicities of, 322

C

Caffeine, **464**, **H-2**, **H-2t to H-3t**
binge drinking and, 227
breastfeeding and, 497
as diuretic, 370
for endurance enhancement, 464
energy drinks and, 457
in pregnancy, 491
Cakes, food composition table for, H-4t to H-9t
Calbindin, **348–349**
Calciferol, **347**. *See also* Vitamin D (calciferol)
Calcitonin, 348, **385**, **A-6** to A-7
Calcium, **384–390**. *See also* Hypercalcemia
absorption of, 386
Adequate Intake of, 386–387
adolescent needs for, 386, 538
aging and, 397–398
balance of, 385–386, 386f
bioavailability of, 388, 389f
in blood, 350, 387f
body role of, 384–385
bone development and, 348, 385, 386
cells and, 385
deficiency of, 386, 388–390
dietary, 386–390, 387t, 400
in disease prevention, 385
estimating daily intake of, 389
food sources of, 387–388, 388f
infant absorption of, 386
lactose intolerance and, 104
in milk products, 53
for older adults, 562
osteoporosis and, 385, 389–390, 396–397, 400
pregnancy and, 386, 482
protein and, 183
supplements of, 400
in teeth, 385
toxicity of, 390
in vegetarian diets, 65
vitamin D and, 349
weight and, 385
Calcium-binding protein, **386**
Calcium channel blockers, for hypertension, 597
Calcium rigor, **386**
Calcium tetany, **386**
Calculation aids, K-1 to K-2
Calmodulin, **385**
Calories, **8**. *See also* kCalories
Calorimeter, 232
CAM. *See* Complementary and alternative medicine
Campylobacter, 625t
Canada. *See also* Dietary Reference Intakes
niacin intake in, 305
Canadian Paediatric Society, on breastfeeding, 507–508
Cancer, 602–606. *See also* specific types
alcohol and, 228t
antioxidants and, 361
calcium and, 385
development of, 602–603, 603f
dietary fats and, 148
dietary promoters of, 605
factors associated with specific sites, 604t
folate and, 313
Healthy People 2020 on, J-1t
high-fiber diet and, 116
iron and, 411
omega-3 fatty acids and, 150
physical activity and, 438
phytoestrogens and, 429
protein and, 183
reduced risks of, 438
risk reduction recommendation, 605, 606t
selenium and, 420
skin, 350–351
vegetarian diets and, 62
vitamin D and, 348
weight and, 247
Candy. *See* Sugars
Canola oil, 134f
Canola plants, genetic engineering of, 653
Capillaries, **81**
Capsaicin, blood clotting and, 429t
Carbohydrate loading, **447**
Carbohydrates (chemistry), 96–101, C-1 to C-2
monosaccharides, C, Cf
Carbohydrates (dietary), 95–96, 458
absorption of, 103
in breast milk, 509
for children, 518
diabetes and, 601
digestion of, 75, 76f, **84**, 101–102, 102f
energy from, 105f, 201
excess, 215
in food, 6
gas from, 92
glucose from, 104–105
kcalories in, 124–125
metabolism of, 105–106
as nutrients, 7, 8
for older adults, 560
pregnancy/lactation needs for, 480
starch, fibers, and, 115–121
weight management and, 279
Carbonated water, 371
Carbon chain, in fatty acids, 130–131
Carbon filters, 640
for water, 371
Carbonic acid, **377**, 377f
Carboxypeptidases, 172f
Carcinogenesis, **602**
Carcinogens, **603**, **642**
BHT and, 644
cooking and, 605
Cardiac output, **442**, **595**
Cardiac sphincter. *See* Esophageal sphincter
Cardiorespiratory conditioning, **442**
Cardiorespiratory endurance, **440**, 442–443
Cardiovascular disease (CVD), **147–148**, **586–592**
Alzheimer's disease and, 567
breast milk protection against, 510
physical activity and, 438–439
weight and, 247–248
Carnitine, **318**, 324, **465**
Carotenoids, **340**, 346f, **429**, 429t. *See also* Vitamin A
antioxidant properties of, 644
arthritis and, 565
disease prevention and, 363t
plant pigmentation and, 345
Catabolic reactions, 175, 200f
Catabolism, **199**
Catalyst, **74**
Cataracts, **564**
Cathartics, **256**
Catholic Relief Services, 675t
Cations, **373**
Cauliflower, genetically modified, 653f
Celiac disease, **90**
Cells, 198f, **A-2** to A-3. *See also* specific types
in absorption, 79
calcium and, 385
cytoplasm, A-2
electrolytes and, 374f
epithelial, 342

Cells (*continued*)
fluids in, 368f
intestinal, 78–79
membrane, A-2
nucleus, A-2
phospholipids in, 136–137
selective permeability of, 374
structure of, A-3f
vitamin A in differentiation of, 341–342
Cellulose, C-1
starch bonds compared with, 100f
Central nervous system, **A-8**. *See also* Nervous system
Central obesity, **244**
Cereals
breakfast, 50–51
food composition table for, H-10t to H-15t
iron-fortified, 514f
Certification, 638–639
Certified lactation consultants, **493**
Certified nutritional consultants, **30**
Certified nutritionists, **30**
Certified nutrition therapists, **30**
Cesarean section, **476**
Chaff, 50f
Chamomile, 618t
CHD. *See* Coronary heart disease
CHD risk equivalents, **590**
Cheater's Diet, 295t
Cheeses. *See* Dairy products; Milk and milk products
Cheilosis, 321f
Chelate, **411**
Chemical pollution, 670–671
food safety and, 631
Chemicals
in nutrients, 7
phytochemicals, 6
Chemistry
of carbohydrates, 96–101
of fatty acids, 129–136
of human body, 198–200
of nutrients, 201
of phospholipids, 136–137
of protein, 168–171
Chemistry concepts
acids, B-6
atoms, nature of, **B-1** to B-3
bases, B-6
chemical bonding, B-3 to B-4, B-4f
elements, B-2t
free radical formation, B-7 to B-8
ion formation, B-5 to B-6
molecules, B-3
reactions, B-6 to B-7, B-7f
water, B-6
Chewing tobacco, pregnancy and, 489
Child and Adult Care Food Program (CACFP), 535–536
Child health, Healthy People 2020 on, J-2t
Childhood, Healthy People 2020 on, J-1t
Childhood obesity, 526–531
American Heart Association guidelines and, 547t
behavioral changes for, 531
blood pressure and, 547
chronic disease development and, 545–548
diet and, 530, 547–548
drugs for, 548
genetic and environmental factors in, 527–528
growth and, 528
heart disease and, 546–547
physical activity and, 528, 530
physical health and, 529
prevention and treatment of, 529
psychological development and, 529
psychological support and, 531
surgery for, 531
type 2 diabetes and, 545–546
Children. *See also* Infants; Kwashiorkor; Marasmus
analysis of measures in, E-6 to E-7
diabetes among, 597
dietary supplements for, 519
diet of overweight, 530
estimated daily energy needs for, 519t
food preferences of, 532
food skills of preschoolers, 532t
height measurement of, E-6, E-6f
hunger and malnutrition in, 520–522
hyperactivity and "hyper" behavior in, 524
iron deficiency in, 408
iron for, 518–519
malnourished, 668f
meal planning for, 519–520
mealtimes for, 531–534
mercury in foods and, 636
nutrient deficiencies and behavior of, 521–522
nutrition for, 517–536
obesity in, 526–531, 526f
physical activities for, 530t, 547
physical signs of malnutrition in, 522t
rehabilitation of malnourished, 669–670
snacking by, 532–533
vitamin A and, 342–343, 344
vitamin K for, 355f
weight of, E-6
Chilling, of foods, 628–629
Chips, food composition table for, H-4t to H-9t
Chloride, 382
AI, 383
deficiency and toxicity of, 382
Chlorophyll, **345**
Choice cuts. *See also* Beef
of beef, 52
Choking, 72, 88–90, 89f, 93t
prevention of, 532
Cholecalciferol (vitamin D_3), **347**
Cholecystokinin (CCK) hormone, **84**, 85f, 138, 235, 236, A-8
Cholesterol, **137**, 137f, 141. *See also* Blood cholesterol; HDL (high density lipoprotein) cholesterol; LDL (low density lipoprotein) cholesterol; Sterols; VLDL (very-low density lipoprotein) cholesterol
cancer and, 148
CHD and, 590
dietary fat reduction and, 153
food label nutrient claims for, 56
HDL (high density lipoprotein), 143
heart disease and, 147–148
LDL (low density lipoprotein), 142, 143, 588
obesity and, 148
recommended intakes of, 148–149
VLDL (very-low density lipoprotein), 142
Choline, **136**, **318**
deficiency and toxicity, 318
food sources for, 318
Chondroitin, 565
Chromium
Adequate Intake of, 423
body role, 423
deficiency and toxicity of, 423
sources of, 423
supplements of, 423
Chromium picolinate, **465**
Chromosomes, **190**, 198f, **A-2**
Chronic diseases, **3**, 25–26. *See also* Diseases; specific conditions
childhood obesity and early development of, 545–548
dietary guidelines for, 607t
inflammation and, 584
interrelationships among, 586f
nutrition and, 110, 585–586
during pregnancy, 474–475
recommendations for, 606–609
risk factors for, 586t
sugar consumption and, 110
vitamin and mineral supplements for, 617
Chronic malnutrition. *See also* Malnutrition
acute malnutrition and, 668t
Chronological age, **553**
Chylomicrons, 79, **141**
transport of lipids and, 141–142
Chyme, **72**, 73, 75, 83
Chymotrypsin, 172f
Cigarette smoking. *See also* Smoking
CHD and, 590–591
Cinch! diet, 295t
Cinnamon, 618t
Circulation
enterohepatic, 141f
physical activity and, 438
Circulatory systems, 80–82
vascular system, 80–82, 80f
Cirrhosis, **223**
Cis-fatty acids, 135f
Citric acid cycle. *See* TCA (tricarboxylic acid) cycle
CKK. *See* Cholecystokinin (CKK) hormone
Claudication, intermittent, 353
Cleanliness, in kitchen, 627, 628
Cleft lip and palate, folate and, 313
Clinically severe obesity, **272**
Clinical trials, 14f
Cloning, **654**
FDA on foods produced by, 655
Clostridium botulinum, 625t, 626
Clostridium perfringens, 625t
Clotting. *See* Blood clotting
CoA (coenzyme A). *See* Coenzyme A
Cobalt, in Vitamin B_{12}, 405, 405f
Cocaine. *See* Illicit drugs
Coconut oil, 134f
Coenzyme A (CoA), **208**, **308**, **319**
Coenzyme PLP, **309**
Coenzyme Q_{10} (ubiquinone), **319**
Coenzymes, **200**, **300**, 301f, C-4f to C-7f. *See also* Enzymes
biotin as, 307
B vitamin roles and, 319
of folate, 310
of niacin, 305
riboflavin, 304f
vitamin B_{12} and, 318
Cofactors, **323**, **405**
Cognition, vitamin B_{12} deficiency and, 317
Cognitive behavioral therapy, in weight management, 284
Cognitive influences, on eating, 233, 234f
Cold, vitamin C and, 324
Cold pasteurization, irradiation as, 633
Colitis, 90
Collagen, **173**, **323**
vitamin C and, 323
Collagenase, 172f
College students, drinking among, 227
Colon, 72, 72f. *See also* Large intestine
diverticula in, 91, 91f
Colon cancer, 148, 603, 604t
calcium and, 385
Colonic irrigation, **91**
Color
additives, 644, 644f
of vegetables, 51, 345, 346f
Colorectal cancer, folate and, 313
Colostrum, **510**
Combination foods, food list for, G-14t
Comfort foods, stress and, 235
Comfrey, 618t
Commission on Accreditation for Dietetics Education (CADE), 31n
Committee on Dietary Reference Intakes (DRI), 300, 362
on calcium, 388
Common cold, vitamin C and, 324
Community-based programs, Healthy People 2020 on, J-1t
Community Food Security Coalition, 675t
Community programs, for weight management, 286, 287t
Competition, meals before and after, 458–459
Complementary and alternative medicine (CAM), **614**–620. *See also* Herbal supplements
Complementary proteins, 181–182, 182f
Composition (of molecule), **B-1**
Compound, **B-1**
Computed tomography (CT), 245
Conception, **470**
maternal weight before, 475–476
Condensation, **98**, **133**
of amino acids to form dipeptide, 169f
of glycerol and fatty acids, 133f
of monosaccharides, 98f
Condiments, food composition table for, H-58t to H-59t
Conditionally essential amino acid, 169
Conditionally essential nutrient, **145**
Conditioning, **440**
Congregate meals, **570**

Congressional Hunger Center, 675t
Conjugated linoleic acid (CLA), 135
Constipation, 91. *See also* Diverticulosis; Hemorrhoids; Irritable bowel syndrome; Laxatives
  in pregnancy, 484
  preventing or alleviating, 93t
Consumers
  biotechnology and, 654, 655f
  complementary and alternative medicine and, 620
  environmental contaminant threats to, 636
  food irradiation concerns of, 633
  food label education for, 58
  food safety awareness by, 623–624, 627
  water and, 648–650
Contaminant minerals, 424
Contaminants, 634. *See also* Environmental contaminants
  environmental, 634–637
  in natural foods, 637
  in water, 649
Contamination, in bottled water, 650
Contamination iron, 414
Continuous elimination, 73
Contractions. *See* Peristalsis
Control group, 12
Convenience, food choices and, 4–5
Convenience meals, food composition table for, H-84t to H-87t
Convenient dietary supplements, 464
Conventional medicine, 614
Conversions, calculation aids for, K-1
Cookies, food composition table for, H-4t to H-9t
Cooking
  carcinogens and, 605
  of foods, 628, 630f
  thiamin and, 302
Cool-down (from exercise), 441
Copper, 420–421
  body role of, 420
  deficiency of, 421–422
  food sources of, 421
  RDA of, 421
  serotonin and, 420
  toxicity of, 421
Cori cycle, 447
Corn, 652f
  genetic engineering of, 653
Cornea, 341
Coronary arteries, 586
Coronary heart disease (CHD), 586. *See also* Atherosclerosis; Blood cholesterol; Cardiovascular disease (CVD)
  antioxidants and, 591
  deaths from, 588
  risk assessment for, 592
  risk factors for, 588–589, 588–591, 589t
  risk reduction strategies for, 591, 593, 593t
Correlation, 15–16
Cortical bone, 396
Corticotropin-releasing hormone (CRH), A-5
Country of Origin Label. *See also* Food labels
  for foods, 627
Coupled reactions, 199, 268n
Covalent bonds, B-3
Covert condition, 23
Cow's milk
  in early infancy, 513
  introducing into diet, 512–513
  nutrients in, 511f
CP (creatine phosphate), 444
Crackers, food composition table for, H-4t to H-9t
Cravings
  in pregnancy, 484
  weight management and, 125
C-reactive protein (CRP), 587–588
Creatine, 464
Credentials, fake, 31
Cretinism, 418
Critical periods, in pregnancy, 472–475, 473f
Crop(s). *See also* Agriculture; Food(s)
  biotechnology and, 656t
  genetic engineering of, 652
  organic, 640–641
  pesticide alternatives for, 639–640
  planting of, 670–671
  water misuse and, 672
Cruciferous vegetables, cancer risk reduction and, 605
Cryptosporidium, 648
Crypts, tubular glands in absorption as, 78
Cultural competence, 4
Curcumin, 429t, 430
Cyanocobalamin. *See* Vitamin B_{12}
Cyanogens, 637
Cyclamate, 114t
Cyclospora, 648
Cystic acne, 344
Cytoplasm (cells), 198f, A-2
Cytosol, 198f, A-2

D

Daidzein, 429t
Daily Food Patterns, E-4. *See* also Food Patterns
Daily Values
  calculating personal, 56
  for fats, 154–155, 155t
  for fiber, 118
  for food labels, 55–56, 55t
Dairy products. *See also* Milk and milk products
  food composition table for, H-32t to H-41t
Dark green vegetables. *See also* Vegetables; specific vegetables
  nutrients in, 40–41
DASH (Dietary Approaches to Stop Hypertension) diet, 380, 385, 596–597
  USDA Food Pattern compared with, 597
Deamination, 179
  of amino acids, 179f, 207
Death
  from alcohol abuse, 227
  from diabetes, 598
  factors contributing to, 26t
  leading causes in United States, 25t, 585f
  of malnourished children, 667
  from obesity, 247
Decaffeinated coffee, additives in, 647
Defecation, 72, 91
Deficiency
  of biotin, 308
  of B vitamins, 319–322
  of calcium, 386, 388–389, 390
  of chloride, 383
  of choline, 318
  of chromium, 423
  of copper, 420–421
  of folate, 312–316
  of iodine, 418, 419
  of iron, 23, 321, 408–409, 414, 452–453
  of magnesium, 392–393
  of manganese, 421, 422
  of molybdenum, 423
  of niacin, 305–306, 306f, 319–320
  nutrient and child behavior, 521–522
  of nutrients, 321, 667
  of pantothenic acid, 309
  of phosphorus, 391
  of potassium, 383
  of riboflavin, 304
  primary, 23, 353, E-17
  secondary, 23, 314, 355
  of selenium, 419, 420
  stages in development of, 23f
  of sulfate, 393
  supplements for correcting, 331–332
  for thiamin, 301–302, 302f
  of trace minerals, 404
  of vitamin A, 342–344
  of vitamin B_6, 309
  of vitamin B_{12}, 316–317
  of vitamin C, 325
  of vitamin D, 347, 348–350
  of vitamin E, 353
  of vitamin K, 355
  of zinc, 415, 416, 416f
Deficient nutrient intake, 18
Dehydration, 368. *See also* Hydration, and physical activity; Temperature regulation, of body; Water
  alcohol and, 225
  electrolyte imbalance and, 376
  in older adults, 560
  in physical activity, 453f
  signs of, 369t
  from vomiting, 90
Dehydroascorbic acid, 323f
Delaney Clause, 642–643
Dementia, 566. *See also* Alzheimer's disease
De minimis rule, 643
Denaturation, of proteins, 170, 170f
Density, nutrient, 36–38, 41–44, 235
Dental caries, 111f
  prevention in children, 533–534
  sugar alcohols and, 114–115
Dental plaque, 112
Department of Agriculture (US). *See* USDA
Department of Health and Human Services (DHHS). *See also* Healthy People program
Department of Health and Human Services (DHHS), Healthy People survey by, 24
Departments of government. *See* specific departments
Depletion, of glucose, 447–448
Depression
  eating disorders and, 257
  late-life, 559
  physical activity and, 439
Desert, croplands as, 671f
Desserts
  food list for, G-6t to G-8t
  for heart health, 594
Detoxification, by liver, 81
Developing countries, child labor in, 666f
Development, sustainable, 673–674
DEXA scan, 396, 397f
Dextrins, 101n
DHA. *See* Docosahexaenoic acid
DHEA (dehydroepiandrosterone), 465
DHF (dihydrofolate). *See* Folate (B vitamin)
Diabetes (diabetes mellitus), 107–108, 590, 597–602, 598. *See also* Insulin; Insulin resistance; Metabolic syndrome
  breastfeeding and, 495
  calcium and, 385
  childhood obesity and, 545–546
  complications of, 599
  exchange lists for, G-1 to G-16
  genetic component of, 193
  gestational, 108, 487
  metabolic consequences of untreated, 600f
  physical activity and, 439
  pregnancy and, 475, 486
  prevalence among adults, 598f
  recommendations for, 601–602
  type 1, 107, 600f
  type 2, 107–108, 248, 600f
  vegetarian diets and, 62
  weight and, 247, 248
Diabetes, Healthy People 2020 on, J-1t
Diaphragm, 72
Diarrhea, 90
  colitis and, 90
  irritable bowel syndrome and, 90
  in malnourished children, 669–670
  preventing or alleviating, 93t
  protein overload and, 506
  sodium deficiency and, 375
  traveler's, 632
  treatment of, 90–91
Diet, 3–4. *See also* Balanced diet; Fad diets; Mediterranean diet; Weight management; specific foods and substances
  analysis programs for, 284f
  antioxidants in, 556
  balanced, 36
  cancer and, 604, 605
  cancer risk reduction and, 605, 606t
  cataracts and, 564
  for children, 547–548
  for chronic diseases, 607t
  comparison of, 294–295t
  drug toxicities and, 578
  energy restriction in animals and, 554–555
  genes and, 175, 194
  GI bacteria and, 83

Diet (*continued*)
glycogen and, 446
health and, 25–27, 581–609
heart-healthy, 594
for lactose intolerance, 104
longevity and, 554
low-carbohydrate, 218–219, 218f
macrobiotic, 66
nonheme iron and, 407
nutritional adequacy of, 633–634
obesity and, 266
of overweight children, 530
physical endurance and, 446f
for physically active people, 457–460
planning a healthy, G-3t to G-16t
planning principles for, 36–38
pregnancy and, 470
psychology of weight cycling and, 271f
vegetarian, 62–66
Diet, Nutrition, and Prevention of Chronic Diseases report (WHO), 607
Dietary Approaches to Stop Hypertension (DASH). *See* DASH diet
Dietary fiber, **100**. *See also* Insoluble fiber; Soluble fiber
Dietary folate equivalents (DFE), **312**
estimating, 312
Dietary Guidelines for Americans (USDA), 22, 40f
for adolescents, 537
on alcohol use, 221
for children, 535
chronic diseases and, 607
on dental caries, 112
for dietary fats, 148
food labels and, 58, 59t, 633
Healthy Eating Index assessment and, 45–46
hypertension and, 596
nutrient recommendations in, 38–40, 39t
on physical activity, 438
sodium recommendations, 380
for sugars, 109
USDA Food Patterns and, 40–47, 44t, 48t, 58, 59t, 380
weight-loss strategies and, 274
Dietary Reference Intakes (DRI), 17–21, 21f. *See also* Adequate Intake; Estimated Average Requirements (EAR); RDA (Recommended Dietary Allowances); Tolerable Upper Intake Level (UL)
for dietary fats, 148, 150
energy requirements estimation and, 239–240
for iron in children's diets, 519
nutrient recommendations in, 38
for protein, 184
sugar level recommendations in, 112–113
Dietary Supplement Health and Education Act, 404, 619
Dietary supplements, **331**. *See also* Vitamin(s); Vitamin and mineral supplements
body weight, image, and, 5
for bone health, 400
to breast milk, 510
calcium, 400
cancer prevention and, 606
for children, 519
chromium, 423
convenient, **464**
as conventional or alternative medicines, 617
dangerous, banned, or illegal, 465–466
as ergogenic aids, 463–466
FDA and, 619
iron, 411, 414
lactation and, 494
for older adults, 563
performance and, 451–452
for pregnancy, 483
that may perform as claimed, 464–465
that perform as claimed, 463–464
for weight loss, 271
zinc, 416
Diet-drug interactions, 576t. *See also* Nutrient-drug interactions
Dietetic technician, **31**
registered (DTR), 20, **31**
Diet history, E-3
Diet-induced thermogenesis (DIT), 238f
Dieting, malnutrition from, 485
Dietitian, **29**
Diet-planning guides, 40–53
Food Guide (USDA), 40–47, 44t, 48t
Diffusion, absorption and, 77
Digestibility, protein, 181
Digestion, **69**–77
blood circulation and, 81
of carbohydrates, 101–102, 102f
enzymes of, 70, 84, 172f
of fat, 141f
glands of, 74
hormonal and nervous systems in, 83
of lipids, 137–140, 139f, 141f
muscular action of, 72–73
in older adults, 558
process of, 70f
of proteins, 171, 172f
of sandwich, 76f
secretions of, 73–75, 75t
of triglycerides, 138–140, 140f
of vitamin B_{12}, 315
zinc and, 416
Digestive problems, 88–93
choking as, 88–90, 89f
vomiting as, 89–90
Digestive system, **72**. *See also* Circulatory systems; Digestion; Gastrointestinal (GI) tract; Lumen
alcohol and, 222
Digoxin, 617f
Dioxin, 496, **647**
Dipeptide, **169**
Diploma mills, **31**
Disaccharides, **98**–99, 98f
Discretionary kcalories, **44**, 45f, 280
Diseases. *See also* Chronic diseases; Health; specific conditions
abdominal fat and, 245f
age-related, 554
antioxidant nutrients and, 360–363, 363t
biotechnology and, 654
body weight, body fat, and, 246–249
breast milk protection from, 510
calcium in preventing, 385
cancer and, 602–606
chronic, 3, 25–26
family history of, 585–586
fat and, 264
genetic variation and, 192–194
hemorrhagic, 355
iron and, 411
of large blood vessels, 600
magnesium and, 392–393
of nerves, 600–601
of older adults, 558
of poverty, 667
resistance to, 438
of small blood vessels, 600
sugar consumption and chronic, 110
trends in, 582
vegetarian diets and, 62
vitamin D and, 347, 348
vitamin supplements and, 332
from water, 648
Disordered eating, **253**. *See also* Eating disorders
Dispensable amino acids, 169
Dissociates, **373**
Distilled water, 371
Distractions, eating environment and, 282–283
Diuretics. *See also* Antidiuretic hormone
alcohol as, 457
caffeinated beverages as, 370
for hypertension, 597
Diverticula, **91**, 91f, 116
Diverticulitis, **91**
Diverticulosis, **91**
DNA (deoxyribonucleic acid), **190**, 246f
folate and, 310
human genome and, 192f
methylation of, 191
protein synthesis and, 173
DNA synthesis, vitamin B_{12} and, 315
Docosahexaenoic acid (DHA), **145**, 509
Dolomite, 396, **400**
Doses. *See also* specific vitamins
of vitamins, 299f
Double-blind experiment, **15**
Double bonds (fatty acids), 131–132
location of, 132
Down syndrome, **489**
DRI. *See* Committee on Dietary Reference Intakes; Dietary Reference Intakes
Dried fruits, 64
Drink, alcoholic, **221**
Drinking. *See also* Alcohol; Alcohol abuse; Drink
excessive, 227
in pregnancy, 501–503
Drinking water, 648–650. *See also* Water
bottled, 650
sources of, 648–649
treatment of, 649–650
Drought, famine and, 664
Drug history, E-3
Drug interactions, with folate, 314–315
Drugs, **221**. *See also* Illicit drugs; Medicine
actions of, 575
alcohol as, 221
for bone loss and formation, 399
breastfeeding and, 496
for childhood obesity, 548
diet, toxicity, and, 578
diet and absorption of, 576
diet and excretion of, 577
efficient delivery of, 654
FDA approved for weight loss, 273t
grapefruit juice interactions with, 577t
herb interactions with, 620t
for hypertension, 596, 597
inactive ingredients in, 578
nutrient interactions with, 575–578
in pregnancy, 489
for treating obesity, 272–273
Dry beriberi, 302
Dual-energy X-ray absorptiometry (DEXA scan). *See* DEXA scan
Dukan Diet, 295t
Duodenum, **72**
Duration (of activity), **441**, 447
Dwarfism, as zinc-deficiency symptom, 416f
Dwarf wheat, 655
Dysphagia, **558**

E

E. coli infection, 625t, 626
EAR. *See* Estimated Average Requirements
Eating. *See also* Appetite; Eating disorders; Hunger
away from home, 539–540
cues for, 233
healthy, 39t, 59t, 276–279, 608f
records of, E-4 to E-5
Eating disorders, **252**–258. *See also* Anorexia nervosa; Bulimia nervosa; Cathartics; Emetics; Unspecified eating disorders
amenorrhea and, 253
anorexia nervosa as, 254–256
of athletes, 252–254
binge-eating disorder and, 257–258
body weight, image, and, 5
bulimia nervosa as, 256–257
combating, 254t
female athlete triad and, 252–253
hunger pangs and, 234
osteoporosis and, 253
restrictive dieting-binge eating cycle, 257f
in society, 258
Eating habits, of older adults, 568–572
Eating patterns, **35**–36
Echinacea, 618t
Eclampsia, **487**–488
Ecological footprints, 678f, 679
Economic changes, in aging process, 559
Economic stress, obesity and, 662
Economy
food choices and, 4–5
global foods and, 680
Ecosystems, biotechnology and, 654

Edema, **176**, 176f
of kwashiorkor, 668f
Education, family life improvements and, 666–667
Educational programs, Healthy People 2020 on, J-1t
EER. *See* Estimated Energy Requirement
Eggs
health benefits of, 153
phospholipids in, 136
vitamin D in yolks, 350
Eicosanoids, **145**, 588
Eicosapentaenoic acid (EPA), **145**
18-carbon fatty acids, 130–132, 132t, 145, 147
Elastase, 172f
Elderly. *See* Aging; Older Adults
Elderly Nutrition Program. *See* Older Americans Act
Electrolyte balance, regulation of, 374–375, 453–458
Electrolytes, **373**. *See also* Anions; Cations; Milliequivalents per liter; Sodium
in cells, 374f
important, 373t
losses and replacement of, 455
for physical activity, 453–457
regulation of fluids and, 374–375
in sports drinks, 457
water attraction to, 373–374
water dissolves salts and, 374f
Electrolyte solutions, **373**
Electrons, in atom, B-3, B-3f
Electron transport chain, **202**–203, 212f, C-13f, C-13 to C14
Elements, **B-1**, B-2t
inorganic, 377–378
in nutrient classes, 7t
Elimination, 70, 71f
continuous, 73
Embolism, **588**
Embryo, **471**
Emergency shelters, **663**
Emerging risk factors, **591**
Emetics, **256**
Emotion, food choices and, 5
Empty-kcalorie foods, **38**, 279
Emulsifiers, 75, **136**, 136f, 137, 645
Endocrine system, **83**, A-5f. *See also* Hormones
Endocrinology, A-3
Endocytosis, 77f
Endogenous cholesterol, **137**
Endometrial cancer, 603, 604t
Endoplasmic reticulum, 198, **A-3**. *See also* Cells
Endosperm, 50f
Endurance
caffeine for, 464
cardiorespiratory, **440**, 442–443
diet and, 446f
fuels for, 445–446, 445t
Enema, **91**
Energy, **6**. *See also* Energy expenditure; Estimated energy requirement; Kcalories
adolescent needs for, 537
from alcohol, 226
in body, 10
calculating, 10f
calculation aids for, K-2
capture and release by ATP, 201f
from carbohydrates, 95
in children, 528
children's needs for, 517–520
conservation of, 218
daily intake over time, 124f
determining estimated requirement (EER), F-1t
estimated daily needs for children, 519t
Estimated Requirement (EER) for, 20
estimating requirements for, 239–240, 240f
estimating requirements for older adults, 561
exchange list and, G-2
from fat, 146f, 212
feasting as excess, 213–215
from fiber, 102
for food production, 678
for global foods, 680
glucose for, 105
glycogen storage and, 105
higher-density foods and, 8f
infant needs for, 506
infant vs. adult needs for, 506t
from kcalories, 212, 226, 232–236
for lactation, 493–494
lower-density foods and, 8f
nutrients for, 124f, 201–213
older adult needs for, 560–563
overuse of, 671–672
physical activity and, 269, 444–446, F-1 to F-6
in pregnancy, 480
protein as source of, 177–178
restriction in human beings, 555–556
set-point theory and, 265
unsustainable and sustainable methods for, 674t
Energy balance, 231–249, **232**
Energy density, 8–10, 8f, 235, 277, 277f
food comparisons based on, 278
for weight gain, 288
Energy drinks, caffeine in, 457
Energy expenditure, 236–240, 280
by activity, 238t, 281–282
components of, 237f
thermogenesis and, 236
Energy metabolism, 197–219. *See also* Metabolism
alcohol interference with, C-14f, C-14 to C-15
central pathways of, 214f
CoA and, 208f
glucose and, 203–206
glycerol, fatty acids, and, 207
phosphorus and, 390
Energy nutrients, in breast milk, 509, 509f
Energy restriction, 555–556
Energy-yielding nutrients, **8**, 445–446
Energy-yielding pathways, 203f
Engineering. *See* Genetic engineering
Enhanced water, **456**–457, 650
Enriched grains, **49**, 50
with iron and B vitamins, 413
Enterohepatic circulation, 141f, 316
Enteropancreatic circulation, **415**–416
of zinc, 415f
Enteropeptidase, 172f
Enterostatin (hormone), 236
Environment
biotechnology and, 656t
and childhood obesity, 527–528
epigenetics and, 191, 266
food choices friendly to, 678–683
food production and, 670–673
global, 670–675
hunger and, 670–673
impact of common seafood choices, 681t
nation's impact on, 678
obesogenic, 268
weight-loss strategies and, 282–283
Environmental contaminants, 634–637
breastfeeding and, 496–497
cancer from, 603
pregnancy and, 490
Environmental health, Healthy People 2020 on, J-1t
Environmental influences, on eating, 233
Environmental Protection Agency. *See* EPA (Environmental Protection Agency)
Enzymes, 74, **175**, **200**. *See also* Coenzymes; specific enzymes
in absorption, 79
actions of, 175f
digestive, 70, 84, 171, 172f
iron and, 406, 420
proteins as, 175
weight and, 265
EPA. *See* Eicosapentaenoic acid
EPA (Environmental Protection Agency), 636, 638
animal waste management and, 671
Ephedra, 618t
Ephedrine, for weight loss, 271–272
Epidemics, **264**. *See also* AIDS (acquired immune deficiency syndrome); Childhood obesity; Chronic disease; HIV (human immunodeficiency virus); Hypertension; Obesity
HIV and AIDS as, 584t
of obesity, 264
Epidemiological studies, 14f
Epigenetics, **191**. *See also* Genetics and genetics in obesity, 266–268
Epiglottis, **72**
Epinephrine, **107**, 178, 525, A-6
Epithelial cells, **342**, 344
Epithelial tissue, **342**
Ergocalciferol (vitamin D_2), **347**
Ergogenic aids, supplements as, **463**–466
Erythrocyte hemolysis, **353**
Erythrocyte protoporphyrin, **409**, E-21
Erythropoietin, A-7
Esoinophilia-myalgia syndrome (EMS), 187
Esophageal cancer, 603, 604t
folate and, 313
Esophageal sphincter, **72**
Esophagus, **72**, 90
Essential amino acids, 168t, **169**
Essential fatty acids, **145**. *See also* Eicosanoids; Linoleic acid; Linolenic acid; Omega-3 fatty acids; Omega 6 fatty acids
pregnancy/lactation needs for, 481
Essential nutrients, **8**
Estimated Average Requirements (EAR), 17–**18**, 18f
Estimated Energy Requirement (EER), **20**, 239
equations to determine, 240, F-1t
Estrogens, **A-7**. *See also* Phytoestrogens
bone loss and, 399
breast cancer and, 603–604
Ethanol, **220**, 229
Ethics, biotechnology and, 655, 656t
Ethnic foods, **4**, 45, 46t
Ethnicity
body composition and, 243
food choices and, 4
Excessive drinking, **227**. *See also* Alcoholism
Exchange lists, **46**–47, G-1 to G-16
Excretion, 70, 76, 377
of nutrients, 577
of urea, 180
of wastes, 80
of water, 369
Exercise, 281, **438**. *See also* Aerobic physical activity; Fitness; Physical activity
guidelines for older adults, 555t
lactation and, 493–494
during pregnancy, 478, 479f
for spot reducing, 282
Exocrine gland, A-5f
Exogenous cholesterol, **137**
Experimental group, **12**
Experiments
blind, 15
double-blind, 15
in scientific method, 13f
studies as, 14f
Expert Committee, of the American Medical Association, 526, 529
Experts, in nutrition, 29–31
Extinction, of plant species, 672–673
Extracellular fluid, **368**, 385
Eyes. *See also* Vision
blindness and, 343–344
night blindness and, 343, 343f
in physical examination, E-16t
vitamin A and, 341

F

FAD. *See* Flavin adenine dinucleotide (FAD).
Facilitated diffusion, 77, 77f
Fad diets, **271**, 294–297
appeal of, 295–297
identifying, 297
Failure to thrive, 506
False negative, **325**
False positive, **325**
Family history
CHD and, 589
of disease, 585–586
Famines, **664**
FAO. *See* Food and Agriculture Organization
FAS. *See* Fetal alcohol syndrome
Fashion, healthy weight and, 241
Fast foods, 5
fats in, 150f
food composition table for, H-64t to H-85t

Fast foods (*continued*)
food list for, G-15t to G-16t
obesity and, 268–269
Fasting. *See also* Eating disorders; Insulin resistance; Ketosis
body fat metabolism and, 146–147
transition to, 215–218
Fat (animal). *See* Animal fats
Fat (body), 232n. *See also* Central obesity; Subcutaneous fat; Visceral fat; Waist circumference
abdominal, 245f
amino acids for, 179
amount and distribution, 243–245
assessment methods for, 246f
body weight, body fat, and, 246–249
composition of, 232f
energy balance and, 231
estimating, 246f, E-16t
from glucose, 106
intensity of activity and, 449
kcalorie calculation and, 151f
measures of, 243t, 246f, E-7 to E-15
oxidation of, 268
percent of, 244t
storage of, 264, 267–268
use during physical activity, 448–449
visceral, 244
Fat (dietary), **134**. *See also* Invisible fats; Lipids; Monounsaturated fats/fatty acids; TCA (tricarboxylic acid) cycle
absorption of, 141f
carbohydrates and, 115
characteristics of solid, 133–135
for children, 518
cholesterol reduction and, 153
composition of, H-1
Daily Values of, 154–155, 155t
diabetes and, 601
digestion of, 75, 76f, 84, 137–140
energy density of, 8
energy from, 146f, 201, 212
in energy pathway, 209f
energy storage by, 144
excess, 215
exchange list and, G-2
firmness of, 133–134
food composition table for, H-52t to H-55t
food intake and, 235
on food labels, 56, 154
food list for, G-12t
food sources of, 162t
gallbladder and, 84
guidelines for, 159
for heart health, 594
high-fat foods and heart health, 159–161
for infants, 514
metabolism of, 146–147
in milk and milk products, 53, 153
oil as, 10, 133–134
for older adults, 560
portion size and, 235f
in protein foods group, 41
recommended intakes of, 147–149
removal from food, 151
role in body, 144–145
solid, 38, 133–135, 134f, 154
transport of, 79
in vegetables, fruits, and grains, 153–154
weight management and, 278–279
Fat cells (body)
development of, 4, 264, 265f
metabolism of, 264–265
Fat-free milk products, 53
Fatigue, from iron deficiency, 409
Fat replacers, **155–156**
Fat-soluble vitamins, 299, 355. *See also* Emulsifiers; Vitamin A; Vitamin D; Vitamin E; Vitamin K; Water-soluble vitamins
list of, 299
vs. water-soluble vitamins, 300t
Fatty acid oxidation, **207**, C-9 to C-10, C-10f
Fatty acids, 130. *See also* Essential fatty acids; Monounsaturated fats/fatty acids; Omega-3 fatty acids; Omega-6 fatty acids; Polyunsaturated fats/fatty acids; Saturated fats/fatty acids
-to-acetyl CoA, 208f
biotin and, 307
chemistry of, 129–136
for children, 518
in common food fats, 134f
condensation to form triglyceride, 133f
deficiencies of, 146
energy metabolism and, 207
essential, 145–146
food sources of, 162t
glycerol and, 207
lipid digestion and, 138
omega-3, 132, 138
omega-6, 132, 138
saturated, 131
saturated acids compared with, 133f
short-chain, 100n
structure of, 130–132
triglyceride formation from, 133f
unsaturation and firmness of, 133–134
Fatty liver disease, **223**
Fatty streaks, **546**
FDA (Food and Drug Administration), **331**, **623**. *See also* Daily Values; Pesticides
on antibiotics in foods, 648
on BGH, 648
on biotechnologically produced and cloned foods, 655–657
certification by, 638
on infant formula standards, 511
Nutrition Facts panel and, 54, 54f
pesticide regulation by, 638, 639
supplement regulation by, 335f, 336
tanning lamp warning by, 351
weight-loss products and, 272
Feasting (excess energy), 213–215
Feces, constipation and, 91
Federal food assistance programs, 662–663
Feedback mechanisms, in digestion, 83
Feeding America, 675t
Feeding Infants and Toddlers Study (FITS), 519–520
Female athlete triad, 252–253
Fermentable substance, dietary fiber as, **100**, 102
Ferric iron, 405
Ferritin, **406**, 411
Ferrous iron, 405
Fertility, **469**
malnutrition and, 485
Fertilizers
for organic foods, 640
unsustainable and sustainable methods for, 674t
Fetal alcohol spectrum disorder, **501**
Fetal alcohol syndrome (FAS), 228t, **501–503**, 502f, 503f
Fetal programming, **475**
Fetus, **472**, 472f. *See also* Blastocyst; Embryo; Zygote
critical periods in development, 473f
growth and development of, 470–475
malnutrition and, 486
Feverfew, 618t
Fiber
characteristics, sources, and health effects of, 117t
for children, 518
colon health and, 91
before competitions, 459
dietary, **100**
digestion and, 76f, 86
energy from, 102
in fruit, 52
health effects of, 115–118,117t
heart disease and, 116
high-fiber foods and, 235
insoluble, **100**, 117t
for older adults, 560
recommended intakes of, 118
in selected foods, 119t
soluble, **100**, 117t
weight loss and, 278
Fiber content, 49
Fiber-rich diet, 458
Fibrocystic breast disease, **353**
Fibrosis, **223**
Field gleaning, 663
Filbert nuts. *See* Nuts and nut butters
Filtered water, 371
First aid, for choking, 89f
Fish. *See also* Sushi
food composition table for, H-40t to H-43t
food safety and, 631, 631f
for heart health, 160
mercury in, 153, 636
omega-3 fatty acids in, 149, 150, 151–153, 160–161
vitamin D in, 350
Fishing, environment and, 671
Fish oil. *See also* Omega-3 fatty acids
in pregnancy, 490
Fitness, **437–460**, 439. *See also* Exercise; Physical activity
balanced program of, 443t
benefits of, 438–444
development of, 440–442
diet for, 457–458
program, 441–442
Flatulence, **91–92**
Flavin adenine dinucleotide (FAD), 302–303, 304f, 320f, C-4f
Flavin mononucleotide (FMN), 302, 304f, 319, 320f, C-4f
Flavonoids, **430**
Flavor, 71–72
Flavor additives, 644–645
Flaxseeds, **428**
Flexibility, **440**
Flora (gastrointestinal bacteria), **82**
Flour
food composition table for, H-10t to H-15t
types of, 50f
Fluid(s). *See also* Water; specific fluids
alcohol and, 457
body, 368–377
in digestion, 76f
loss from vomiting, 90
for physical activity, 453–457
poor choices for replacing, 457
replacing after loss, 455
Fluid and electrolytes
imbalanced, 375–376
for physical activity, 453–457
replacing after loss, 376, 455–457
Fluid balance, **176**, 373–376. *See also* Water
regulation of, 374–375, 453–457
Fluorapatite, **422**
Fluoride, **422**
Adequate Intake of, 422
body role of, 348, 422
sources of, 422
in teeth, 385
toxicity of, 422, 423f
Fluorosis, **422**
FMN. *See* Flavin mononucleotide (FMN)
Folacin. *See* Folate
Folate (B vitamin), **310–315**, 317
absorption and activation of, 311, 311f
alcohol use and, 226
anemia and, 314–315, 321
birth defects and, 312–313, 313f, 473
cancer and, 313
deficiency of, 314–315
dietary folate equivalents and, 312
dosage recommendations for, 312
drug interactions with, 314–315
food fortification with, 313
food sources of, 312, 315, 315f, 316
heart disease and, 313
homocysteine and, 310, 313
intake of, 313
methotrexate and, 315, 577f, C-6f
methylation by, 191
neural tube defects and, 312–313, 313f
for older adults, 562
pregnancy and, 481
RDA, 315
toxicity of, 315
Folate anemia, assessment of, E-21t, E-21 to E-22
Folic acid. *See* Folate
Follicle-stimulating hormone (FSH), A-4
Fontanel, baby bones and, 352f
Food(s), **3**. *See also* Food sources; specific foods
alternative therapies and, 616–617
antimicrobials in, 643–644
assistance programs for, 662

in breastfeeding, 495
caffeine content of, H-2t to H-3t
calculating energy values of, 10f
cancer risk reduction and, 605, 606t
children's preferences in, 532
combining of, 79
cravings and aversions in pregnancy, 484
donated, 667
energy density of, 8–10, 8f
environmental contaminants in, 634–637
environmentally friendly choices of, 682
ethnic, 4, 45
fiber in, 119t
flavor of, 71–72
fortified, 49
functional, 430–433
future of, 433
gas-producing, 92
for GI health, 86
for heart health, 152, 159–161
increasing in diet, 39t, 59t
individual's response to, 126
infant, 513–514, H-86t to H-87t
intake of, 233–236
iron enrichment of, 413
kcalories from, 232–236
lactose in, 104f
local food choices, 680–682
mixtures of, 45
natural toxicants in, 637
nutrient contributions of, 302
nutrients in, 6–8
nutrients in sugar and, 111t
nutritional adequacy of, 633–634
odors of, 631
older adult purchasing of, 571
packaging materials and, 646–647
pesticides and, 637–642
phospholipids in, 136
portion sizes of, 235
potassium in, 384f
preschool skills with, 532t
processed, 49
production vs. hunger, 670
recommendations vs. intakes of, 45–46
records of, E-4 to E-5
reducing in diet, 39t, 59f, 59t
safety of, 623–650
shortages of, 664–665
sodium in, 381
as starch sources, 99–100, 99f, 116f
tyramine content of, 578t
variety of, 20
washing off pesticides, 639f, 640t
water in, 369, 369t
Food, Drug, and Cosmetic Act, Food Additive Amendment to, 642
Food Additive Amendment, to Food, Drug, and Cosmetic Act, 642
Food additives. *See* Additives
Food allergies, 177, 513–514, 524–526
Food and Agriculture Organization (FAO), 21, 632, 675t
on sugar consumption, 113
Food and Drug Administration. *See* FDA (Food and Drug Administration)
Food assistance programs, 486. *See also* Congregate meals; Meals on Wheels; WIC program
Child and Adult Care Food Program (CACFP) and, 535–536
for older adults, 569–570
in United States, 662–663
World Food Program and, 675t
Food aversions, 484
Food bank, 663
Food biotechnology, 650
Foodborne illnesses, 625–633, 625t. *See also* Food safety; Kitchen, food safety in
of older adults, 570–571
in pregnancy, 490–491
Food chain, 634. *See also* Dioxin
bioaccumulation of toxins in, 635f
fuel required to feed people eating at points on, 680f
Food choices, 4–6
for adolescents, 538–539
animal or vegetable, 678–680
environmentally friendly, 678–683
global or local, 680–682
of older adults, 568–572
for pregnancy and lactation, 481f
in vegetarian diets, 66
Food composition, 232–233
bomb calorimeter for, 232f
tables of, H-1 to H-87
Food cravings, 484
Food crisis, 670
Food deserts, 662
Food footprint. *See* Ecological footprints
Food frequency questionnaire, E-4
Food group plans, 40–47, 42F-43f. *See also* Food plans
for heart-healthy choices, 152
Food groups, daily amounts for 1200- to 1600-kcalorie diets, 276–277, 276t
Food industry
advertising by, 268f
safety controls by, 626–627
Food insecurity, 660
in United States, 660t
Food intolerance, 526
Food intoxications, 626
Food labels, 53–59, 525–526, 630f, 633
biotechnology and, 656t
bread labels compared, 120f
carbohydrates in, 120
as consumer education, 58
Daily Values on, 54–56, 55t
Dietary Guidelines, USDA Food Patterns, and, 58, 59t
fat contents on, 154–155
health claims on, 57, 58f
ingredient list on, 53–54
nutrient claims on, 56–57, 58f
nutrition facts panel on, 54–56, 54f
on organic foods, 640f, 641f
protein regulations for, 186
structure-function claims on, 57–58, 58f
for vitamin and mineral supplements, 336f
whole grain on, 118f
Food lists, G-1t, G-2
planning a healthy diet, G-3t to G-16t
Food packaging, 646–647
Food pantries, 663
Food Pattern (USDA), 40–47, 44t, 48t, 54, 608
DASH diet compared with, 597t
food nutrient values and, 302
hypertension and, 596
protein and, 185–186
vegetarian foods and, 40–47, 44t, 48t, 564t
Food patterns, for children, 520f
Food plans. *See also* Food group plans
Food plans, for weight management, 295
Food poisoning, staphylococcal, 625t
Food poverty, 661
Food preparation, mineral preservation in, 378
Food processing, 653–654
Food production
environmental impact of, 670–673
sustainable solutions to, 673–675
Food record, 284f, E-4
in weight management, 284f
Food safety, 623–650. *See also* FDA; Foodborne illnesses; Hazard Analysis Critical Control Points; Irradiation; Pasteurization; Pathogens
advances in, 632–633
consumer concerns about, 623–650
from farm to table, 627f
Healthy People 2020 on, J-2t
in kitchen, 627–631
in marketplace, 626–627
while traveling, 632
Food security, in US, 661f
Food sources. *See also* Food(s)
of antioxidants, 362–363
of biotin, 307, 307f
for B vitamins, 322
of calcium, 387–388, 388f
of choline, 318
of chromium, 423
of copper, 421
to defend against heart disease, 430–433
of fatty acids, 162t
of fluoride, 422
of folate, 312, 315, 315f, 316
of iron, 412–413, 413f
of magnesium, 392, 392f, 393
of manganese, 421
of molybdenum, 423
of niacin, 305, 307, 307f
of pantothentic acid, 309
of phosphorus, 391f
of phytochemicals, 428, 429t, 431f, 432t
of riboflavin, 304, 304f
of saturated fats, 134f
of selenium, 420
of sulfate, 393
of thiamin, 302, 303f
of vitamin A, 345, 346f
of vitamin B_6, 310, 310f
of vitamin B_{12}, 317
for vitamin C, 326–327
of vitamin D, 347, 350
of vitamin E, 354
of vitamin K, 356
of zinc, 416, 417f
Food Stamp Program. *See* Supplemental Nutrition Assistance Program
Food substitutes, 53
Food waste, 673
Formaldehyde, aspartame and, 645
Formulas. *See* Infant formula
Fortification of foods, 49
cereals and, 514f
folate and, 313, 315, 317
with iron, 411
milk as, 345, 350f
olestra as, 156
for vitamin D, 350
Fossil fuels, 671–672
4-Hour Body diet, 294t
"Four Ds" (dermatitis, dementia, diarrhea, death), from niacin deficiency, 319–320
Fraudulent businesses, 31
Free foods, food list for, G-13t
Free radicals, 323, 360. *See also* Antioxidants; Beta-carotene; Selenium; Vitamin C; Vitamin E
in Alzheimer's disease, 566
copper, zinc, and, 420
damage caused by, 361f
defending against, 361
formation of, B-7 to B-8
stress and, 556
Frequency (of activity), 440
Fried foods, carcinogens and, 605
Fructose, 97. *See also* High fructose corn syrup
appetite and, 235
Fruits and fruit juices, 42f, 51–52
antioxidants and phytochemicals from, 362
cancer prevention and, 361, 605
carbohydrates in, 119
dietary fat in, 153–154
disease prevention and, 363, 363t
dried, 64
food composition table for, H-14t to H-19t
food list for, G-5t
as heart-healthy choices, 594
most and least pesticide-contaminated, 641t
phytochemicals in, 431f
protein and, 186
vitamin C in, 322–323, 326
FSH/LH-releasing hormone (FSH/LH-RH), A-5
Fuel, 197. *See also* Diet; Food(s)
for activities, 445t
energy overuse and, 671–672
physiological fuel value and, 232
protein used as, 450
required to feed people, 680f
Full term, 472
Functional fiber, 100
Functional foods, 6, 428, 430–433
phytochemicals and, 428–430

G

Galactose, 97, 97f
Gallbladder, 72
cancer of, 603, 604t

Gallbladder (*continued*)
disease of, 439
GI hormones and, 84–85
physical activity and, 439
weight and, 247
Gamma-linolenic acid, 145n
Garlic, 618t
Gas, intestinal, 91–92, 93t
Gastric bypass surgery, 273, 274f
Gastric glands, **74**
Gastric-inhibitory peptide, A-8
Gastric juice, **74**
vitamin A and, 342
Gastric lipase, 74
Gastrin (hormone), **83,** 85f, A-8
Gastroesophageal reflux, **92,** 92f
Gastrointestinal hormones, 236, A-7
Gastrointestinal (GI) tract, **70–72.** *See also* Digestion; Digestive system; Large intestine; Liver (body); Pancreas; Small intestine; Stomach
in aging process, 558
alcohol in, 222
carbohydrate digestion in, 102f
health and regulation of, 82–86
hormones in, 83–85
lipid digestion in, 137–140
lymphatic system and, 78f, 81f, **82**
preventing problems in, 93t
protein digestion in, 172f
starch, fiber, and, 116
Gatekeepers, parents as, **531,** 539
Gelatin, 181
Gender. *See also* Men; Women
alcohol doses and blood level percentages by, 225t
CHD and, 589
energy requirements by, 239
iron overload and, 411
in osteoporosis, 398–399
Gene(s), **190**
methylation and, 191
silencing, 191–192
Gene expression, **175, 190**
Gene pool, **268**
biotechnology and, 656t
Generally recognized as safe (GRAS), **642**
Genetic engineering, **652**
of agriculture, 654
efficient drug delivery and, 654
efficient food processing from, 653–654
selective breeding and, 653f
Genetic pollution, biotechnology and, 656t
Genetics, **192.** *See also* Epigenetics
Alzheimer's disease and, 566
in childhood obesity, 527–528
diseases and, 192–194
energy restrictions in animals and, 554–555
family history of disease and, 585–586
as hypertension risk factor, 595
in obesity, 266–268
osteoporosis and, 399
Genistein, 429t
Genome, human, 190
Genomics, **190**
nutritional, 12, 190–192, 191f
Genotoxicant, **646**
Germ, 50f
Gestation, **472**
Gestational diabetes, 108, **487**
Gestational hypertension, **487**
GH-inhibiting hormone (GHIH/somatostatin), A-5
GH-releasing hormone (GHRH), **A-5**
Ghrelin (hormone), 236, **267**
Giardia, 650
Ginger, 616f, 618t
Ginkgo, 616f, 618t
Ginseng, 616f, 618t
GI tract. *See* Gastrointestinal (GI) tract
Glands. *See also* Salivary glands
adrenal, 324, 372
digestive, 74
exocrine, A-5f
gastric, 74
mammary, 492
pituitary, A-4 to A-6
Global environment, hunger, poverty, and, 670–675
Global food choices, 680–682
Global hunger, 659–676
Glossitis, 321f
Glucagon, **106,** 107f, A-6
Glucagon-like peptide-1 (GLP-1) hormone, 236
Glucocorticoids, **A-6**
Gluconeogenesis, **105,** 178, **217–218**
Glucosamine, 565
Glucose, 95, **96,** 97f, 104–109. *See also* Blood glucose; Cori cycle; Glucose polymers
activity and, 448
amino acids and, C-1f
anaerobic breakdown of, 206f
blood, 106–109
carbohydrate digestion, absorption, and, 101, 101f
catabolism of, 201
depletion of, 447–448
for energy, 105
in energy pathway, 207f
fat made from, 106
homeostasis maintenance for, 83, 106–109
making of, 217
metabolism balance sheet, C-14t
in physical activity, 446
from protein, 105, 177–178, 217–218
Glucose polymers, in sports drinks, **455**
Glucose Revolution diet, 295t
Gluten-free diet, 90
Glycemic effect, diabetes and, 601
Glycemic index, **107–108,** 125–126
body weight and, 126
Glycemic response, **107,** 448
Glycerol, **133,** 133f
fatty acids and, 207
lipid digestion and, 138
metabolism and, 207
Glycerol condensation to form triglyceride, 133f
Glycine (amino acid), 168, 169f, C-3f
Glycogen, 95, 97, **99,** 105, 106, C-1. *See also* Cori cycle
after activity, 448
diet and, 446
duration of activity and, 447
glucose stored as, 105
starch compared with, 99f
Glycolysis (glucose splitting), **203–205,** 204f, A-3n, C-9, C-9f
Goals, for weight loss, 274–275
Goblet cells, **78**
Goiter, **418,** 418f
Goitrogen, **418**
Goldenseal, 618t
Golgi apparatus, **A-3**
"Good" cholesterol, 137, 143. *See also* Cholesterol; specific types
Gout, **565**
Grain. *See also* specific types
B vitamins in, 322
carbohydrates from, 118
complementary proteins and, 184
dietary fat in, 153–154
enriched, 49
folate in fortified, 315
food composition table for, H-10t to H-15t
as heart-healthy choices, 594
iron enrichment of, 413
nutrients in, 42f
proteins and, 186
refined, 49
riboflavin in, 304
starches from, 99–100, 99f
thiamin in, 302f
vitamin C in, 326
wheat plant and, 50f
whole-grain products, 49
Grams, as measure, 9f
Grapefruit juice, drug interactions with, 577t
GRAS (generally recognized as safe) list, **642**
Green tea, 191
Grocery shopping, 49–53. *See also* Food labels
Ground beef, 52. *See also* Beef; Meat
Groundwater, 649
Growth and development
of adolescents, 537
energy requirements for, 239, 506, 507
failure of, 667–668
of infants, 506, 507
measures of, E-5 to E-7
overweight children and, 528–529
vitamin A in, 342
zinc in, 415, 416, 416f
Growth hormone (GH), **A-4**
Gums. *See also* Mouth; Teeth
in physical examination, E-16t
vitamin C and, 325, 325f

H

H. pylori. *See Helicobacter pylori* infection
Habits
food choices and, 4
of older adults, 553
HACCP. *See* Hazard Analysis Critical Control Point
Hair. *See also* Keratin
in physical examination, E-16t
Hard water, **370,** 640
Hazard, **623,** 624
Hazard Analysis Critical Control Point (HACCP), **626,** 631
Hazardous wastes, in water, 649
Hazelnuts. *See* Nuts and nut butters
HDL (high density lipoprotein) cholesterol, **143**
CHD and, 590
Head circumference, of infants, E-6, E-7
Health. *See also* Heart; Obesity; Physical activity; Weight management; specific conditions
of adolescents, 538–539, J-1t
alcohol use and, 222–229, 228t
behaviors in United States, 26
as criterion for weight, 242
diet and, 25–27, 581–609
of digestive system, 85–86
fat intake recommendations and, 147–156
food selection and, 6
gene expression regulated by, 191
of GI tract, 82–86
healthy weight and, 241
LDL, HDL, and, 143–144
maternal, 486–489
pregnancy and, 470
protein in, 182–187
risk factors for overweight and obese, 270
smoking and, 247
starch and fibers in, 115–118
water and, 370
Health claims, on food labels, **57,** 58f
Health history, 22, E-2
Health services, Healthy People 2020 on access to, J-1t
Healthy Eating Index, **45–46**
Healthy eating plate, 608f
Healthy People program, **24,** 25t
Healthy People 2020, J-1, J-1t to J-2t
lead poisoning and, 424
Heart. *See also* Cardio- entries
dietary fat and, 159–163
food group choices for health of, 152
Heart attacks, **588.** *See also* Atherosclerosis; Blood cholesterol; Cardiovascular disease (CVD); C-reactive protein; HDL (high density lipoprotein) cholesterol; Hypertension
predicting, 587–588
Heartburn (acid indigestion), 92. *See also* Acid (stomach); Gastroesophageal reflux
in pregnancy, 484
Heart disease. *See also* American Heart Association; Blood cholesterol; Cardiovascular disease (CVD); Coronary heart disease (CHD); Diseases; Hypertension
alcohol and, 228t
antioxidants and, 361–362
childhood obesity and, 546–547
defending against, 430
fats and, 147–148, 193
folate and, 313
genetic component of, 193
Healthy People 2020 on, J-2t
high-fat foods and, 161–162

Keshan disease as, 419
magnesium and, 393
Mediterranean diet and, 162–163
protein and, 182–183
risk assessment for, 592
starch, fiber, and, 116
vegetarian diets and, 62
vitamin E and, 362
Heart-healthy diet, 594
Heart rate, infant and adult, 506t
Heat, generation of (thermogenesis), 236
Heat stroke, 453–454
Heavy drinking, 227. *See also* Alcoholism
Heavy metals, 424, 634
Height
of infants and children, E-6, E-6f
osteoporosis and, 398f
Heimlich maneuver, 88, 89f
Helicobacter pylori infection, 93, 316
Hematocrit, 409, E-19
Heme, 309
Heme iron, 406, 407f, 413
Hemicelluloses, 100n, 117t, C-1f, C-2f
Hemochromatosis, 411
Hemoglobin, 170, 406, E-19
iron and, 452
protein, 176–177
structure of, 171f
Hemolytic anemia, 353
Hemophilia, 355
Hemorrhage, pinpoint, 325f
Hemorrhagic disease, 355
Hemorrhagic stroke, vitamin E and, 353
Hemorrhoids, 91, 116
in pregnancy, 484
Hemosiderin, 407
Hepatic portal vein, 81
Hepatic vein, 81
Hepcidin, 408
Herbal remedies, 615, 616f, 617–619, 618t
precautions for, 617
Herbal supplements. *See also* Complementary and alternative medicine; Herbs
in pregnancy, 489
for weight loss, 271–272
Herbicides
pollution from, 670–671
unsustainable and sustainable methods for, 674t
Herbs
drug interactions with, 620t
as ergogenic aids, 465
hGH (human growth hormone), 466
High blood pressure. *See* Hypertension
High-carbohydrate diets. *See also* Carbohydrate loading
glucose and, 446
pregame/postgame meals, 459, 459f
High-fat foods
energy density of, 235
heart disease and, 161–162
High-fiber diet, iron and, 411
High-fiber foods, 116, 235
digestion and, 86, 118
High-fructose corn syrup, 110
High potency supplements, 331, 335
High-quality proteins, 181
High-risk pregnancy, 484–491. *See also* Low-risk pregnancy
factors in, 485t
Hispanics, weight and, 537
Histamine, 324
HIV (human immunodeficiency virus), 584. *See also* AIDS (acquired immune deficiency syndrome)
breastfeeding and, 495
epidemic of, 584t
vitamin A deficiency and, 343
HMB. *See* Beta-hydroxymethylbutyrate
Homelessness, meals and, 663
Homeostasis, 83, A-8
glucose, 83, 106–109
Home water, treatment of, 649–650
Homocysteine
folate and, 310, 313
heart disease and, 183, 589
Honey, nutritional value of, 110–111
Hormones, 83, 176t, A-4 to A-8. *See also* Aldosterone; Androstenedione; Cortisone; Estrogen; Progesterone; Testosterone; specific hormones
as additives, 647–648
antidiuretic (ADH), 225, 371
bone growth and, 347–348
bone metabolism and, 398
calcium metabolism and, 398, A-6 to A-7
calcium regulating, A-6 to A-7
cancer and, 603–604
comfort food and, 235
corticotropin-releasing hormone (CRH), A-5
gastrointestinal, 236, A-7
ghrelin and, 267
of GI tract, 83–85
leptin, 266
in osteoporosis, 398–399
parathyroid hormone, 385
proteins as, 178
regulating, 106–109
sex, A-7
triglycerides and, 144
Hormone-sensitive lipase enzyme, 146
Hourly sweat rate, 454
Human beings, energy restrictions in, 555–556
Human body. *See* Body
Human genome, 190, 192f, 194
obesity and, 266
Human growth hormone. *See* hGH
Hunger, 233, 659. *See also* Eating disorders; Malnutrition; Overeating; Pica
behavior and, 521
biotechnology as defense against, 655
in children, 520–522
global environment and, 659–676
obesity and, 661–662
population growth and, 666
relieving in United States, 662–663
satiation, satiety, and, 234f
in United States, 660–663, 661
worldwide, 664–667, 665f
Hunger Project, The, 675t
Hunger-relief organizations, 675t
Husk, 50f
Hydration, 560. *See also* Dehydration; Fluid(s); Sports drinks; Water
and physical activity, 454
schedule for, 454t
Hydrochloric acid, 74, 172f
Hydrodensitometry measurement, 246f
Hydrogenated foods, 161–162
Hydrogenation, 134–135, 135f
Hydrolysis, 74
of ATP, 199
of disaccharide, 98f
of proteins, 171
of triglycerides, 138–139, 140f
Hydrophilic, 136
amino acid side groups as, 170
digestive enzymes as, 137
vitamins, 298
Hydrophobic, 136
amino acid side groups as, 170
lipids as, 137
vitamins, 298
Hydrosensitometry, E-15
Hydroxyapatite, 385, 422
Hydroxyproline, proline as, 323
Hygiene, diarrhea and, 90f
Hyperactivity and "hyper" behavior, in children, 524
Hypercalcemia, 350n
Hyperglycemia, 228t, 598
Hyperkeratosis, 344f
Hypertension, 373, 590, 595–597. *See also* Blood cholesterol; Blood pressure; Coronary heart disease; DASH diet; Diabetes, type 2; Gestational hypertension; Heart attacks; Metabolic syndrome
calcium as protection against, 385
DASH diet for, 596, 597
genetic component of, 193
gestational, 487
lifestyle modifications for reducing, 596t
magnesium and, 393
medications for, 597
potassium and, 383
pregnancy and, 475, 487
risk factors for, 595
sodium and, 379–380
treatment of, 595–596
vegetarian diets and, 62
weight and, 247
Hyperthermia, 453
Hypertrophy, 441
Hypoglycemia, 108, 228t
Hyponatremia, 368, 381, 455
Hypothalamus, 233, 368
eating/hunger control and, 235–236
pituitary gland interaction, A-4 to A-6
thyroid hormone and, 418
Hypothermia, 454
Hypothesis, 12
in scientific method, 13f

I

IGF-1 (insulin-like growth factor 1), E-18
Ileocecal valve, 73
Ileum, 72
Illegal supplements, 465–466
Illicit drugs. *See also* Drugs
in pregnancy, 489
Illness. *See also* Diseases; specific conditions
Illness, foodborne, 625–633
Imitation foods, 53
Immune response, 582
Immune system, 582–583. *See also* AIDS (acquired immune deficiency syndrome); Antibodies; Antigens; B-cells; Histamine; HIV (human immunodeficiency virus); Macrophages; Neutrophils; Phagocytes; Rheumatoid arthritis; T-cells
aging and, 557–558
breast milk and, 510
vitamin C and, 324
Immunity, 177
aging and, 557–558
nutrition and, 583–584, 584f
Immunoglobulins, 583
Implantation, 471
Inactivity. *See* Physical inactivity
Indigestion, 92
Indirect (incidental) food additives, 646–648
Indispensable amino acids, 169
Individual approach, to disease prevention, 608–609
Individual nutrition assessment. *See* Nutrition assessment
Individuals, nutrition assessment of, 22–24
Indoles, 429t
Infant formula, 511–512
nutrients in, 511f
special formulas, 512
Infant health, Healthy People 2020 on, J-2t
Infants and infancy. *See also* Breastfeeding; Breast milk; Children; Cretinism; Preterm infants; Sudden infant death syndrome
breast milk for, 507–508
food allergies in, 513
growth chart for, 507
head circumference of, E-6, E-7
heart rate, respiration rate, and energy needs of, 506t
intakes compared with adult, 508f
iron for, 514
length measurement of, E-6, E-6f, E-7
low birthweight and, 484–485, 489
meal plan for 1 year old, 516f
newborn, 472f
nutrition and, 505–516
preterm, 476, 489, 512
risk of botulism in foods, 515
solid foods for, 507, 512–516, 514t
vegetarian diets for, 515–516
vitamin C for, 514
weight gain of, 506f
weight of, E-7f
Infectious diseases. *See also* Diseases; Epidemics
nutrition and, 582–584
pasteurization of milk and, 632n
physical activity and, 438
vitamin A and, 343

Infertility
alcohol use and, 228t
weight and, 247
Inflammaging, 557
Inflammation, 248. *See also* Anti-inflammatory drugs
aging and, 557–558
in atherosclerosis, 587–588
chronic diseases and, 584
insulin resistance and, 599
metabolic syndrome and, 248–249
Information sources, about nutrition, 28–29, 32t
Ingestion, 71f
Ingredient list, on food labels, 53–54
Inhibitory nerves, alcohol sedation of, 224
Initiators, 604
Inorganic, 7
nutrients, 7, 7t
Inorganic elements, 377–378
Inositol, 318
Insecticides, natural, 640
Insoluble fiber, 100
Inspection, meat, 630f
Insulin, 106, A-6. *See also* Blood glucose; Diabetes
amino acid sequence of, 170f
disulfide bridges in, 170
obesity and, 125–126
Insulin resistance, 248, 591, 598–599. *See also* Metabolic syndrome
Integrative medicine, 614
Intelligence, breastfeeding and, 510–511
Intensity (of activity), 441, 442–443, 446, 449
Intentional food additives, 643–646, 646t
Interactions
food, 79
herb-drug, 619, 620t
nutrient, 378
nutrient-drug, 575–578
among trace minerals, 405
Intermittent claudication, 353
Internal systems, in physical examination, E-16t
International Units (IU) measurement, 345
Internet, 16, 28. *See also* Websites
information reliability on, 28–29
precautions for information from, 619–620
Interstitial fluid, 368
Intestinal aminopeptidases, 172f
Intestinal dipeptidases, 172f
Intestinal gas, 91–92
foods causing, 92, 92f
preventing or alleviating, 93t
Intestinal ischemia, 86
Intestinal tripeptidases, 172
Intestine. *See* Gastrointestinal (GI) tract; Large intestine; Small intestine
Intoxication, water, 368
Intracellular fluid, 368, 385
Intrinsic factor, 315
In vitro studies, 14f
Iodide, body role of, 418
Iodine, 418
deficiency of, 418, 419
RDA of, 419
sources of, 418–419
toxicity of, 419
Iodized salt, 418, 419
Ions, 373, 374f, B-5 to B-6
Iron, 405. *See also* Ferritin; Iron deficiency; Kwashiorkor; Transferrin
absorption of, 406–407, 406f, 411
adolescent needs for, 408, 409, 538
assessing status of, E-4, E-20t
behavior and, 410–411
bioavailability of, 413, 513
in body, 405–406
in cereals, 514f
in children, 408
chronic diseases and, 411
contamination by, 414
copper and, 420
in enzymes, 406
as essential nutrient, 405
food fortification with, 411
foods enriched with, 413
food sources of, 412–413, 413f
in infant foods, 514
and iron deficiency blood cells compared, 410f
for older adults, 562–563
overload of, 411
pica and, 410–411, 484
poisoning by, 411–412
pregnancy and, 481
RDA of, 412, 414
recycling in body, 408f
in red blood cells, 408
serum, E-20
storage of, 407–408
supplements of, 411, 414
total iron-binding capacity (TIBC), E-20
toxicity of, 411
transport of, 177, 407–408, 409
in vegetarian diets, 64
vitamin C and, 325–326
women's needs for, 408
Iron deficiency, 23, 321, 408–409, 414, 452
anemia and, 321
assessment of, 409
behavior and, 521
lead toxicity and, 424
Iron-deficiency anemia, 408, 452, 562, E-19 to E-21, E-20t
in children, 518–519
Irradiation, 632–633
Irrigation
food production and, 673
salt from, 671
Irritable bowel syndrome, 90
Ischemia, intestinal, 86
Isoleucine, 182f, 187, C-3f
Isoniazid, 309, 577
Isothiocyanates, 429t

J

Japan
contamination in, 634–635
food shortages in, 664–665
Jejunum, 72
Journals, publishing research results in, 17
Juice. *See also* Fruits and fruit juices; Gastric juice
grapefruit-drug interactions and, 577t
vs. whole fruit, 52

K

Kava, 618t
kCalorie (kCal) control, 36–38
kCalories (kCal). *See also* Bomb calorimeter; Food composition, tables of; Physiological fuel value
adult daily needs, 44t
in alcoholic beverages and mixers, 226t
in carbohydrates, 124–125
counting of, 296
dietary fat and, 151f
discretionary, 44, 45f, 280
empty foods and, 38, 279
energy from, 212, 226
energy in, from food, 232–236
in energy nutrients, 8, 8t
energy out body expenditure, 236–239
fat control and, 151f
for older adults, 560
portion size and, 269
weight control and, 59t
Kefir, 104
Kenya, hunger in, 665f
Keratin, 344
Keratinization, 344, 344f
Keratomalacia, 344
Keshan disease, 419
Keto acid, 179, 217
Ketogenic diets, adverse side effects of, 219t
Ketone, 106
Ketone bodies, 105–106, 217, 218, 218f
formation of, C-16, C-16f
low-carbohydrate diets and, 218–219
Ketosis, 106
Kidney(s), 369
electrolyte regulation by, 375
excretion by, 377
glucose and, 204–205
wastes filtered by, 80
water regulation function in, 371f
Kidney cancer, 603, 604t
Kidney disease
alcohol use and, 228t
protein and, 184
vitamin C and, 325
Kidney stones, vitamin D and, 247, 325, 350
Kilojoules, food energy measurement in, 232n
Kitchen, food safety in, 627–631
Kombucha tea, 617
Kwashiorkor, 668–669, 668f

L

Labels. *See* Food labels
Laboratory tests. *See also* Nutrition assessment
in nutrition assessment, 23
Lactadherin, 510
Lactaid, 104
Lactase, 101
Lactase deficiency, 103
Lactate, 205, 447. *See also* Cori cycle
pyruvate conversion to, 205–206, 205f
transported to liver, 206
Lactation, 492. *See also* Breastfeeding
energy during, 493–494
food choices for, 481f
mercury in foods during, 636
nutrition during, 479–480, 492–497
Lactoferrin, 510
Lacto-ovo-vegetarians, 64
Lactose, 99, 578
in selected foods, 104t
Lactose intolerance, 103–104
Lactovegetarians, 65
Laetrile, 637
Lamb. *See also* Meat
food composition table for, H-44t to 45t
Large intestine (colon), 72, 73, 76, 76f, 101. *See also* Colitis
carbohydrate digestion and, 101, 102f
dietary fiber and, 116
digestion and, 76f
Larynx, 88
cancer of, 604t
Late-life depression, 559
Laxatives, 91. *See also* Constipation
LDL (low density lipoprotein) cholesterol, 142, 143, 588
CHD and, 590
risks of, 591
vitamin E and, 353
Lead
malnutrition and, 522–523
toxicity of, 523
Lead poisoning, 424
Leafy green vegetables. *See* Vegetables
Lean body mass, 237
Lean tissue, measurement of, E-7 to E-15
Lecithin, 136, 136f, 309
Legumes, 41, 51, 182f
complementary proteins and, 184f
food composition table for, H-18t to H-28t
nutrients in, 41
thiamin in, 303
Length
calculation aids for, K-2
of infants, E-6, E-6f, E-7
Length-for-age percentiles
boys (birth-36 months), E-9f
girls (birth-36 months), E-9f
Leptin (hormone), 266–267
mice with and without, 267f
Let-down reflex, 493
Leucine, 187, C-3f
Leukemia, 603
License to practice, 30
Life expectancy, 552. *See also* Physiological age
body weight, body fat, and, 246–249
Mediterranean diet, 162
Life span, 552

Lifestyle
for blood pressure reduction, 596t
cancer risk reduction and, 605
CHD risk reduction through, 593
chronic diseases and, 585
genetics and, 585–586
Lignans, 429t, **430**
Limiting amino acid, **181**
Lind, James, 322
Linoleic acid, 130, **131–132**
conjugated, 135
recommended intakes of, 150
Linolenic acid, 130, **132**, 145
recommended intakes of, 150
Lipase. *See also* Lipoprotein-associated phospholipase
gastric, 74
pancreatic, 74
Lipids (fats), 129–136, **130**, 138t, C-2f. *See also* Blood cholesterol; Blood lipids; Dietary cholesterol; Fat (dietary); Fatty acids; Omega-3 fatty acids
absorption of, 140–141
blood lipid profile and, 147
in breast milk, 509
composition of, 129
digestion of, 137–140, 139f, 141f
in foods, 6
inflammation and, 248
metabolism of, 146–147
as nutrients, 7
phospholipids, 136–137
role in body, 144–147
synthesis of, 198f
transport of, 141–144, 143f
triglycerides, 130
Lipoic acid, 319
Lipoprotein-associated phospholipase A(2), **588**
Lipoprotein lipase (LPL), **146**, **264**
Lipoproteins, **141**
lipid transport via, 141–144, 143f
sizes and compositions of, 142f
transport by, 177–178
Liposuction, 273
Liquor. *See also* Alcohol
Liquor (distilled spirits), **220**
Listeria, 625t, 626
Listeria monocytogenes, 625t, 626, 644
Listeriosis, **491**
Liters, as measure, 9f
Lithium, diet and, 577
Liver (body organ), **75**, 105. *See also* Blood cholesterol; Fatty liver disease; HDL (high-density lipoprotein) cholesterol; LDL (low-density lipoprotein) cholesterol; Preeclampsia
alcohol and, 222–224, 226, 228t
cancer of, 604t
cholesterol and, 137, 142, 143
chylomicrons and, 79
glucose and, 204–205
lactate in, 206
metabolism by, 81, 199t
nutrient transport by, 81, 81f
Liver (food)
phospholipids in, 136
vitamin A in, 346
Livestock. *See also* Animals
as environmental stressor, 671
unsustainable and sustainable methods for, 674t
Local, defined, 681–682
Local food choices, 680–682
Longevity, **552**
energy intake and, 554–555
nutrition and, 552–556
Low birthweight (LBW) infant, **484–485**, 489
Low-carbohydrate diets, 218–219, 218f
adverse side effects of, 219t
Low-density lipoproteins (LDL). *See* LDL (low density lipoprotein) cholesterol
Low-fat milk and milk products, 53. *See also* Milk and milk products
soy milk vs., 63f
Low-risk pregnancy, **484**
LPL. *See* Lipoprotein lipase
Lp-PLA(2), **588**
Lumen, **70**
Lunch, at school, 534–535, 535t
Lungs
cancer of, 604t
physical activity and, 438
respiration in, 377
vitamin A and, 343
Lutein, **430**
Luteinizing hormone (LH), **A-4**
Lycopene, 360, **429**
Lymph, **82**
Lymphatic system, 78f, 81f, **82**
chylomicrons in, 79
Lymphocytes, **583**
Lysine, 182f, C-3f
as supplement, 187
Lysosomes, **A-3**

M

Macrocytic anemia, folate and, 314f
Macrobiotic diet, **66**
Macronutrients, 8. *See also* Carbohydrates; Fats; Protein
Acceptable Macronutrient Distribution Ranges and, 20
Macrophages, **583**
Macrosomia, **476**
Macular degeneration, **564**
Magnesium, **391–393**
body role of, 391–392
bone development and, 348
deficiency of, 392–393
disease and, 392–393
food sources of, 392, 392f, 393
hypertension and, 393
toxicity of, 393
Magnetic resonance imaging (MRI), 245
Ma huang, 272n
Major minerals, **377**, 378f, 379–394
Malabsorption
diseases of, 91–92
of lactose, 103
Malaria, 343
Malignant tissue, **602**
Malnutrition, **21**, 667–670
acute and chronic compared, 668t
aging and, 569, 569t
alcohol use and, 225–227, 228t
assessment of, 21–22
blood vessels in, 176f
in children, 520–522
fertility and, 485
fetal development and, 486
immune system and, 583
kwashiorkor, 668
lead and, 522–523
marasmus, 668, 669, 669f
in older adults, 569, 569t
physical signs in children, 522t
physical symptoms of, E-16
pregnancy and, 475, 485–486
protein, E-18
protein-energy, 182
scurvy and, 322–323, 324
zinc deficiency and, 416
Maltase, **101**, 102f
Maltose, **98**, 101, 102f
Mammary glands, **492**
Manganese, **421–422**
body role of, 421
deficiency of, 421
food sources of, 421
RDA of, 421
toxicity of, 421
Manure, organic products and, 641
Marasmus, **668**, 669, 669f
Margarine, fats in, 154
Margin of safety, **643**
Marijuana. *See also* Illicit drugs
as alternative therapy, 615
Marketplace, food safety in, 626–627
Mastication, 71n
Maternal age, in pregnancy, 488–489
Maternal health concerns (during pregnancy), 486–489, 495–496
breast health and, 495–496
diabetes (type 1) and, 495
energy/nutrient needs and, 493–494
Healthy People 2020 on, J-2t
HIV/AIDS and, 495
postpartum amenorrhea and, 495
Matrix, **175**
Meal(s)
for children, 519–520
for children at home, 531–534
for children at school, 534–536, 535t
before and after competition, 458–459
congregate, 570
creative, 572
healthy and thrifty, 663
healthy eating patterns and, 276
heart-healthy choices for, 594
of older adults, 568–569
postgame, 459, 459f
pregame, 459, 459f
for single older adults, 570–572
with toddlers, 516
for weight gain, 288
Meal preparation, vs. fast foods, 5
Meals on Wheels, **570**, 662
Mean corpuscular volume (MCV), E-21
Measurement
analysis in adults, E-7
analysis in infants and children, E-6 to E-7
anthropometric, E-5t, E-5 to E-15, E-8f to E-13f
of body fat and lean tissue, E-7 to E-15
calculation aids for, K-2
of older child or adult weight, E-7f
Meat. *See also* specific types
food composition table for, H-42t to H-49t
food list for, G-10t to G-11t
food safety for, 629, 630f
in infant diet, 514
lean, 52
nitrites in, 643
nutrients in, 10
processed, H-46t to H-49t
in school lunches, 535
as snacks, 533, 539
Meat-processing plants, food safety in, 626
Meat replacements, **64**
food composition table for, H-42t to H-49t
food list for, G-10t to G-11t
Mechanism, in correlations, 16
Medical approach, to disease prevention, 608
Medical care. *See* Health entries; Medicine
Medications, caffeine content of, H-2t to H-3t
Medicine. *See also* Drugs
complementary and alternative, 614–620
conventional, 614
life expectancy increase and, 552
Mediterranean diet, 46t, 162–163, 556
arthritis and, 565
pyramid for, 164f
Megaloblastic anemia, 314
Melanin, 178
Membrane, cells, A-2
Men. *See also* Gender
bone loss in, 399
Menadione, C-8f
vitamin K as, 355n
Menarche, 538
Menkes disease, **420–421**
Menopause, osteoporosis and, 398–399
Menstruation
bone loss and, 398–399
iron and, 482, 538
malnutrition and, 485
Mental health, Healthy People 2020 on, J-2t
Mental retardation
from alcohol during pregnancy, 489
cretinism and, 418
rickets and, 349
Menu, sample, 48t, 481f, 516f
MEOS (microsomal ethanol-oxidizing system), **223–224**
Mercury
in fish, 153, 634–636
pregnancy and, 490
Messenger RNA, 173, 174f, 190
Metabolic alkolsis, 382n
Metabolic pathways
amino acids in, C-11f
fatty acid oxidation, C-10f
glycolysis, C-9f
Metabolic rate, resting, 236
Metabolic syndrome, **591**. *See also* Diabetes; Insulin resistance
obesity and, 248–249
Metabolic water, **369**

Metabolism, **198**. *See also* Acetyl CoA; Anabolism; ATP; Basal metabolic rate; Basal metabolism; Catabolism; Coenzymes; Energy balance; Energy metabolism; Enzymes; Fatty acids; Glucose; Glycerol; Glycogen; Hormones; Pyruvate; TCA (tricarboxylic acid) cycle
alcohol and, 222f, 224
of amino acids, 207–213, C-11f
aspartame and, 645
basal, 236
B vitamins in, 319, 320f
of carbohydrates, 105
chemistry of, 198–201
drug alteration of nutrient, 576–577
drug-nutrient interactions and, 576t
of energy, 197–219
fasting and, 217
fat cell, 264–265
of feasting, 213–215
feasting to fasting, 215–216
glucose in, 203–206, C-9f
of glycerol and fatty acids, 207, C-10f
hormones regulating, A-6
of lipids, 146–147
by liver, 81, 199t
methotrexate and, 577
oxygen in, 205
of protein, 178–180
of short-chain fatty acids, 102
zinc in, 415, 416
Metalloenzymes, **414**–415, 423
Metastasize, **602**
Methionine, 184f, C-3f
alcohol use and, 226
vitamin B_{12} and, 315
Methotrexate, 577
folate and, 315, 577f
Methylation, **191**
Methyl groups, folate and, 311–312
Methylmercury, 634–635, 635f
Metric measurements, 9f, K-2
Mexican foods, 46t
Mexico, dwarf wheat in, 655
MFP factor, **407**
Mice, energy-restricted diet in, 554–555
Micelles, **140**
Michigan, PBB accident in, 635
Microangiopathies, **600**
Microarray technology, **190**–191, 190f
Microbial contamination, food safety and, 631
Microbial toxins, 626
Micronutrients, 8
Microvilli, **78**, 78f, 79
Microwave products, packaging of, 646–647
Middle East, zinc deficiency in, 416
Milk and milk products, 53. *See also* Breast milk; Cow's milk; Dairy products; Lactase deficiency; Lactose intolerance; Rennin; Soy products
calcium values of, 385, 387, 388f
carbohydrates in, 119
fats in, 153
food composition table for, H-32t to H-40t
food list for, G-6t
fortification of, 345
for heart health, 161, 594
lactose intolerance and, 103–104
low-fat, 53, 63f
mineral content, 367
nutrients in, 43f
protein in, 185
riboflavin in, 304, 304f
vitamin C and, 326
vitamin D-fortified, 350, 350f
Milk anemia, 409n, 516, **516**
Milk group, B vitamins in, 322
Milliequivalents per liter, **373**
Minamata, Japan, contamination in, 634–635
Mineralization, **385**
Mineral oil, **91**
Minerals, 7, **11**, 377–394. *See also* Trace minerals; specific minerals
bioavailability of, 378
biochemical tests for assessing status, E-17t
in body, 377–395, 378
body handling of, 378
in breast milk, 509
for children, 518–519
contaminant, 424
as conventional or alternative medicine, 617
deficiencies of, 104
in digestion, 76f
in foods, 6
in hard and soft water, 370
in human body, 378f
for infants, 506
in lactation, 494
major, 11n, 377, 378f, 379–394
needs for, 367
as nutrients, 7
for older adults, 562–563
to support activity, 451–453
trace, 377, 378f
in water, 367
Mineral water, 371
Misinformation, **31**
about vitamin and mineral supplements, 333
Mitochondria, 198f, **205**, 210f, **A-3**. *See also* Cells
TCA cycle in, 210
Mixed foods, food composition table for, H-60t to H-65t
MOA (monoamine oxidase) inhibitors, diet-drug toxicities and, 578
Moderate-intensity physical activity, **439**
Moderation, **38**
in alcohol use, 221
in energy consumption, 556
in fat consumption, 156
Molecules, B-3
water, 374f, B-6
Molybdenum, **423**, 424
Monoglutamate. *See* Folate
Monoglycerides, **138**
Monosaccharides, 96–97, 97f, 110, C-1, C-1f
absorption of, 103f
Monosodium glutamate (MSG), 644–645
Monoterpenes, 429t
Monounsaturated fats/fatty acids, **131**, 138t. *See also* Blood cholesterol; Mediterranean diet; Nuts and nut butters; Olive oil
food list for, G-12t
food sources of, 134f, **162t**
health effects of, 149–156
recommended intakes of, 150–156
Morning sickness, 483
Mortality. *See also* Death
late-life depression and, 559
weight, fitness, and, 247, 249
Mouth, **71**–72. *See also* Gums; Teeth
carbohydrate digestion and, 101, 102f
digestion and, 76f
protein digestion and, 172f
Mouth cancer, 604t
MSG, 644–645
MSG system complex, **645**
Mucous membranes, **342**, 342f
Mucus, **75**, 78
Multigene disorders, 193–194
Multi-grain products, 49
Multivitamin-mineral supplement, for older adults, 563
Muscle(s)
in digestion, 72–73
of older adults, 554
physical activity and, 237
in physical examination, E-16t
protein used in building, 449–451
stomach, 73f
Muscle cells, glucose storage in, 105
Muscle dysmorphia, **254**
Muscle endurance, **440**
Muscle power, **443**, 444
Muscle strength, **440**
Mutations, **193**, 603
Myoglobin, **406**
MyPlate (USDA), 45, 46, 46f, 633
vegetarian diets and, 63–64
MyPyramid. *See Dietary Guidelines for Americans;* Healthy Eating Index; MyPlate

N

NAD. *See* Nicotinamide adenine dinucleotide
Nails, in physical examination, E-16t
Nanoceuticals, 331, **335**
Nanotechnology, 331, **335**
Narcotic, **224**–225. *See also* Alcohol
Nasopharynx cancer, 604t
National Center for Complementary and Alternative Medicine, 615
National food recovery programs, **663**
National Health and Nutrition Examination Survey (NHANES), 24n, 124
National Institute of Allergy and Infectious Diseases (NIAID), 524–525
National Institutes of Health, on BGH, 648
National Library of Medicine, 28
National Nutrition Monitoring program, 24
National School Lunch Program, 534–535, 536
Natural disasters, famines from, 664–665
Natural fats
saturated fatty acids in, C-2t
unsaturated fatty acids in, C-2t
"Natural" foods, contamination and, 637
Natural water, 371
Nausea, in pregnancy, 483–484
Near-infrared spectrophotometry, 245
Negative associations, food choices and, 5
Negative correlation, **15**
Negative feedback loop, 84f
Neotame, 114t
Nerve diseases, alcohol use and, 228t
Nerves, A-8 to A-9, A-9f
diseases of, 600–601
Nervous system
in digestive and absorptive processes, 83, A-8 to A-9
organization of, A-9f
Net protein utilization (NPU), **D-3**
Neural tube, **312**. *See also* Anencephaly; Spina bifida
folate and defects of, 312–313, 313f
Neural tube defect, **472**–473
Neurofibrillary tangles, **566**–567
Neuromuscular dysfunction, vitamin E and, 353
Neurons, **565**
Neuropeptide Y, **236**
Neurotransmitters, **178**. *See also* Norepinephrine; Serotonin
aging brain and, 565–566
Neutrons, B-1
Neutrophils, **583**
Newborn, 472f. *See also* Infants
New Sonoma Diet, 295t
NHANES. *See* National Health and Nutrition Examination Survey
Niacin (vitamin B_3), **305**–307, C-5f. *See also* Nicotinamide adenine dinucleotide (NAD)
coenzymes of, 305
deficiency in, 319–320
deficiency symptoms, 305–306, 306f
equivalents of, **305**
flush from, **306**
food sources of, 306, 307, 307f
RDA, 308
toxicity of, 306–307
Niacinamide. *See* Niacin
Nicotinamide adenine dinucleotide (NAD), 305, 319, 320f
Nickel, 405
Nicotinamide. *See* Niacin
Nicotinic acid. *See* Niacin
Night blindness, **343**, 343f
9/11. *See* September 11, 2001
Nitrites, 643, **643**
Nitrogen, in urea, 180
Nitrogen balance, **178**
Nitrosamines, **643**–644
Nonessential amino acids, **168**, 168t, 179, 179f
Nonessential trace minerals, 405
Nonexercise activity thermogenesis (NEAT), **269**
Nonheme iron, **406**, 407f, 413
Nonnutritive sweeteners, **113**
Nonperishable food collection, 663
Nonpoint water pollution, **670**
Nonstarch polysaccharides, 100
Nonstarchy vegetables, food list for, G-9t
Nonvitamins, 318–319

Noodles, food composition table for, H-10t to H-15t
Norepinephrine (neurotransmitter), 178, A-6
Norovirus, 625t
North America, pesticide policy for, 638
Nucleic acids, vitamin B_6 and, 309
Nucleotide, **190**
Nucleotide bases, **190**
Nucleus, A-2
  in atoms, B-1
Nursing bottle tooth decay, **512**
Nutrient(s), 6–12. *See also* Dietary supplements; Essential nutrients; Minerals; Pregnancy; Trace minerals; Vitamin listings; specific nutrients
  absorption of, 77–79, 77f
  additives for, 645–646
  adolescent needs for, 537
  in aging, 563t
  alcohol abuse and, 225–226
  bioavailability of, 378, 403, H-1
  biotechnology and, 656t
  in body, 6–7
  for bone development in pregnancy, 482
  bone health and, 400
  brain function and, 565–566
  in bread, 51
  in breast milk, infant formula, and cow's milk, 508, 511f
  chemistry of, 7, 201–202
  deficiencies and behavior of children, 521–522
  deficiencies in, 110, 321, 667
  density of, 36–38, 41–44
  dietary guidelines for, 38–40
  in digestion, 75
  drug interactions with, 575–578
  elements in, 7t
  energy from, 8, 10–11, 124f, 201–213, 445–446
  essential, 8
  in foods, 6, 302
  gene expression regulated by, 191, 193f
  genetic engineering of, 653
  to increase, 39t
  for infant energy, 506
  information on, 633
  inorganic, 7
  interactions of, 378
  iron as, 405
  lactation and, 493–494
  in legumes, 41
  macro- and micro-, 8, 20
  minimizing losses of, 633–634
  needs for, 331
  older adult needs for, 560–563
  organic, 7, 7t
  in pregnancy, 479–480
  recommendations for, 17–21, 38–40, 39t
  satiating, 235
  in sugar and other foods, 111t
  trace mineral interactions and, 405
  transport by liver, 81
  in vascular system, 82
  in vegetables, 40–41
  vegetarian sources of, 65t
  vitamin E and, 452
  water as, 367
Nutrient claims, 56–57, 58f
Nutrient density, 36
  of breakfast options compared, 37f
  food comparison based on, 37
  of healthful diet, 457
  snacks for, 458t
Nutrient-drug interactions, 575–578
Nutrient intake
  adequate, 19
  inaccurate vs. accurate view of, 19f
Nutrient profiling, 38
Nutrient recommendations. *See* Adequate Intake (AI); *Dietary Guidelines for Americans*; Estimated Average Requirements; RDA (Recommended Dietary Allowances); Tolerable Upper Intake Level
Nutrigenetics, **190**
Nutrigenomics, **190**
Nutrition, 3. *See also* Adolescence; Children; Infants; Malnutrition; Nutrition assessment; Pregnancy
  in adolescence, 536–540
  in adulthood and later years, 551–572
  alternative therapies and, 616–619
  assessments of, E-5t
  in childhood, 517–536
  chronic diseases and, 110, 585–586
  experts in, 29–31
  facts on food label, 54–56
  food selection and, 5f, 6
  at home, 531–534
  immunity and, 583–584, 584f
  during infancy, 505–516
  infectious diseases and, 582–584
  information sources about, 28–29, 32t
  lactation and, 492–497
  over life cycle, 505–540
  longevity and, 553–556
  news information on, 29
  objectives for (2020), 25t
  before pregnancy, 469–470
  during pregnancy, 479–484
  at school, 534–536
  science of, 12–17
  for type 1 diabetes, 602
  WHO recommendations for, I-1
Nutritional adequacy. *See* Dietary adequacy
Nutritional anemias, E-18 to E-19, E-19t. *See* also Anemia
Nutritional experts, 29–31
Nutritional genomics, 12, **190–192**, 191f
Nutritional health, physical activity and, 438
Nutritional research, 12–17. *See also* Research
  analysis of findings in, 15–16
  conducting research, 12–15
  design examples for, 14f
  publication of research in, 16–17
  scientific method in, 13f
Nutrition assessment, 21–25, 22, E-1 to E-22
  anthropometric measurements in, 22
  biochemical analyses in, E-17 to E-22
  cautions about, E-22
  of deficiency stages, 23f
  food frequency questionnaire in, E-4
  food record and, 284f
  health history, 22
  historical information for, E-1t, E-1 to E-5
  of individuals, 22–24
  iron status in, 23–24
  laboratory tests for evaluating anemias, E-19t, E-19 to E-21, E-20t
  laboratory tests in, 23
  physical examinations in, 22–23, E-16t
  of populations, 24
  socioeconomic history in, E-2 to E-3
  24-hour recall in, E-3 to E-5
Nutrition-related alternative therapies. *See* Complementary and alternative medicine; Herbal remedies; Herbal supplements
Nutrition Reviews, 17
Nutrition screening, E-1
Nutrition Screening Initiative, 569
Nutritive sweeteners, 114
Nuts and nut butters. *See also* Flaxseeds
  food composition table for, H-28t to H-31t
  for heart health, 160

O

OAA Nutrition Program, 569, 570
Oatmeal, 116
Obesity, 558. *See also* Body mass index; Childhood obesity; Fat (body); Overweight; Waist circumference; Weight; Weight-loss strategies; Weight management
  aggressive treatments for, 272–274
  aging and, 557
  alcohol use and, 228t
  cancer and, 603–604
  causes of, 266–269
  central, 244
  CHD and, 590
  in children, 526f
  clinically severe, 272
  deaths from, 247
  dietary fats and, 148
  diseases related to, 242–243
  drug treatments for, 272–273
  fad diets and, 294–297
  genes promoting, 191–192, 266–268
  genetic component of, 193
  health risks from, 270
  hunger and, 661–662
  as hypertension risk factor, 595
  in older adults, 557
  overweight and, 263–265
  perceptions and prejudices about, 270–271
  physical activity and, 269
  poverty and, 662f
  predisposition to, 266
  pregnancy and, 476
  prevalence in United States, 264f
  prevention and treatment of childhood, 529
  prevention of, 286
  problems of, 270–272
  recommended eating and physical behaviors for preventing, 529t
  sugar consumption and, 110
  surgery for, 273, 273f
  in teenagers, 537
  in type 2 diabetes, 599
  vegetarian diets and, 62
Obesogenic environment, **268**
Obligatory water excretion, **369**
"Off-label" drug use, for obesity, 273
Oils, 10, **134**. *See also* Fatty acids; Flaxseeds; Monounsaturated fats/fatty acids; Olive oil; Omega-3 fatty acids; Omega-6 fatty acids; Saturated fats; Vegetable oil
  characteristics of solid, 133–135, 154
  food composition table for, H-52t to H-55t
  for heart health, 159–160, 594
  nutrients in, 43f
Older adults. *See also* Aging process; Chronological age; Physiological age; Quality of life
  aging process and, 556–560
  alcohol use by, 567–568
  arthritis in, 564–565
  body composition in, 557
  body weight of, 557
  brain, aging of, 565–568
  calcium for, 562
  carbohydrate and fiber needs of, 561
  diet and, 554–556
  diseases of, 558
  energy and nutrient needs of, 560–563
  estimating energy requirements for, 561
  exercise guidelines for, 555t
  fat needs of, 561
  folate for, 562
  food assistance programs for, 569–570
  foodborne illnesses of, 570–571
  food choices of, 568–572
  healthy habits of, 553
  Healthy People 2020 on, J-2t
  iron for, 562–563
  malnutrition in, 569, 569t
  meals for singles and, 570–572
  nutrient concerns of, 563t
  nutrition for, 551–572
  physical activity for, 444, 553–554
  protein needs of, 561
  vision of, 564
  vitamin B_{12} and, 562
  vitamin D and, 350, 562
  vitamins and minerals for, 562–563
  water needs in, 560
  zinc for, 563
Older Americans Act (OAA), 569
Olestra, **155–156**
Oligopeptide, 171n
Olive oil, 134f, 150t. *See also* Monounsaturated fats/fatty acids
  for healthy cooking, 159–160

Omega-3 fatty acids. *See also* Arachidonic acid; Docosahexaenoic acid; Eicosapentaenoic acid; Olive oil
for arthritis, 565
egg content of, 153
essential fatty acids and, 145
in fish, 149, 150, 151–153, 160–161
food sources of, 134f, 162t
health benefits of, 149, 159–163, 362, 496
mercury in fish and, 132, 138, 636
omega-6 compared with, 130, 132f, 146
as supplements, 150
in vegetarian diets, 66
Omega-6 fatty acids, 130, **132,** 138. *See also* Arachidonic acid
essential fatty acids and, 145
food sources of, 134f, 151–152, 162t
omega-3 compared with, 130, 132f, 146
Omega number, **132**
Omnivorous diets, **63**
Opsin, **341**
Oral health. *See also* Gums; Mouth; Teeth
Healthy People 2020 on, J-2t
Oral rehydration therapy (ORT), **376, 670**
Organelles, **A-2**
Organic crops, **640–641**
compared with conventional foods, 641
costs of, 641
home-grown, 640f
seal on labels of, 640f
Organic halogens, **634**
Organic sources, **7**
of nutrients, 7, 7t
of vitamins, 298
Organ meats, vitamin C and, 326–327
Ornish Diet, 295t
Orotic acid, 319
Osmosis, **374,** 375f
Osmotic pressure, **374**
Osteoarthritis, **564–565**
weight and, 247
Osteocalcin, **355**
Osteomalacia, **349**
Osteoporosis, **349,** 380–381, **389–390, 396.** *See also* Stress fractures
alcohol and, 399
calcium and, 385, 396–397, 400
eating disorders and, 253
gender and hormones in, 398–399
genetics and, 399
Healthy People 2020 on, J-1t
height loss through, 398f
magnesium and, 392
in men, 399
physical activity, weight, and, 399
protein and, 183
risk factors for, 397t
scan of, 397f
smoking and, 399
sodium and, 380–381
vitamin D and, 349
in women, 398–399
Outbreaks, **625**
Ovarian cancer, 604t
Overeaters Anonymous (OA), 285
Overeating, 234f, 268–269. *See also* Binge eating disorder; Eating disorders; Feasting
Overload principle, 440–441
Overnutrition, **21**
Overpopulation, poverty and, 665–667
Oversight, biotechnology and, 656t
Overweight. *See also* Obesity; Weight
Alzheimer's disease and, 567
in children, 526–531
dementia and, 566
health risks of, 249
obesity and, 263–265
osteoarthritis and, 564–565
pregnancy and, 476
problems of, 270–272
Ovum, **471**
Oxaloacetate, **210,** 211, 211f
Oxfam America, 675t
Oxidants, **361**
Oxidation, **134**
of fat, 268
fatty acid, 207
Oxidative stress, **323, 360,** 556–557
in Alzheimer's disease, 566
in cataracts, 564
smoking and, 325
Oxygen
and cardiorespiratory endurance, 442
in metabolism, 205
Oxyntomodulin (hormone), 236
Oxytocin (hormone), **493, A-6**
Oyster shell, 396, **400**
Ozonation, 650

P

PABA (para-aminobenzoic acid), 319
Packaged foods
labeling of, 53
packaging materials and, 646–647
weight management and sizes of, 283
Pakistan, crop production in, 655
Palm oil, 134f
Pan American Health Organization, 675t
Pancreas, **72,** A-5f
carbohydrate digestion and, 101, 102f
protein digestion and, 172f
secretin and, 84
Pancreatic amylase. *See* Amylase
Pancreatic cancer, 603, 604t
Pancreatic lipase, 74
Pancreatic polypeptide (PP) hormone, 236
Pantothenic acid
Adequate Intake of, 309
deficiency and toxicity of, 309
food sources of, 309
Parathyroid hormone, 347, **385**
Parents
children's mealtimes and, 531–534
as gatekeepers, **531,** 539
Passive packaging, of microwave products, 647
Pasta, food composition table for, H-10t to H-15t
Pasteurization, **626,** 632n
irradiation and, 633
Pathogens, **626**
PBB (polybrominated biphenyls), **635**
PCB (polychlorinated biphenyls), 496, **635**
PDCAAS (Protein digestibility-corrected amino acid score, **D-2,** D-2t
Peer review, in research, **16**
Peers, adolescent nutrition and, 540
Pellagra (disease), **305–306,** 306f, 320, 321
Pepsin, **171,** 172f
Pepsinogen, 171
Peptic ulcer, 92
Peptidase enzymes, **171**
Peptide bond, **169**
Peptide YY (PYY) hormone, 236
Percentages, calculation aids for, K-1
Percent Daily Value, **54–55**
Performance, of dietary supplements, 463–466
Perinatal, **489**
Peripheral nervous system, **A-8**
Peripheral resistance, **595**
Perishable food rescue (salvage), 663
Peristalsis, **73,** 75
GI bacteria and, 82
promoting, 91
Pernicious anemia, **317**
Persistence, **634**
Pesticides, **637–642.** *See also* Certification; Organic crops; Residues; Tolerance level
alternatives to, 639–640
biotechnology and, 656t
consumer concerns about, 639–642
EPA tolerance level for, 638
hazards of, 638
minimizing residues of, 639f, 640t
monitoring of, 638–639
from other countries, 638
pollution from, 670–671
regulation of, 638
residues of, 637
unsustainable and sustainable methods for, 674t
pH, **75,** 377
scale of, 75f, 376f
of stomach, 75, 83, 171
Phagocytes, **583**
Phagocytosis, **583**
Pharmacological effect, of foods, 430–433
Pharynx, **72**
cancer of, 604t
Phenylalanine, 169, 169f, C-3f
Phenylketonuria (PKU), **169, 193**
pregnant women with, 491
Phosphocreatine, 444
Phospholipids, **136–137,** 141, 390. *See also* Lecithin
Phosphorus, **390–391.** *See also* Hydroxyapatite
in blood, 390
in body, 390
in bones, 390
for bones/teeth, 348
deficiency of, 391
food sources of, 391f
toxicity of, 391
Photosynthesis, **197**
Phylloquinone, vitamin K as, 355n
Physical activity (PA), 40f, **438.** *See also* Aerobic physical activity; Exercise; Female athlete triad; Fitness; Nonexercise activity thermogenesis
body composition and, 281
body's response to, 441
calculating level of, F-1 to F-2, F-2t
cancer risk reduction and, 606t
CHD and, 590
childhood obesity and, 528, 530
in children, 547
children's energy and, 517–518
choosing types of, 281–282
diabetes and, 602
diet for, 457–460
digestion and, 86
discretionary kcalories and, 280f
duration of, 441, 447
energy output and, 237, 238t, 280, F-2t to F-3t
energy requirements and, 239, F-1 to F-6
energy systems of, 444–446
equivalents and their PA factors, F-3t
fat use during, 448–449
fluids and electrolytes for, 453–457
fuels use for, 445t
glucose during and after, 446, 448
guidelines for Americans 2008, 531
Healthy People 2020 on, J-2t
hydration for, 454
for hypertension, 596
of infants, 506
intensity of, **441,** 442–443, 446, 449
levels of intensity compared, 439t
meals before and after competition, 458–459
for older adults, 444, 553–554
osteoporosis and, 399
pregnancy and, 470
protein use during and between, 449–451
vitamins and minerals for, 451–453
water for, 458
weight and, 249f, 286
in weight management, 279–282
Physical endurance. *See* Endurance
Physical examinations, E-15 to E-16, E-16t
in nutrition assessment, 22–23
Physical health, of overweight children, 529
Physical inactivity, 269
Physicians, as nutrition experts, **29–30**
Physiological age, **553**
Physiological changes, in aging process, 557–559
Physiological fuel value, **232**
Physiological influences, on eating, 233, 234f
Phytate, 65, 100, 378, 653
as calcium inhibitor, 386
in foods, 407, 416, 416n
as iron inhibitor, 407, 411
as manganese inhibitor, 421
as zinc inhibitor, 415, 416
Phytic acid, **100,** 429t
Phytochemicals, **6, 361, 428–433,** 605. *See also* Carotenoids
antioxidants and, 363, 556

cancer and, 429, 430
colors of foods with, 432t
food sources of, 52, 428, 429t, 430–433
in fruits and vegetables, 431f
functional foods and, 428–433
gene expression and, 191
heart disease and, 430–433
Phytoestrogens, 428
Pica, 411–412, 484, 522
Pickwickian syndrome, 247
Pies, food composition table for, H-4t to H-9t
Pigments, 341, 345
skin cancer and, 351
Pituitary gland, A-4
PKU. *See* Phenylketonuria
Placebo, 15
Placebo effect, 15, 615
Placenta, 470
alcohol use and, 489
associated structures and, 471f
Plant-based diets, 63
Plant foods, cancer risk reduction and, 606t
Plants
fats from, 150
protein from, 181
Plant sterols, 430
Plaque(s)
atherosclerosis and, 137, 361–362, 545–546, 586–590
dental, 112
senile, 566–567
Plastics, dioxins and, 647
Platelets, 588
PLP. *See* Coenzyme PLP
Point of unsaturation, 131
Poisoning
iron, 411–412
from lead, 522–523
Politics, food shortages and, 664
Pollution
crop chemicals and, 670
food safety and, 631
water, 670
Polyglutamate. *See* Folate (B vitamin)
Polyols, 113
Polypeptide, 169, 173
hemoglobin and, 170
shape of, 170
tangle of, 170
Polysaccharides (starches and fibers), 97, 99–101, 102f, 168, C-1, C-1f
Polyunsaturated fats/fatty acids, 130, 131, 138t. *See also* Monounsaturated fats/fatty acids; Unsaturated fats/fatty acids
food list for, G-12t
food sources of, 162t
gene expression and, 175
health effects of, 149–156
recommended intakes of, 150–156
vitamin E and, 354
Poorest poor. *See also* Poverty
worldwide, 664
Popcorn, food composition table for, H-10t to H-15t
Population
aging of, 551–552, 552f
nutrition assessment of, 24
poverty and, 665–667
worldwide, 666f
Population approach, to disease prevention, 608
Pork. *See also* Meat
food composition table for, H-44t to H-47t
thiamin in, 302, 303f
Portion size, 45, 52, 235, 269, 277
fat and, 235f
weight gain and, 288
weight loss and, 283
Positive associations, food choices and, 5
Positive correlations, 15
Postabsorptive influences, on eating, 234f
Postgame meals, 459, 459f
Postingestive influences, on eating, 234f
Postmenopausal women, breast cancer in, 604t
Postpartum amenorrhea, 495
Postterm, 476
Potassium, 383, 384
deficiency symptoms, 383, 597
fluid/electrolyte regulation and, 375
in foods, 384f
hypertension and, 383, 597
processing and contents of foods, 381, 381f
toxicity, 383
Potato
vitamin A and, 345–346
vitamin C in, 326
Poultry
food composition table for, H-46t to H-47t
kitchen safety for, 629, 630f
serving sizes for, 52
Poverty
breaking cycle of, 666–667
food, 661
obesity and, 662f
overpopulation and, 665–667
population growth and, 666
Poverty line
international, 664
in United States, 661
Powdered bone, 396
Prader-Willi syndrome, 266
Prebiotics, 83
Precursors, of vitamins, 298
Prediabetes, 597
Predicting, in scientific method, 13f
Preeclampsia, 487–488
Preferences, in food choices, 4
Preformed vitamin A, 344
Pregame meals, 459, 459f
Pregnancy
during adolescence, 488
alcohol use during, 489, 501–503
blood pressure during, 487
breastfeeding and, 492–497
caffeine in, 491
calcium needs in, 482
carbohydrate needs in, 480
diabetes during, 486, 487
dietary supplements for, 483
energy needs in, 480
environmental contaminants during, 490
essential fatty acids in, 481
exercise during, 478, 479f
fetal growth and development during, 470–475
folate during, 313, 481
foodborne illness in, 490–491
food choices for, 481f
gestational diabetes and, 487
high-risk, 484–491
illicit drugs in, 489
iron needs in, 408–409
low-risk, 484
malnutrition and, 485–486
maternal discomforts in, 483–484, 483t
maternal weight during, 475–479
medicinal drugs in, 489
mercury and, 636
mother's age during, 488–489
nausea and vomiting during, 483–484
neural tube defect and, 472–473
nutrition during, 479–48
nutrition prior to, 469–470
in older women, 488–489
overweight and, 476
practices incompatible with, 489–491
preexisting diabetes and, 486
protein needs in, 480–481
sugar substitutes in, 491
underweight and, 476
vitamin A during, 344
vitamin D in, 482
vitamin-mineral megadoses in, 491
weight gain during, 476–478, 477t
weight loss after, 477–478
zinc in, 482
Prehypertension, 590
Premenopausal women, breast cancer in, 604t
Prenatal alcohol exposure, 501
Prenatal weight gain, 476, 477f
Prepared food rescue, 663
Prepared foods, cancer risk reduction and, 606t
Prepared meal plans, 277
Preschoolers, food skills of, 532t
Preservatives, 642
salt and sugar as, 643f
Preserved foods, cancer risk reduction and, 606t
Pressure ulcers, 560
Preterm (premature) infants, 476, 489
nutritional needs of, 512
Prevention
of childhood obesity, 529t
of obesity, 286
Preventive approach, to disease prevention, 608
Primary deficiency, 23
of vitamin K, 355
Prime cuts. *See also* Beef; Meat
of beef, 52
Probiotics, 83
Processed foods, 49
breakfast cereals as, 50–51
meats, H-46t to H-49t
salt without iodine in, 419
vitamins in, 298
Product tracking, biotechnology and, 656t
Proenzyme, 171n
Profits, biotechnology and, 656t
Progesterone, A-7
Progressive overload principle, 440
Prolactin (hormone), 493, A-4
Prolactin-inhibiting hormone (PIH), A-5
Proline, as hydroxyproline, 323
Promoters, 604, 605
Prooxidant (dietary), 361
vitamin C as, 326
Propionic acid, 102n
Prostaglandins, 588
Prostate cancer, 604t
Proteases, 171
in protein digestion, 171
Protein (animal), 181. *See also* Eggs; Fish; Meat; Pork; Poultry
Protein (body), 173–180. *See* also Amino acids; Collagen; Hemoglobin; Transport proteins
absorption of, 171
as acid-base regulator, 176
adipokines as, 144
amino acids and, C-3f
as antibody, 177
in breast milk, 509
calcium-binding, 386
as energy and glucose source, 177–178
as enzyme, 175–176
fluid and ion flow regulated by, 374–375
as fluid balance regulator, 176
as fuel, 450
functions of, 180t
glucose from, 105
health effects of, 182–187
as hormone, 176
malnutrition, E-18
as nutrients, 7
recommended amounts of, 44t, 450
retinol-binding, 340
role of, 175–178
as satiating nutrient, 235
as structural material, 175
subgroups of, 41
synthesis of, 173
transport, 176–177, 177f, 407
uncoupling of, 267–268
used in muscle building, 449–452
Protein (dietary), 6, 168, 181–182. *See also* Protein (animal); Reference protein; Soy protein; Tempeh; Textured vegetable protein; Tofu
absorption of, 171, 172f
amino acids and, 167–188, D-1 to D-4
amino acids for, 179
for athletes, 451, 451t
B vitamins in, 322
calculating recommended intakes, 185
carbohydrates in, 120
cell links in, 169–170
chemistry of, 168–171
for children, 518
complementary, 181–182

Protein (dietary) (*continued*)
denaturing of, 170, 170f
diabetes and, 601
digestion of, 76, 171, 172, 181
excess, 215
energy from, 201
fats and, 150
food options for, 151
health effects of, 458
metabolism of, 178–180
nutrients in, 43f
for older adults, 560
overload of, 506
plant, 181
pregnancy/lactation needs for, 480–481
quality of, 181, D-1 to D-4
recommended intakes of, 184–185, 184f
reference, 181
sources of, 52, 167
supplements for, 186
textured vegetable protein and, 52
use during and between physical activities, 449–451
for vegetarians, 64, 185f
vitamin B_6 and, 310f
Protein digestibility-corrected amino acid score (PDCAAS), **D-2,** D-2t
Protein efficiency ratio (PER), **D-4,** D-4t
Protein-energy malnutrition (PEM), 182
Protein-rich foods, zinc in, 416
Protein synthesis, vitamin A in, 341–342
Protein turnover, **178**
Proteome, **190**
Prothrombin, 354–355
Protons, B-2
Provitamins, 298
Psychological changes, in aging process, 559
Psychological issues
alcohol use and, 228t
obesity and, 271, 284–285
in overweight children, 529
Psychological support, for weight loss, 531
Pteroylglutamic acid (PGA). *See* Folate (B vitamin)
Puberty, **537**
Public health dietitians, **30**–31
Public policy, national nutrition surveys and, 24
Public water, 371
Publishing, of research, 16–17
PubMed, 28, 30f
Purified water, 371
Purines, **565**
Pyloric sphincter, **72,** 73, 83, 138
Pyridoxal. *See* Vitamin B_6
Pyridoxamine. *See* Vitamin B_6
Pyridoxine. *See* Vitamin B_6
Pyrroloquinoline quinone, 319
Pyruvate, **202**. *See also* Glycolysis
-to-acetyl CoA, 206, 206f, 319
anaerobic vs. aerobic options for, 205
glucose-to, 203–205
-to-lactate, 205–206, 205f
paths of, 206f
PYY (peptide), 236

Q

Quackery, 31, 32f
Quality of life, **553**
Que She, for weight reduction, 272

R

Race, body composition and, 243
Rachitic rosary, 349n, **352f**
Radiation, vitamin D synthesis and, 351
Radioactive potassium count, 245
RAE. *See* Retinol activity equivalents
Raisins, in water, 375f
Randomization, **12**
RDA (Recommended Dietary Allowances), **18**–19, 18f, 20–21
actual intakes compared with, 47f
of calcium, 390
for calcium in adolescents, 538
for dietary fats, 148–149, 150–156
of folate, 315
by food group, 44t
of iodine, 419
of iron, 412, 414
of magnesium, 393
of molybdenum, 424
of niacin, 308
for older adults, 570
of phosphorus, 391
during pregnancy, 482
of proteins, 184–185
of riboflavin, 304
of selenium, 420
of thiamin, 302, 303
of trace minerals, 404f
of vitamin A, 347
of vitamin B_6, 309, 311
of vitamin C, 327
of vitamin D, 352, 643
of vitamin E, 353–354
for vitamins for adolescents, 537–538
of zinc, 417
Reactions, chemical, B-6 to B-7, B-7f
Ready-to-use therapeutic food (RUTF), 669, 669f
Recommendations
food buying practices and, 49–53
vs. intakes, 45–46, 47f
nutrient, 17–21, 38–40, 39t
Recommended Dietary Allowances. *See* RDA (Recommended Dietary Allowances)
Rectal cancer, 604t
Rectum, **72,** 73
Recycling, of iron in body, 408f
Red blood cells. *See also* Anemia; Erythrocyte hemolysis; Hemolytic anemia; Pernicious anemia
hematocrit measurement of, 409
iron in, 408
lifespan of, 408
Reference protein, **181,** D-1 to D-2, D-1t
Refined grains, **49,** 50f
Reflexes, let-down reflex, 493
Reflux, **73**
gastroesophageal, 92
Refrigeration
of foods, 628–629
safe storage times, 631t
Regional cuisines, food choices and, **4**
Registered dietitian (RD), 20, **30**
Registration, **30**
Regulation
of drinking water, 649–650
of fluid and electrolyte balance, 374–375, 453–458
of food additives, 642–643
of GI tract, 82–86
of vitamin and mineral supplements, 336
Rehabilitation, for malnutrition, 669–670
Rehydration, 376
for malnourished children, 669–670
Relaxin, **A-7**
Reliability, of websites, 29
Religion, food choices and, 5
Remodeling (bone), **342**
Renin, **372,** A-7
Rennin, **653,** 655
Replication, of research findings, **16**–17
Reproduction, vitamin A in, 342
Requirement, for nutrient, **17**–18
Research
on alternative therapies, 614–615
analyzing findings of, 15–16
conclusions in, 16
controls in, 12, 13
designs of, 14f
double-blind experiment in, 13
nutritional, 12–17
placebos in, 13
publishing of, 16–17
sample size in, 15
scientific method in, 13f
terminology in, 13
Residues, **637**
Resistance training, 440, **443**
Resistant starches, **100**
Respiration, in lungs, 377
Respiration rates, infant and adult, 506t
Respiratory problems, weight and, 247
Restaurant foods, 53
Resting metabolic rate (RMR), **236**
Resveratrol, 429t
Retardation. *See* Mental retardation
Retina, **341**
Retin-A acne ointment, 344
Retinal, **340,** 341. *See also* Vitamin A
Retinoic acid, **340,** 341. *See also* Vitamin A
Retinoids, **340,** 345, 346f
Retinol, **340,** 341, 345. *See also* Vitamin A
Retinol activity equivalents (RAE), **345**
Retinol-binding protein, **340,** 415, E-18
Reverse osmosis, 649–650
Rheumatoid arthritis, 558, **565**
Rhodopsin, **341**
Riboflavin (vitamin B_2), 303–304, 305f, C-4f
coenzyme of, 304f
deficiency and toxicity of, 304
food sources of, 304, 305f
lactose intolerance and, 104
RDA for, 304
Ribose, **465**
Ribosomes, 173, 174f, 198f, **A-2**
Rickets, 25, **349**
Risk, **623**
of complementary and alternative medicine, 615–617, 616f
of pesticide ingestion, 639
Risk factors, **26**
for CHD, 588t, 591
for chronic diseases, 26, 586t
for gestational diabetes, 487
for hypertension, 595
for osteoporosis, 397t
for overweight and obesity, 270
for physical activity, 442
for poor nutrition status, E-2t
reducing for cancer, 605, 606t
RMR (Resting metabolic rate), **236**
RNA (ribonucleic acid), **190**
protein delivery and, 173
RNA synthesis, vitamin B_{12} and, 315
Running, for exercise, 450

S

Saccharin, 645
Safety (food), **624**. *See also* Food safety
St. John's wort, 271, 616f, 618t
Saliva, **74**
in digestion, 101
Salivary glands, **74,** 74f
carbohydrate digestion and, 75, 102f
fat digestion and, 139f
protein digestion and, 172f
Salmonella bacteria, 625t, 626, 626f
Salt (sodium), **373,** 379. *See also* Sodium
cutting intake of, 380
dissolved in water, 374f
from field irrigation, 671
as hypertension risk factor, 595
iodized, 418, 419
as preservative, 643f
water movement in vegetables and, 375f
Salt sensitivity, **379**
Salt tablets, 455
Sample size, in research, 15
Sandwiches
digestion of, 76f
food composition table for, H-60t to H-65t
Saponins, 429t
Sarcopenia, **557,** 557f
Satiating hormones. *See* Cholecystokinin (CCK) hormone; Leptin; PYY (peptide)
Satiating nutrients, **235**
Satiation, **233**
hunger, satiety, and, 234f
sustaining, 235
Satiety, **101, 233**
hunger, satiation, and, 234f, 235
sustaining, 235
Saturated fats/fatty acids, **131,** 138t. *See also* Coconut oil; Meat; Milk and milk products; Monounsaturated fats/fatty acids; Palm oil; Polyunsaturated fats/fatty acids; Stearic acid
in common foods, 134f
food list for, G-12t
food sources of, 162, 162t

heart disease and, 147–148, 161
in natural fats, C-2t
obesity and, 148
oils as, 133–134
recommended intakes of, 148–149
replacing with unsaturated fats, 150t, 163f
unsaturated fatty acids compared with, 133f
Sauces, food composition table for, H-58t to H-61t
Saw palmetto, 616f, 618t
School
food influences at, 536
nutrition at, 534–536, 535t
School Breakfast Program, 535
Schwarzenegger, Arnold, 243
Scientific method, 13f
Scientific research. *See* Research
Scorbutic gums, 325f
Scurvy, 25, 322–323, 324, 325
Seafood. *See also* Fish; Sushi
environmental impact of common choices, 681t
food composition table for, H-40t to H-43t
mercury in, 636
safe handling of, 631, 631f
serving sizes for, 52
Seasonings, for heart health, 594
Seattle, Chief, 675f
Secondary deficiency, 23
of vitamin K, 355
Secretin (hormone), 84, 85f, A-8
Secretions, of digestion, 73–75, 75t
Sedentary lifestyle, 269, 437
Seeds. *See also* Grain; Legumes; Nuts and nut butters
food composition table for, H-28t to H-31t
Segmentation, 73
Selective breeding, genetic engineering and, 653f
Selective permeability, of cell membranes, 374
Selenium, 419–420
body role of, 419
cancer and, 420
deficiency of, 419
food sources of, 420
RDA of, 420
toxicity of, 420
Senile dementia, 566
Senile plaques, 566–567
Sensory influences, on eating, 234f
Sensory losses, in aging process, 558–559
Separation, of raw foods, 628
September 11, 2001, food safety after, 624
Sequencing, of amino acids, 173
Serotonin, 179, 565–566
copper and, 420
Serum iron, E-20
Serum proteins, normal values for, E-18
Serum transferrin, E-18
Serving sizes, 52, G-2
Set-point theory, 265
17 Day Diet, 294t
Sex hormones, A-7. *See also* Estrogen; Progesterone; Testosterone
in bone loss, 399
Shelf life, genetic engineering and, 653
Short-chain fatty acids, 100n, 102
Sickle-cell anemia, 173
sickle cell compared with normal red blood cell, 175f
SIDS. *See* Sudden infant death syndrome
Silicon, 405
Simple diffusion, 77, 77f
Single-gene disorders, 192, 193
Skeletal system. *See* Bone(s); Bone density
Skin. *See also* Epithelial cells; Pressure ulcers; Xerosis
keratinization of, 344, 344f
in physical examination, E-16t
sunlight, vitamin D, and, 350–351
vitamin A and, 344, 345f
vitamin D and, 347
vitamin deficiencies and, 321
Skin cancer, 350–351, 604t
Skinfold measure, of body fat, 246f, E-7 to E-15, E-14f
Sleep
digestion and, 86
ghrelin and, 267
physical activity and, 438
Sleep apnea, weight and, 247
Small intestine, 72, 72, 73, 76, 76f, 77, 101. *See also* Duodenum; Ileum; Jejunum
absorption in, 77–78
carbohydrate digestion and, 101, 102f
digestion and, 76f, 172f
fat digestion in, 138–139
protein digestion in, 172f
villi in, 78, 78f, 79f
Smallpox, 582
Smoking
breastfeeding and, 496
CHD and, 590
free radicals and, 360
as health risk, 247, 248f
osteoporosis and, 399
pregnancy and, 489–490
as risk factor, 26
by teenagers, 548
vitamin C and, 324–325
weight management and, 284
Snacking
by adolescents, 539
healthful, 533t
heart health and, 594
nutrient-dense, 458t
nutritious, 537
parent controls of, 532–533
weight gain and, 282–283, 288
SNAP. *See* Supplemental Nutrition Assistance Program
Social changes, in aging process, 560
Social consequences, of overweight/obesity, 271
Social interactions, food choices and, 4
Socializing, eating environment and, 282
Society of St. Andrew, 675t
Socioeconomic history, E-2 to E-3
Socioeconomic status, nutrient intake and, 559
Sodium, 379, 578. *See also* Salt
blood pressure and, 372–373
bone loss (osteoporosis) and, 380–381
cutting intake of, 380
DASH diet and, 380
deficiency symptoms, 381
exchange list and, G-2 to G-3
in foods, 381
hypertension and, 379–380
in milk products, 53
processing and contents of foods, 381, 381f
recommendations for, 379
in sports drinks, 456
toxicity of, 382
Sodium bicarbonate, 75
as dietary supplement, 464
Soft drinks. *See* Beverages
Soft water, 370. *See also* Water
Soil, unsustainable and sustainable methods for, 674t
Solanine, 637
Solid fats and oils, 38, 154
characteristics of, 133–135, 134f
Solid foods, introduction into infant diet, 507, 512–516, 514t
Solubility
of nutrients, 79
of vitamins, 298–299
Soluble fiber, 100
Solutes, losses of, 374, 375
Somalia, famine in, 664
Somatic nervous system, A-8
Somatostatin, A-5
Somatotropin, A-4
Sorbitol, 578
Soup kitchens, 663
Soups, food composition table for, H-60t to H-65t
Sources. *See* Food sources
South Beach Diet, 295t
Southerland, Phil, 601f
Soybeans, genetic engineering of, 653
Soy phytochemicals, 427
bones, breast cancer, and, 399
Soy products, 63, 617. *See also* Soybeans; Soy protein
cancer and, 429, 430
phospholipids in, 136
soy milk compared with low-fat milk, 63f
vitamin D and, 350
Soy protein, in special infant formulas, 512
Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). *See* WIC program
Specific dynamic activity (SDA), of food, 238f
Specific dynamic effect (SDE), of food, 238f
Sperm, 471
Sphincter, 72
muscles of, 72, 73f
pyloric, 72, 73, 83
stomach action and, 73
Spices
food composition table for, H-56t to H-59t
for heart health, 594
Spina bifida, 473, 474f
folate and, 313f, 474
Spinal cord, vitamin E and, 353
Sports anemia, 409, 453
Sports drinks, 455
carbohydrate concentration of, 456
Spot reducing exercise, 282
Spring water, 371
Stability
additives for, 635
of fats, 134
Staphylococcal food poisoning, 625t
Staphylococcus aureus, 626
Starches, 97, 99–100, 99f, C-1f
cellulose bonds compared with, 100f
food list for, G-3t to G-4t
glycogen compared with, 99f
health effects of, 115–118
recommended intakes of, 118
resistant, 100
sources of, 99f
Starchy vegetables, nutrients in, 41
Starvation (energy deprivation), 217. *See also* Fasting; Malnutrition
in anorexia nervosa, 255, 287
to extend life, 556
Stature-for-age percentiles
boys (2-20 years), E-13f
girls (2-20 years), E-12f
Stearic acid, 130–131, 147
Sterile, 355
Steroids, anabolic, 465
Sterols, 137. *See also* Adrenocorticotropin (ACTH) hormone; Bile; Blood cholesterol; Testosterone; Vitamin D
Stevia (herbal sweetener), 113, 114t
Stillbirth, malnutrition and, 486
Stimulants, caffeine as, 464
Stomach, 72. *See also* Hydrochloric acid
action of, 73
cancer of, 604t
carbohydrate digestion and, 101, 102f
digestion and, 76f
hormones in, 83
muscles of, 73f
pH of, 75, 83
protein digestion in, 171
Stone-ground products, 49
Stools, 75, 118
Stool softeners, 91
Storage, of refrigerated food, 631t
Strength training, 282, 288
for bones, 399
Stress, 556–557. *See also* Epinephrine; Oxidative stress
economic, 662
oxidative, 323, 360
water, 672
Stress fractures, 253
Stress hormones, comfort foods and, 235
Stressors, 556
environmental, 671–675
Stress response, 556. *See also* Epinephrine
Stroke, 588
Healthy People 2020 on, J-2t
Structure-function claims, on food labels, 57–58, 58f
Students, drinking among, 227

Subclavian vein, **82**
Subclinical deficiency, **23**
Subcutaneous fat, **244**
Subjects, **12**
Sub-Saharan Africa, crop production in, 655
Substituted energy, alcohol and, 226
Successful weight-loss maintenance, **285**–286
Sucralose, 114t
Sucrase, **101**
Sucrose, **98**–99
Sudden infant deaths, 489
Sudden infant death syndrome (SIDS), 489, **490**, 510
Sugar alcohols, **113**
Sugar alternatives, 645
Sugars, 10, **96**, 578
  added, 38, 109, 112
  food sources of, 110f
  health effects of, 109–112
  nutrients in, 111t
  as preservative, 643f
  weight management and, 125
Sugar substitutes, in pregnancy, 491
Sulfate, **393**
  deficiency of, 393
  food sources of, 393
Sulfites, 644
Sulfur, **393**
Sunlight, vitamin D and, 347, 350
Supplemental Nutrition Assistance Program (SNAP), 559, 570, 662
Supplements. *See* Dietary supplements
Support groups, for weight-loss, 285
Surgery
  for childhood obesity, 531
  for weight management, 273, 274f
Surveys, of national nutrition, 24
Sushi, **631**
Sustainable solutions (to hunger), 673–675
  for agriculture, 673
  for development, 673–674
  sustainable actions for, 674–675
Swallowing, 89f. *See also* Dysphagia
Sweating, 453–454
  hourly sweat rate, 454
Sweetener alternatives, 113–115, 113f, 114t
Sweeteners, artificial, 645
Sweets
  food composition table for, H-54t to H-57t
  food list for, G-6t to G-8t
Symptomatic allergy, 524n

T

Tagatose, 114t
Taiwan, PCB accident in, 635–636
Take Off Pounds Sensibly (TOPS), 285
Tannins, 429t
Taste of foods
  fats and, 150
  sports drinks and, 457
  zinc and, 415
TCA (tricarboxylic acid) cycle, **202**–203, 210–212, 211f, C-12f. *See also* Oxaloacetate
  biotin and, 307
T-cells, 583
Technology. *See* Biotechnology; Genetic engineering
TEE. *See* Total Energy Expenditure
Teenagers. *See* Adolescence/adolescents
Teeth. *See also* Gums; Mouth
  aging process and, 558–559
  calcium component, 385
  dental caries and, 111–112, 111f
  dental plaque and, 112
  fluoride and, 422
  in physical examination, E-16t
  prevention of caries in children, 533–534
  vitamin C and, 325, 325f
Television, childhood obesity and, 528
Tempeh, **63**
Temperature, calculation aids for, K-2
Temperature regulation, of body, 453–455. *See also* Heat stroke; Hyperthermia; Hypothermia
Teratogen, **344**
Testosterone, **A-7**
Tetrahydrofolate, C-6f
Texture, additives for, 635
Textured vegetable protein, **52**
Theory, **15**
Thermic effect of food (TEF), **238**–239, 238f
Thermogenesis, **236**
  adaptive, 239
THF (tetrahydrofolate), 310. *See also* Folate (B vitamin)
Thiamin (vitamin B_1), **301**, C-4f
  alcohol and, 226, 301
  deficiency and toxicity of, 301–302, 302f
  dosage recommendations for, 301
  food sources for, 302, 303f
  RDA, 303
Thiamin pyrophosphate (TPP), 301
Thirst, **368**
Thoracic duct, **82**
Thrombosis, **588**
Thromboxanes, 588
Thyroid, zinc and, 416
Thyroid-stimulating hormone (TSH), A-4
Thyroxin, 179, 237t, A-6
TIA. (Trans ischemic attack), 588
Tissue, epithelial, 342
Tobacco. *See* Smoking
Tocopherol, **353**
Toddlers. *See also* Children
  meals with, 516
Tofu, **63**. *See also* Soybeans
Tolerable Upper Intake Level (UL), **19**, 300
  for phosphorus, 390
  for sodium, 379
  for preformed vitamin A, 344
  for sugar, 112
  for trace minerals, 404f
  for vitamin A, 344
  for vitamin D, 352
  for vitamin E, 353
Tolerance level, **526**, **638**
Tongue. *See also* Glossitis
  in physical examination, E-16t
  vitamin deficiencies and, 321, 321f
Tooth decay, from nursing bottles, 512f
Total body water measurement, 245
Total Energy Expenditure (TEE)
  estimating, F-2
  men, 30 years of age, F-5t to F-6t
  women, 30 years of age, F-4t to F-5t
Toxicity, **623**
  alcohol, 226
  of biotin, 308
  of B vitamins, 322
  of calcium, 390
  of chloride, 383
  of choline, 318
  of copper, 421
  of fluoride, 422, 423f
  of folate, 315
  of iodine, 419
  of iron, 411–412
  of lead, 424, 523
  of liver, 346
  of magnesium, 393
  of manganese, 421
  of molybdenum, 423
  of niacin, 306–307
  of nutrient-drug interactions, 575, 576t
  of pantothenic acid, 309
  of phosphorus, 391
  of potassium, 383
  of riboflavin, 304
  of selenium, 420
  of sodium, 382
  of supplements, 332–333
  of thiamin, 301
  of trace minerals, 403
  of vitamin A, 344, 345f
  of vitamin B_6, 309
  of vitamin C, 325–326
  of vitamin D, 350
  of vitamin E, 353
  of vitamin K, 355–356
  of vitamins, 299–300
  of zinc, 416
Toxins. *See also* specific toxins
  bioaccumulation in food chain, 635f
  botulism and, 625t
  from environmental contaminants, 634
  in fish, 671
  from genetically modified crops, 654
  liver and, 81
Toxoplasma, 625t
TPP (thiamin pyrophosphate) coenzyme, 301
Trabecular bone, **396**, 397f
Trace minerals, 11n, **377**, 378f, **403**–425. *See also* Minerals; specific minerals
  deficiencies of, 404
  interactions among, 405
  nonessential, 405
  RDA/AI and UL compared for, 404f
  toxicity of, 403
Trachea, **88**
Training
  carbohydrates for, 458
  glycogen and, 448
  resistance, 440, 443
Transamination, **179**, 179f
Transcription, **173**
Trans-fats/fatty acids, **135**, 135f
  cancer and, 148
  composition of, H-1
  diabetes and, 601
  food sources of, 38, **154**, 162t
  heart disease and, 148, 161
  obesity and, 148
  recommended intakes of, 148–149
Transferrin, **406**, 407, 409
  saturation with iron, E-20
Transfer RNA, 173
Transient ischemic attack (TIA), **588**
Translation, **173**
Transport
  of iron, 409, E-20–E-21
  of lipids, 141–144
  of zinc, 415–416
Transport proteins, 176–177, 177f
Transthyretin, E-18
Travel, food safety during, 632
Traveler's diarrhea, **632**
Treatment. *See also* specific treatments
  for obesity, 272–274
Trends, national health, 24
Triceps skinfold, measurement of, E-14f
Triglycerides, 130, **133**, 264
  absorption of, 141–142
  breakdown to glycerol and fatty acids, 207
  condensation of glycerol and fatty acids in, 133f
  digestion of, 138–140, 140f
  hydrolysis of, 138–139
  roles in body, 144–145
  transport of, 141–142
Tripeptide, **169**
Tropical oils. *See* fatty acids; Saturated fats; Unsaturated fats/fatty acids
Trypsin, 172f
Tryptophan, 184f, 566, C-3f. *See also* Eosinophilia-myalgia syndrome; Serotonin
  conversion to niacin, 305, 309
  as supplement, 187
TSH-releasing hormone (TRH), **A-5**
Tumeric, 618t
Tumor, **602**
Tuna, mercury in, 636f
24-hour recall, E-3 to E-5
Type 1 diabetes, **107**, **598**, 598t. *See also* Diabetes
  recommendations for, 601–602
Type I nutrients, 667n
Type II nutrients, 668n
Type 2 diabetes, **107**–108, 248, 439, 545–546, **598**–599, 598t. *See also* Diabetes
  recommendations for, 602
Tyramine, foods with, 578t
Tyrosine, 169, 178, C-3f

U

Ubiquinone. *See* Coenzyme Q_{10}
UL. *See* Tolerable Upper Intake Level
Ulcers, **92**–93
Ultimate Weight Solution Diet, 295t
Ultrahigh temperature (UHT) treatment, 571, **632**
Ultrasound measurement, 245
Umbilical cord, **471**
Undernutrition, **21**
Underweight, **287**–288, 289t
  health risks of, 247
  pregnancy and, 476

UNICEF (United Nations International Emergency Fund), vitamin A deficiency and, 343
United Nations. *See also* specific agencies
on ecological footprints, 678
United Nations Children's Fund (UNICEF), 675t
United States. *See also* specific departments and agencies
factors contributing to deaths in, 26t
food insecurity in, 660t
health behaviors in, 26
hunger in, 660–663
hunger relief in, 662–663
leading causes of death in, 25t, 585f
niacin intake in, 305
Unsaturated fats/fatty acids, **131**. *See also* Monounsaturated fats/fatty acids; Polyunsaturated fats/fatty acids; *Trans*-fats/fatty acids
in natural fats, C-2t
replacing unsaturated fats with, 150t, 163f
saturated fatty acids compared with, 133f
Unspecified eating disorders, **257**
Upper Level (UL). *See* tolerable Upper Intake Level (UL)
Urea
ammonia as, 179–180
cycle of, C-15f, C-15 to C-16
excretion of, 180
synthesis of, 179–180, 180f
Urine, 369
acidity and drug excretion, 578
acidity of, 377
USDA (U.S. Department of Agriculture), **624**. *See also Dietary Guidelines for Americans* (USDA); Food Pattern (USDA); MyPlate (USDA); Supplemental Nutrition Assistance Program
fish and poultry safety and, 630f
food nutrient evaluations by, 302
Food Patterns by, 40–47, 44t, 48t, 302
food precautions and, 631
MyPlate from, 45
organic farming standards from, 7
school lunch program, 534, 536
Uterus, **470**
UV rays, 351

V

Valerian, 618t
Validity, of research, **16**
Valine, 187, C-3f
Values
food choices and, 5
percent Daily Value and, 54–55
Vanadium, 405
Variables, **15**
Variety (dietary), nutrient adequacy and, **38**
Vascular system, 80–82, 80f
Vasoconstrictor, **372**
Vasopressin, **A-6**
Vegans (vegan diets), **63**
of infants, 515
pregnancy and, 483
Vegetable oils, 134f
Vegetables, 40–41, 678–680
antioxidants and phytochemicals from, 362
calcium values of, 387–388
cancer and, 605f
cancer prevention and, 361
carbohydrates in, 119
colors of, 51
dietary fat in, 153–154
disease prevention and, 363, 363t
fats in, 153–154
folate in, 315, 315f
food composition table for, H-18t to H-29t
as heart-healthy choices, 594
for infants and toddlers, 519–520
most and least pesticide-contaminated, 641t
nonstarchy, G-9t
nutrients in, 42f
phytochemicals in, 431f
proteins and, 186
recommended weekly amounts of, 44t
riboflavin in, 304, 304f
subgroups of, 40–41
vitamin C from, 326
Vegetarian diet, 62–66. *See also* Lacto-ovo-vegetarians; Lactovegetarians; Macrobiotic diet; Vegans
calcium in, 65
cancer and, 63
food choices in, 64t, 66
food composition table for, H-30t to H-33t
health benefits of, 62–63
iron in, 64, 407, 412
nutrient sources in, 65t
omega-3 fatty acids in, 66
planning of, 63–66
pregnancy and, 483
protein in, 64
vitamin B_{12} in, 65
vitamin D in, 65–66
zinc in, 64–65
Vegetarianism
during infancy, 515–516
during pregnancy and lactation, 483
Vegetarians, **62**. *See also* Vegetarian diet
food guide for, 45
lacto-ovo-, 64
lactovegetarians, 65
protein for, 64, 185f
vitamin D and, 350
Veins. *See also* Thoracic duct
hepatic, 81
hepatic portal, 81
Vibrio vulnificus, 648
Vigorous-intensity physical activity, **439**
Villi, in small intestine, **78**, 78f, 79f
Virus, protein antibodies and, 177
Visceral fat, **244**
Viscous substance, dietary fiber as, **100**
Vision. *See also* Cataracts; Cornea; Eyes; Macular degeneration; Night blindness; Opsin; Retina; Rhodopsin; Xerophthalmia; Xerosis
DHA for infants, 509
night blindness and, 343, 343f
of older adults, 564
vitamin A and, 341, 341f
Vitamin(s), **11**, C-4f to C-7f. *See also* B vitamins; Vitamin and mineral supplements; specific vitamins
absorption of, 77f
for adolescents, 537–538
biochemical tests for assessing status, E-17t
in breast milk, 494, 509
characteristics of, 298
for children, 518–519
as conventional or alternative medicine, 617
in digestion, 76f
dose levels and effects of, 299f
fat-soluble, 150
in foods, 6
GI tract bacteria and, 83
for infants, 506, 510
losses from foods, 634
nonvitamins mistaken for, 318–319
as nutrients, 7
for older adults, 562–563
omega-3 supplements and, 150
in pregnancy, 491
to support activity, 451–453
water-soluble, 328t, 634
Vitamin A, 150, **340**, C-4f. *See also* Beta-carotene; Carotenoids; Eyes; Retinoids; Retinol activity equivalents
AAP recommendations, 343
alcohol and, 226
birth defects and, 344
body functions of, 340–341
in cell differentiation, 341–342
children and, 342–343, 344
composition of, H-1
conversion of compounds, 341f
deficiency of, 342–344
food sources of, 345, 346f
forms of, 340f
genetic engineering and, 653
in liver, 346
preformed, 344
during pregnancy, 344
in protein synthesis, 341–342
in reproduction and growth, 342
toxicity of, 344
vision and, 341, 341f, 343–344, 343f
zinc and, 415, 416
Vitamin A activity, **340**
Vitamin and mineral supplements, 331–336. *See also* Dietary supplements; Water-soluble vitamins; specific vitamins and minerals
for antioxidants, 362–363
arguments against, 332–334
arguments for, 331–332
disease prevention and, 363t
FDA regulation of, 335f, 336
food labels on, 336f
people needing, 332
selection of, 334–336
toxic overdoses of, 333
Vitamin B_1 (thiamin). *See* Thiamin (vitamin B_1)
Vitamin B_2 (riboflavin). *See* Riboflavin (vitamin B_2)
Vitamin B_3 (niacin). *See* Niacin (vitamin B_3)
Vitamin B_5 (pantothenic acid). *See* Pantothenic acid
Vitamin B_6, 300, **309–310**, C-5f, C-6f
deficiency of, 309
excretion of, 577
food sources of, 310, 310f
RDA for, 311
toxicity of, 310
Vitamin B_{12}, 300, **315–317**, C-6f
absorption of, 315
alcohol and, 226
amounts needed, 316
anemia and, 317, 321, E-21t, E-21 to E-22
deficiency of, 316–317
digestion of, 315
folate and, 311
food sources of, 317
older adults and, 562
pernicious anemia and, 317
pregnancy/lactation needs for, 481
in vegetarian diets, 65, 483
molecule, 405, 405f
Vitamin C, 322–327, C-7f
active forms of, 323f
as antidioxidant, 323, 644
for blood vessels, 325
cancer prevention and, 361
cataracts and, 564
cigarette smoking and, 324–325
collagen and, 323
common cold prevention and, 324
deficiency of, 325
disease prevention role of, 363t
false positive and false negative from, 325
food sources for, 326–327
free radicals and, 361
in fruits, 322–323
for infants, 514
iron absorption and, 414
iron overload and, 411
RDA for, 324–325, 324f, 327
toxicity of, 325–326
Vitamin D (calciferol), 150, 347, C-7f. *See also* Calcidiol; Vitamin D_2 (ergocalciferol); Vitamin D_3 (cholecalciferol)
AAP recommendations, 349, 509
for adolescents, 537–538
body role of, 347–348
for bones, 347–348
calcium supplements and, 400
deficiency of, 347, 348–350
disease and, 347, 348
lactose intolerance and, 104
latitude and synthesis of, 351f
for older adults, 562
in pregnancy, 482
RDA for, 643
rickets and, 349
skin cancer and, 350–351
sources of, 347, 350–352
in soy milk, 350
sunlight and, 347, 350
from supplements, 352

Vitamin D (calciferol) (*continued*)
synthesis and activation, 348
toxicity of, 350
in vegetarian diets, 65–66
Vitamin D_2 (ergocalciferol), **347**
Vitamin D_3 (cholecalciferol), **347**
Vitamin E, 150, 353–355, 452, C-8f. *See also* Alpha-tocopherol
as antioxidant, 353, 644
body functions of, 353
cancer prevention and, 361
composition of, H-1
deficiency/toxicity of, 353
disease prevention and, 363t
fat-soluble, 354, 354f
food sources of, 354
free radicals and, 361
heart disease and, 361–362
vitamin K and, 353
Vitamin K, 150, 298, 354–356, C-8f. *See also* Menadione; Phylloquinone
for bones, 347
deficiency of, 355
food sources of, 356
for newborns at birth, 355f, 510
nonfood sources, 356
toxicity of, 355–356
vitamin E and, 353
Vitamin-like compounds, 318–319
VLDL (very-low density lipoprotein), **142**
VO_2max, **442**
Volume, calculation aids for, K-2
Vomiting
in pregnancy, 483
sodium deficiency and, 375

W

Waist circumference, **244**–245, 246f, E-14, E-15f
Waist-to-hip ratio, E-14
Walking. *See* Aerobic physical activity
Warfarin, 577
Warm-up (for exercise), **441**
Wars, famines from, 664
Waste
excretion of, 70, 76
of food, 673
from livestock, 671
matter water excretion and, 369
in water, 649
Water. *See also* Dehydration; Extracellular fluid; Fluid entries; Hydrolysis; Hydrophilic; Hydrophobic; Hyponatremia; Interstitial fluid; Intracellular fluid; Osmosis; Osmotic pressure; Thirst
Adequate Intake, 369–370
balance, 370
blood volume/pressure and, 371–373
body fluids and, 368–377
bottled, 370, 650
consumer concerns about, 648–650
electrolytes and, 373–374, 374f
enhanced, 456–457
fluoridation of, 422
in foods, 6, 369, 369t
hard, 370
health effects of, 370
hydration and, 560
for infants, 506–507
kidney functions and, 371f
lactation and, 494
metabolic, 369
mineral content, 367
misuse of, 672
molecule, B-6
as nutrient, 7, 11, 11f, 367
older adult needs for, 560
for physical activity, 458
for rehydration, 455f
soft, 370
systems and regulations, 649–650
treatment of, 649–650
types of, 371
unsustainable and sustainable methods for, 674t
weight management and, 278
Water balance, 368, **368**, 370
Water intoxication, **368**
Water pollution, nonpoint, 670
Water-soluble vitamins, 11n, 297–300, 299, 328t, 634. *See also* B vitamins; Fat-soluble vitamins; Vitamin C; specific vitamins
vs. fat-soluble vitamins, 300t
list of, 299
Water stress, **672**
hotspots of, 672f
Websites, **28**
reliability of, 29
Weight. *See also* Childhood obesity; Eating disorders; Obesity; Overweight; Weight management; Underweight
accepting, 241t
aging and, 557
body composition and, 241–249
body image and, 241
calcium intake and, 385
calculation aids for, K-2
cancer risk reduction and, 606t
of children, 510, 526–531
chronic diseases and, 607, 607f
before conception, 475–476
defining healthy, 241–243
distribution in US adults, 243f
drugs and, 575
energy density of foods and, 8–9
food choices and, 5, 153
gain during pregnancy, 476–478, 477t
glycemic index and, 126
health risks and, 246–249
increases over time, 125
iron deficiency and, 408
kcalorie balance for, 39t
loss after pregnancy, 477–478
maintaining, 285f
measurement of older child or adult, E-7
measurements of, E-6, E-7f
mortality and, 249
objectives for (2020), 25t
osteoporosis and, 399
physical activity and, 439
pregnancy and, 470, 475–479
prenatal, 477f
as risk factor, 26
underweight and, 287–288, 289t
water as percent of, 368
Weight-for-age percentiles
boys (2-20 years), E-11f
boys (birth-36 months), E-8f
girls (2-20 years), E-11f
girls (birth-36 months), E-8f
Weight-for-length percentiles
boys (birth-36 months), E-10f
girls (birth-36 months), E-10f
Weight-for-stature percentiles
boys (2-20 years), E-13f
girls (2-20 years), E-13f
Weight gain. *See also* Obesity
of infants, 506f
pregnancy patterns, 476–478, 477t
strategies, for underweight people, 288, 289t
Weight loss
identifying scams for, 297
products for, 271–273, 273t
psychology of weight cycling and, 271f
Weight-loss strategies, 274–287, 279t
dangerous interventions and, 271–272
determination and, 271
environmental influences on, 282–283
food record (log) and, 284f
Weight management, **263**. *See also* Body composition; Body mass index; Eating disorders; Obesity; Overweight; Underweight; Weight
attitude and, 284–285
behavior modification and, 283–285
BMI and, 242
community programs for, 286, 287t
drug intervention as, 272–273
eating and exercise in, 281
fiber and, 117
food choices for, 153
food record in, 284f
physical activity and, 286
protein and, 183–184
reasonable vs. unrealistic goals, 275f
set-point theory and, 265
successful, 285–286
support groups for, 285
surgical treatment for, 273, 274f
water and, 278
Weight measurements, IU conversion to, 345
Weight Watchers, 285
Well water, 371. *See also* Water
Wernicke-Korsakoff syndrome, **226**
Wet beriberi, 302
What We Eat in America, 24n
Wheat, 50f
bran and, 50f
flour types from, 50f
refined, 49
Wheat germ, phospholipids in, 136
Wheat plant, 50f
Whey protein, **186**
White blood cells, 583
WHO (World Health Organization), 632, 675t
Diet, Nutrition, and Prevention of Chronic Diseases report, 607
nutrition recommendations, I-1
on sugar consumption, 113
vitamin A and, 21, 343
Whole-grain products, **49**, 118f, 119
thiamin in, 303f
WIC program, 486, 494–495, 662
Wilson's disease, **421**
Wine, **220**, 221f
Women. *See also* Amenorrhea; Eating disorders; Estrogen; Gender; Menstruation; Pregnancy
alcohol use and, 221f, 222
calcium for, 538
iron needs of, 408
life expectancy of, 552
World Anti-Doping Agency (WADA), 465
World Food Program, 675t
World Health Organization. *See* WHO
World hunger, 659–676
hot spots of, 665f
World Hunger Year (WHY), 675t
World population, 666f
World Wide Web. *See* Websites

X

Xanthophylls, **345**
Xerophthalmia, **343**
Xerosis, **344**

Y

Yeast, riboflavin in, 304
Yogurt, 83, 83f, 104
Yohimbe, 618t
Yo-yo dieting, 271

Z

Zero risk, of food contamination, 642–643
Zinc, **414**–417
absorption of, 415
body role of, 414–415
deficiency of, 415, 416, 416f
enteropancreatic circulation of, 415–416, 415f
food sources of, 416, 417f
free radicals and, 420
for older adults, 563
in pregnancy, 482
RDA of, 417
toxicity of, 416
transport of, 415–416
in vegetarian diets, 64–65
vitamin A and, 415, 416
Zone Diet, 295t
Zygote, **471**, 472f
Zymogen, 171n

w the key points of this chapter below, then take the practice quiz on the back of this card.

Food Choices

People select foods based on such factors as taste and convenience, but selections based on nutrition knowledge may better support good health.

Individual foods are neither "good" nor "bad"; daily food choices made over a lifetime may improve or impair a person's health.

The Nutrients

Foods provide nutrients—substances that provide energy, structural materials, and regulating agents to support the growth, maintenance, and repair of the body's tissues. Essential nutrients *must* be obtained from foods.

The six classes of nutrients include carbohydrates, lipids (fats), proteins, vitamins, minerals, and water. Carbohydrates, lipids, proteins, and vitamins are organic, meaning they contain carbon; minerals and water are inorganic, meaning they do not contain carbon.

Energy is measured in kcalories—a measure of heat energy. One kcalorie is the amount of heat necessary to raise the temperature of 1 kg water 1°C.

The energy-yielding nutrients are carbohydrate (4 kcal/g), fat (9 kcal/g), and protein (4 kcal/g). Alcohol provides 7 kcal/g, but it is not considered a nutrient.

Vitamins, minerals, and water do not provide energy; instead, they facilitate a variety of activities in the body.

The Science of Nutrition

The science of nutrition is the study of nutrients and other substances in foods and the body's handling of them.

Researchers follow the scientific method (review Figure 1-3, p. 12). They randomly assign control and experimental groups, use large sample sizes, provide placebos, and are blind to treatments. Their findings are reviewed and replicated by other scientists before being accepted as valid.

Correlations indicate an association between variables, not a cause.

Dietary Reference akes

Dietary Reference Intakes (DRI) are a set of nutrient intake values used to plan and evaluate diets for healthy people.

- Estimated Average Requirement (EAR) defines the amount of a nutrient that supports a specific function in the body for half of the population. Recommended Dietary Allowance (RDA) is based on the EAR and establishes a goal for dietary intake that will meet the needs of almost all healthy people. Adequate Intake (AI) serves a similar purpose when an RDA cannot be determined.
- Estimated Energy Requirement (EER) defines the average amount of energy intake needed to maintain energy balance, and Acceptable Macronutrient Distribution Ranges (AMDR) define the proportions contributed by carbohydrate, fat, and protein to a healthy diet. Carbohydrates should consist of 45 to 65 percent of kcalories, fat 20 to 35 percent, and protein 10 to 35 percent.
- Tolerable Upper Intake Level (UL) establishes the highest amount that appears safe for regular consumption.

1.5 Nutrition Assessment

- Malnutrition develops when people get too little, too much, or an imbalance of energy or nutrients.
- Four nutrition assessment methods include historical information on diet and health, anthropometric measurements, physical examinations, and laboratory tests. Together, these methods reveal the stages of a nutrient deficiency (review Figure 1-7, p. 23).
- A primary deficiency is caused by an inadequate intake of a nutrient; a secondary deficiency is caused by a condition that reduces absorption, accelerates use, increases excretion, or destroys the nutrient.

1.6 Diet and Health

- Risk factors such as obesity and cigarette smoking increase the likelihood of disease development (review Table 1-6).
- Some risk factors, such as genetics, are important but cannot be changed. Recommendations focus on changeable, personal life choices such as diet and activity habits.
- Diet has no influence on some diseases but is linked closely to others (review Table 1-5).

TABLE 1-5 Leading Causes of Death in the United States

	Percentage of Total Deaths
1. **Heart disease**	24.1
2. **Cancers**	23.3
3. Chronic lung diseases	5.6
4. **Strokes**	5.2
5. Accidents	4.8
6. Alzheimer's disease	3.4
7. **Diabetes mellitus**	2.8
8. Pneumonia and influenza	2.0
9. Kidney disease	2.0
10. Suicide	1.5

NOTE: The diseases highlighted in bold have relationships with diet.

SOURCE: Deaths: Preliminary data for 2010, *National Vital Statistics Reports*, January 11, 2012, Centers for Disease Control and Prevention, www.cdc.gov/nchs.

© Cengage Learning

TABLE 1-6 Factors Contributing to Deaths in the United States

Factors	Percentage of Deaths
Tobacco	18
Poor diet/inactivity	15
Alcohol	4
Microbial agents	3
Toxic agents	2
Motor vehicles	2
Firearms	1
Sexual behavior	1
Illicit drugs	1

SOURCE: A. H. Mokdad and coauthors, Actual causes of death in the United States, 2000, *Journal of the American Medical Association* 291 (2004): 1238–1245, with corrections from *Journal of the American Medical Association* 293 (2005): 298.

© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

1.1 Food Choices (pp. 4–6)

LEARN IT Describe how various factors influence personal food choices.

1. When people eat the foods typical of their families or geographic region, their choices are influenced by:
   a. habit.
   b. nutrition.
   c. personal preference.
   d. heritage or tradition.

1.2 The Nutrients (pp. 6–12)

LEARN IT Name the six major classes of nutrients and identify which are organic and which yield energy.

2. What is the difference between organic and inorganic?
3. How much energy do carbohydrates, fats, and proteins yield per gram? How is energy measured?
4. Describe how alcohol resembles nutrients. Why is alcohol not considered a nutrient?
5. The nutrient found most abundantly in both the human body and most foods is:
   a. fat. b. water. c. minerals. d. proteins.
6. The inorganic nutrients are:
   a. proteins and fats.
   b. vitamins and minerals.
   c. minerals and water.
   d. vitamins and proteins.
7. The energy-yielding nutrients are:
   a. fats, minerals, and water.
   b. minerals, proteins, and vitamins.
   c. carbohydrates, fats, and vitamins.
   d. carbohydrates, fats, and proteins.

1.3 The Science of Nutrition (pp. 12–17)

LEARN IT Explain the scientific method and how scientists use various types of research studies and methods to acquire nutrition information.

8. What is the science of nutrition?
9. Explain how variables might be correlational but not causal.
10. Studies of populations that reveal correlations between dietary habits and disease incidence are:
    a. clinical trials.
    b. laboratory studies.
    c. case-control studies.
    d. epidemiological studies.
11. An experiment in which neither the researchers nor the subjects know who is receiving the treatment is known as:
    a. double blind.
    b. double control.
    c. blind variable.
    d. placebo control.

1.4 Dietary Reference Intakes (pp. 17–21)

LEARN IT Define the four categories of the DRI and explain purposes.

12. What judgment factors are involved in setting the energy nutrient recommendations?
13. An RDA represents the:
    a. highest amount of a nutrient that appears safe for healthy people.
    b. lowest amount of a nutrient that will maintain a spec criterion of adequacy.
    c. average amount of a nutrient considered adequate to the known nutrient needs of practically all healthy peop
    d. average amount of a nutrient that will maintain a spe biochemical or physiological function in half the people.

1.5 Nutrition Assessment (pp. 21–25)

LEARN IT Explain how the four assessment methods are use detect energy and nutrient deficiencies and excesses.

14. What methods are used in nutrition surveys? What kin information can these surveys provide?
15. Historical information, physical examinations, laboratory t and anthropometric measurements are:
    a. techniques used in diet planning.
    b. steps used in the scientific method.
    c. approaches used in disease prevention.
    d. methods used in a nutrition assessment.
16. A deficiency caused by an inadequate dietary in is called a(n):
    a. overt deficiency.
    b. covert deficiency.
    c. primary deficiency.
    d. secondary deficienc

1.6 Diet and Health (pp. 25–27)

LEARN IT Identify several risk factors and explain their relations to chronic diseases.

17. Behaviors such as smoking, dietary habits, physical act and alcohol consumption that influence the developme disease are known as:
    a. risk factors.
    b. chronic causes.
    c. preventive agents.
    d. disease descriptors.

ple Choice Answers
5. b 6. c 7. d 10. d 11. a 13. c 15. d 16. c 17. a

STUDY TOOL 2 Planning a Healthy Diet

Review the key points of this chapter below, then take the practice quiz on the back of this card.

2.1 Principles and Guidelines

- A well-planned diet delivers *adequate* nutrients, a *balanced* array of nutrients, and an appropriate amount of *energy* (*kcalories*). It is based on *nutrient-dense* foods, *moderate* in substances that can be detrimental to health, and *varied* in its selections.
- The *Dietary Guidelines for Americans* offer practical advice on how to eat for good health (review Table 2-1, p. 39).

2.2 Diet-Planning Guides

- The USDA Food Patterns help consumers select the types and amounts of foods to provide adequacy, balance, and variety in the diet. It makes it easier to plan a diet that includes a balance of grains, vegetables, fruits, protein foods, and milk products. In making any food choice, remember to view the food in the context of the total diet.
- The combination of many different foods provides the array of nutrients that are essential to a healthy diet (review Figure 2-2, pp. 42–43).
- MyPlate reminds consumers to make healthy choices from the five food groups (review Figure 2-4).

> FIGURE 2-4 MyPlate

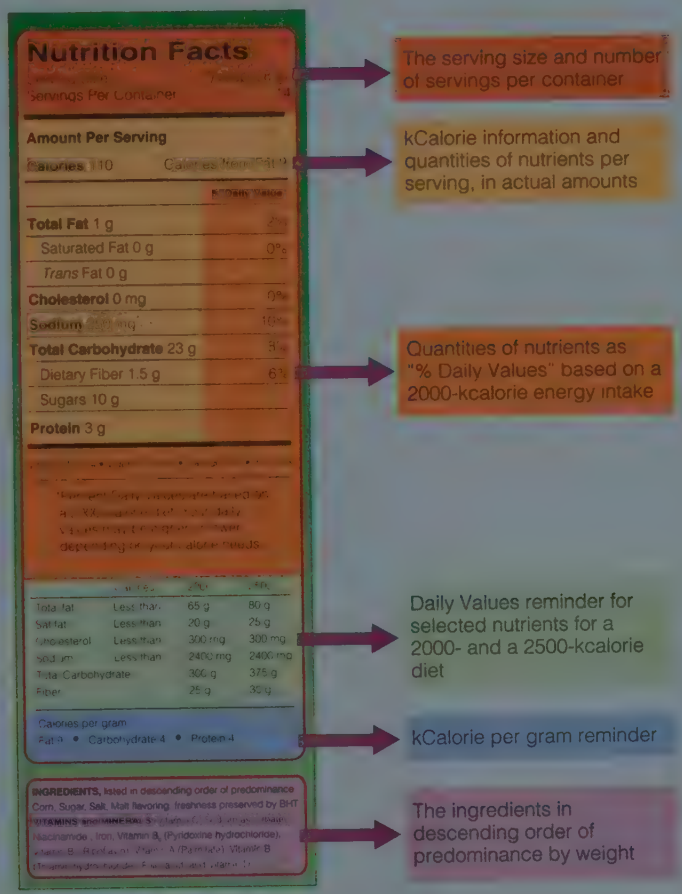


SOURCE: USDA, www.choosemyplate.gov

2.3 Food Labels

- Food labels list ingredients in descending order of predominance by weight, nutrition facts based on standard serving sizes, and Daily Values based on a 2000-kcalorie diet (review Figure 2-8).
- Nutrient claims reflect the quantity of a nutrient (high or low), health claims reflect relationships between a nutrient and a disease (potassium reduces risk of hypertension), and structure-function claims reflect relationships between a nutrient and its function in the body (calcium builds bones).

> FIGURE 2-8 Example of a Food Label



© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

2.1 Principles and Guidelines (pp. 35–40)

LEARN IT Explain how each of the diet-planning principles can be used to plan a healthy diet.

1. What recommendations appear in the *Dietary Guidelines for Americans*?
2. The diet-planning principle that provides all the essential nutrients in sufficient amounts to support health is:
   a. balance.
   b. variety.
   c. adequacy.
   d. moderation.
3. A person who chooses a chicken leg that provides 0.5 milligram of iron and 95 kcalories instead of 2 tablespoons of peanut butter that also provides 0.5 milligram of iron but 188 kcalories is using the principle of nutrient:
   a. control.
   b. density.
   c. adequacy.
   d. moderation.
4. Which of the following is consistent with the *Dietary Guidelines for Americans*?
   a. Choose a diet restricted in fat and cholesterol.
   b. Balance the food you eat with physical activity.
   c. Choose a diet with plenty of milk products and meats.
   d. Eat an abundance of foods to ensure nutrient adequacy.

2.2 Diet-Planning Guides (pp. 40–53)

LEARN IT Use the USDA Food Patterns to develop a meal plan within a specified energy allowance.

5. Review the *Dietary Guidelines*. What types of grocery selections would you make to achieve those recommendations?
6. According to the USDA Food Patterns, cheese is grouped as a:
   a. meat.
   b. protein food.
   c. milk product.
   d. miscellaneous fat.
7. Foods within a given food group of the USDA Food Patterns are similar in their contents of:
   a. energy.
   b. proteins and fibers.
   c. vitamins and minerals.
   d. carbohydrates and fats.
8. In the exchange system, each portion of food on any give provides about the same amount of:
   a. energy.
   b. satiety.
   c. vitamins.
   d. minerals.
9. Enriched grain products are fortified with:
   a. fiber, folate, iron, niacin, and zinc.
   b. thiamin, iron, calcium, zinc, and sodium.
   c. iron, thiamin, riboflavin, niacin, and folate.
   d. folate, magnesium, vitamin B_6, zinc, and fiber.

2.3 Food Labels (pp. 53–60)

LEARN IT Compare and contrast the information on food labe make selections that meet specific dietary and health goals.

10. What information can you expect to find on a food label? can this information help you choose between two si products?
11. What are the Daily Values? How can they help you meet h recommendations?
12. Describe the differences between nutrient claims, he claims, and structure-function claims.
13. Food labels list ingredients in:
    a. alphabetical order.
    b. ascending order of predominance by weight.
    c. descending order of predominance by weight.
    d. manufacturer's order of preference.
14. "Milk builds strong bones" is an example of a:
    a. health claim.
    b. nutrition fact.
    c. nutrient content claim.
    d. structure-function claim.
15. Daily Values on food labels are based on a:
    a. 1500-kcalorie diet.
    b. 2000-kcalorie diet.
    c. 2500-kcalorie diet.
    d. 3000-kcalorie diet.

ple Choice Answers

3.b 4.b 6.c 7.c 8.a 9.c 13.c 14.d 15.b

ew the key points of this chapter below, then take the practice quiz on the back of this card.

Digestion

Digestion breaks down foods into nutrients. Absorption brings the nutrients into the cells of the small intestine for transport to the body's cells.

Food enters the mouth and travels down the esophagus and through the upper and lower esophageal sphincters to the stomach, then through the pyloric sphincter to the small intestine, on through the ileocecal valve to the large intestine, past the appendix to the rectum, ending at the anus (review Figure 3-1).

The wavelike contractions of peristalsis and the periodic squeezing of segmentation keep things moving at a reasonable pace. Along the way, secretions from the salivary glands, stomach, pancreas, liver (via the gallbladder), and small intestine deliver fluids and digestive enzymes (review Table 3-1).

Absorption

The many folds and villi of the small intestine increase its surface area, making nutrient absorption efficient.

Nutrients pass through the cells of the intestinal villi and enter either the blood (if they are water soluble or small fat fragments) or the lymph (if they are fat soluble).

The Circulatory Systems

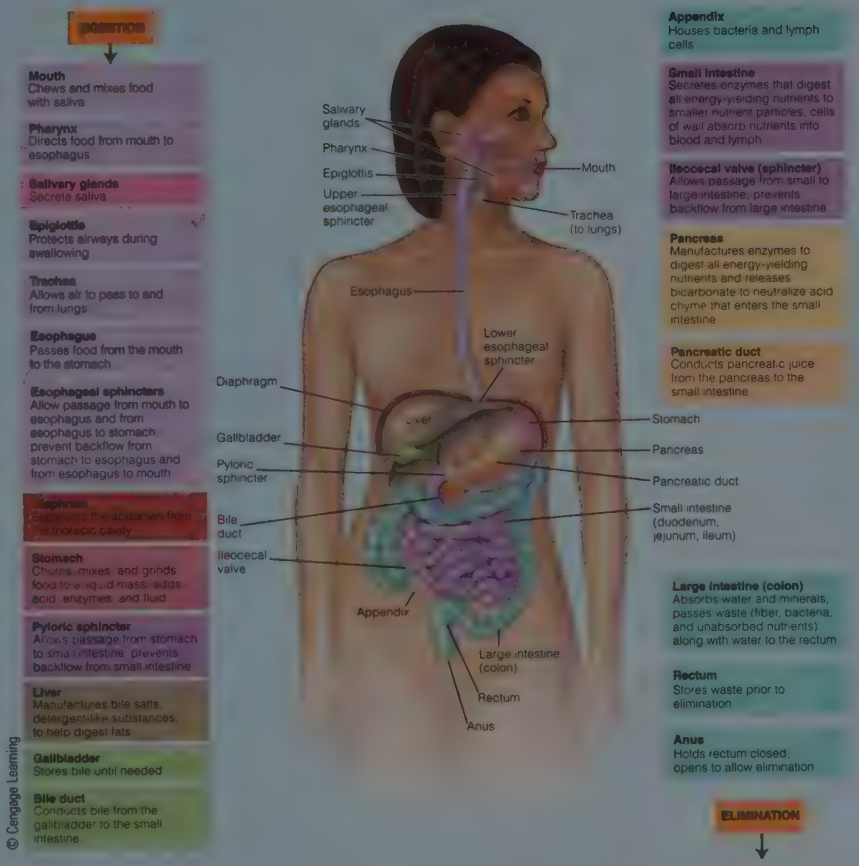
Nutrients leaving the digestive system via the blood are routed directly to the liver before being transported to the body's cells.

Nutrients leaving via the lymphatic system bypass the liver at first, but eventually enter the vascular system via the thoracic duct, which opens into the subclavian vein.

The Health and Regulation the GI Tract

- A diverse and abundant bacteria population supports GI health.
- The regulation of GI processes depends on the coordinated efforts of the hormonal system and the nervous system.
- Together, digestion and absorption break down foods into nutrients for the body's use.
- To function optimally, a healthy GI tract needs a balanced diet, adequate rest, and regular physical activity.

FIGURE 3-1 The Gastrointestinal Tract



© Cengage Learning

TABLE 3-1 Summary of Digestive Secretions and Their Major Actions

Organ or Gland	Target Organ	Secretion	Action
Salivary glands	Mouth	Saliva	Fluid eases swallowing; salivary enzyme breaks down some **carbohydrate.***
Gastric glands	Stomach	Gastric juice	Fluid mixes with bolus; hydrochloric acid uncoils **proteins;** enzymes break down proteins; mucus protects stomach cells.*
Pancreas	Small intestine	Pancreatic juice	Bicarbonate neutralizes acidic gastric juices; pancreatic enzymes break down **carbohydrates, fats,** and **proteins.**
Liver	Gallbladder	Bile	Bile is stored until needed.
Gallbladder	Small intestine	Bile	Bile emulsifies **fat** so that enzymes can have access to break it down.
Intestinal glands	Small intestine	Intestinal juice	Intestinal enzymes break down **carbohydrate, fat,** and **protein** fragments; mucus protects the intestinal wall.

*Saliva and gastric juice also contain lipases, but most fat breakdown occurs in the small intestine.

© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

3.1 Digestion (pp. 69–77)

LEARN IT Explain how foods move through the digestive system, describing the actions of the organs, muscles, and digestive secretions along the way.

1. Describe the challenges associated with digesting food and the solutions offered by the human body.
2. Name five organs that secrete digestive juices. How do the juices and enzymes facilitate digestion?
3. The semiliquid, partially digested food that travels through the intestinal tract is called:
   a. bile.
   b. lymph.
   c. chyme.
   d. secretin.
4. The muscular contractions that move food through the GI tract are called:
   a. hydrolysis.
   b. sphincters.
   c. peristalsis.
   d. bowel movements.
5. The main function of bile is to:
   a. emulsify fats.
   b. catalyze hydrolysis.
   c. slow protein digestion.
   d. neutralize stomach acidity.
6. The pancreas neutralizes stomach acid in the small intestine by secreting:
   a. bile.
   b. mucus.
   c. enzymes.
   d. bicarbonate.
7. Which nutrient passes through the GI tract mostly undigested and unabsorbed?
   a. fat
   b. fiber
   c. protein
   d. carbohydrate

3.2 Absorption (pp. 77–79)

LEARN IT Describe the anatomical details of the intestinal cells that facilitate nutrient absorption.

8. The fingerlike projections on the small intestine that dramatically increase its surface area are called:
   a. villi.
   b. crypts.
   c. goblet cells.
   d. chylomicrons.
9. Absorption occurs primarily in the:
   a. mouth.
   b. stomach.
   c. small intestine.
   d. large intestine.

3.3 The Circulatory Systems (pp. 80–82)

LEARN IT Explain how nutrients are routed in the circulatory sys from the GI tract into the body and identify which nutrients ente blood directly and which must first enter the lymph.

10. All blood leaving the GI tract travels first to the:
    a. heart.
    b. liver.
    c. kidneys.
    d. pancreas.
11. Which nutrients leave the GI tract by way of the lymp system?
    a. water and minerals
    b. proteins and minerals
    c. all vitamins and minerals
    d. fats and fat-soluble vitamins

3.4 The Health and Regulation of the GI Tract (pp. 82–86)

LEARN IT Describe how bacteria, hormones, and nerves influ the health and activities of the GI tract.

12. How does the composition of the diet influence the functi of the GI tract?
13. What steps can you take to help your GI tract functi its best?
14. Digestion and absorption are coordinated by the:
    a. pancreas and kidneys.
    b. liver and gallbladder.
    c. hormonal system and the nervous system.
    d. vascular system and the lymphatic system.
15. Gastrin, secretin, and cholecystokinin are examples of:
    a. crypts.
    b. enzymes.
    c. hormones.
    d. goblet cells.

ple Choice Answers

4. c 5. a 6. d 7. b 8. a 9. c 10. b 11. d 14. c 15. c

4 The Carbohydrates: Sugars, Starches, and Fibers

iew the key points of this chapter below, then take the practice quiz on the back of this card.

The Chemist's View of Carbohydrates

- Carbohydrates include monosaccharides, disaccharides, and polysaccharides (review Table 4-1).
- Carbohydrates are made of carbon (C), oxygen (O), and hydrogen (H); each atom forms a specified number of chemical bonds: carbon forms four, oxygen forms two, and hydrogen forms one (review Figure 4-1, p. 96).
- Monosaccharides (glucose, fructose, and galactose) all have the same chemical formula ($C_6H_{12}O_6$), but their structures differ. Disaccharides (maltose, sucrose, and lactose) each contain a glucose paired with one of the three monosaccharides.
- A condensation reaction can bond two monosaccharides together to form a disaccharide and water (review Figure 4-4, p. 98). A hydrolysis reaction can use water to split a disaccharide into its two monosaccharides (review Figure 4-5, p. 98).
- Chains of monosaccharides are called polysaccharides and include glycogen, starches, and dietary fibers. Both glycogen and starch are storage forms of glucose—glycogen in the body, and starch in plants—and both yield energy.
- Dietary fibers contain glucose (and other monosaccharides), but their bonds cannot be broken by human digestive enzymes; they yield little, if any, energy.
- Soluble fibers dissolve in water to form gels and are easily digested by bacteria in the colon. Insoluble fibers do not dissolve in water or form gels and are less readily fermented.

TABLE 4-1 The Carbohydrate Family

Monosaccharides
Glucose
Fructose
Galactose
Disaccharides
Maltose (glucose + glucose)
Sucrose (glucose + fructose)
Lactose (glucose + galactose)
Polysaccharides
Glycogen[a]
Starches (amylose and amylopectin)
Fibers (soluble and insoluble)

[a]Glycogen is a polysaccharide, but not a common dietary source of carbohydrate.

© Cengage Learning

.2 Digestion and Absorption f Carbohydrates

- The body digests starches into the disaccharide maltose. Maltose and the other disaccharides (lactose and sucrose) from foods are broken down into monosaccharides, which are absorbed (review Figure 4-9, p. 103)
- Fibers help to regulate the passage of food through the GI tract and slow the absorption of glucose.
- Lactose intolerance occurs when there is insufficient lactase to digest the disaccharide lactose found in milk and milk products. Symptoms include GI distress.

4.3 Glucose in the Body

- Dietary carbohydrates provide glucose that can be used by the cells for energy, stored by the liver and muscles as glycogen, or converted into fat if intakes exceed needs.
- All of the body's cells depend on glucose; those of the central nervous system are especially dependent on it.
- Without glucose, the body is forced to break down its protein tissues to make glucose and to alter energy metabolism to make ketone bodies from fats.
- Blood glucose regulation depends on two pancreatic hormones: insulin to move glucose from the blood into the cells when levels are high and glucagon to free glucose from glycogen stores and release it into the blood when levels are low (review Figure 4-10, p. 107).

4.4 Health Effects and Recommended Intakes of Sugars

- Excessive intakes of sugars may increase the risk of dental caries, displace needed nutrients and fiber, and contribute to obesity when energy intake exceeds needs.
- Concentrated sweets are relatively low in nutrients, high in kcalories, and may need to be limited; sugars that occur naturally in fruits, vegetables, and milk are acceptable.
- To control weight gain, blood glucose, and dental caries, consumers may use alternative sweeteners (artificial sweeteners, herbal products, and sugar alcohols) to limit kcalories and minimize sugar intake (review Table 4-4, p. 114).

4.5 Health Effects and Recommended Intakes of Starch and Fibers

- Adequate intake of fiber fosters weight management, lowers blood cholesterol, and may help prevent colon cancer, diabetes, hemorrhoids, appendicitis, and diverticulosis.
- Excessive intake of fiber displaces energy- and nutrient-dense foods, causes intestinal discomfort and distention, and may interfere with mineral absorption.
- Because starches and fibers help control body weight and prevent heart disease, cancer, diabetes, and GI disorders, the *Dietary Guidelines* suggest plenty of whole grains, vegetables, legumes, and fruits—enough to provide 45 to 65 percent of the daily energy intake from carbohydrate.

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

4.1 The Chemist's View of Carbohydrates (pp. 96–101)

LEARN IT Identify the monosaccharides, disaccharides, and polysaccharides common in nutrition by their chemical structures and major food sources.

1. What happens in a condensation reaction? In a hydrolysis reaction?
2. How are starch and glycogen similar, and how do they differ? How do the fibers differ from the other polysaccharides?
3. Disaccharides include:
   a. starch, glycogen, and fiber.
   b. amylose, pectin, and dextrose.
   c. sucrose, maltose, and lactose.
   d. glucose, galactose, and fructose.
4. The making of a disaccharide from two monosaccharides is an example of:
   a. digestion.
   b. hydrolysis.
   c. condensation.
   d. gluconeogenesis.
5. The significant difference between starch and cellulose is that:
   a. starch is a polysaccharide, but cellulose is not.
   b. animals can store glucose as starch, but not as cellulose.
   c. hormones can make glucose from cellulose, but not from starch.
   d. digestive enzymes can break the bonds in starch, but not in cellulose.

4.2 Digestion and Absorption of Carbohydrates (pp. 101–104)

LEARN IT Summarize carbohydrate digestion and absorption.

6. What role does fiber play in digestion and absorption?
7. Describe lactose intolerance and its symptoms.
8. The ultimate goal of carbohydrate digestion and absorption is to yield:
   a. fibers.
   b. glucose.
   c. enzymes.
   d. amylase.
9. The enzyme that breaks a disaccharide into glucose and galactose is:
   a. amylase.
   b. maltase.
   c. sucrase.
   d. lactase.

4.3 Glucose in the Body (pp. 104–109)

LEARN IT Explain how the body maintains its blood glucose conc tration and what happens when blood glucose rises too high or f too low.

10. What are the possible fates of glucose in the body? Wha the protein-sparing action of carbohydrate?
11. The storage form of glucose in the body is:
    a. insulin.
    b. maltose.
    c. glucagon.
    d. glycogen.
12. With insufficient glucose in metabolism, fat fragme combine to form:
    a. dextrins.
    b. mucilages.
    c. phytic acids.
    d. ketone bodies.
13. What does the pancreas secrete when blood glucose ris When blood glucose falls?
    a. insulin; glucagon
    b. glucagon; insulin
    c. insulin; glycogen
    d. glycogen; epinephrine

4.4 Health Effects and Recommended Intakes of Sugars (pp. 109–115)

LEARN IT Describe how added sugars can contribute to hea problems.

14. What are the dietary recommendations regarding concentra sugar intakes?
15. Describe the risks and benefits of using alternative sweeten

4.5 Health Effects and Recommended Intakes of Starch and Fibers (pp. 115–121)

LEARN IT Identify the health benefits of, and recommendations starches and fibers.

16. What foods provide starches and fibers?
17. Carbohydrates are found in virtually all foods except:
    a. milks.
    b. meats.
    c. breads.
    d. fruits.
18. What percentage of the daily energy intake should come fr carbohydrates?
    a. 15 to 20
    b. 25 to 30
    c. 45 to 50
    d. 45 to 65

Multiple Choice Answers
1. c 5. d 8. b 9. d 11. d 12. d 13. a 17. b 18. d

iew the key points of this chapter below, then take the practice quiz on the back of this card.

The Chemist's View of Fatty ids and Triglycerides

- The predominant lipids both in foods and in the body are triglycerides: glycerol with three fatty acids attached by way of condensation reactions (review Figure 5-3, p. 133). Other lipids include phospholipids and sterols (review Table 5-2).
- Fatty acids vary in the length of their carbon chains, their degrees of unsaturation, and the location of their double bond(s). Saturated fatty acids are fully loaded with hydrogens; unsaturated (monounsaturated or polyunsaturated) fatty acids are missing hydrogens and have double bonds.
- Hydrogenation protects against oxidation (thereby promoting shelf-life) and alters the texture of foods by making liquid vegetable oils more solid. This process makes polyunsaturated fats more saturated and creates *trans*-fatty acids.

2 The Chemist's View of Phospholipids d Sterols

- The chemical structure of phospholipids, including lecithin, allows them to be soluble in both water and fat. In the body, phospholipids are part of cell membranes; in foods, phospholipids act as emulsifiers to mix fats with water.
- Sterols have a multiple-ring structure that differs from the structure of other lipids. In the body, sterols include cholesterol, bile, vitamin D, and some hormones. Animal-derived foods contain cholesterol.

3 Digestion, Absorption, and ansport of Lipids

- Bile emulsifies fats, making them accessible to the lipases that dismantle triglycerides to monoglycerides and fatty acids for absorption (review Figure 5-12, p. 140).
- Four types of lipoproteins carry triglycerides, phospholipids, and cholesterol throughout the body: *chylomicrons* are the largest

BLE 5-2 The Lipid Family

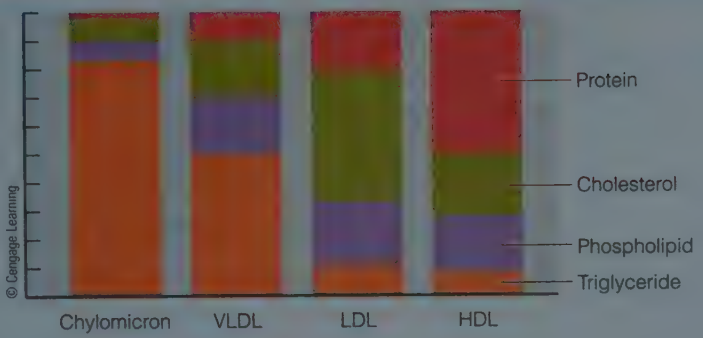
glycerides

- 1 Glycerol (per triglyceride) and
- 3 Fatty acids (per triglyceride); depending on the number of double bonds, fatty acids may be:
  - *Saturated* (no double bonds)
  - *Monounsaturated* (one double bond)
  - *Polyunsaturated* (more than one double bond); depending on the location of the double bonds, polyunsaturated fatty acids may be:
    - *Omega-3* (double bond closest to methyl end is 3 carbons away)
    - *Omega-6* (double bond closest to methyl end is 6 carbons away)

hospholipids such as lecithin

terols such as cholesterol

© Cengage Learning



© Cengage Learning

and contain mostly dietary triglycerides, *VLDL* are smaller and are about half triglycerides, *LDL* are smaller still and contain mostly cholesterol, and *HDL* are the densest and are rich in protein (review Figure 5-16, p. 142).

5.4 Lipids in the Body

- In the body, triglycerides provide energy, insulate against temperature extremes, protect against shock, and help the body use carbohydrate and protein efficiently.
- Linoleic acid (18 carbons, omega-6) and linolenic acid (18 carbons, omega-3) are essential fatty acids, serving as structural parts of cell membranes and as precursors to the longer fatty acids that can make eicosanoids.
- The body stores fat if given excesses, and uses body fat for energy when needed. (The liver can also convert excess carbohydrate and protein into fat.) Fat breakdown requires carbohydrate for maximum efficiency; without carbohydrate, fatty acids break down to ketone bodies.

5.5 Health Effects and Recommended Intakes of Saturated Fats, *Trans* Fats, and Cholesterol

- Some fat in the diet is necessary, but too much fat provides energy (kcalories) without nutrients, which leads to obesity and nutrient inadequacies.
- Too much saturated fat, *trans* fat, and cholesterol increases the risk of heart disease and possibly cancer.
- Recommendations advise that a diet be moderate in total fat and low in saturated fat, *trans* fat, and cholesterol.

5.6 Health Effects and Recommended Intakes of Monounsaturated and Polyunsaturated Fats

- Some fat in the diet has health benefits, especially the monounsaturated and polyunsaturated fats that protect against heart disease and possibly cancer.
- The *Dietary Guidelines* recommend replacing saturated fats with monounsaturated and polyunsaturated fats, particularly omega-3 fatty acids from foods such as fatty fish, not from supplements.
- Many selection and preparation strategies can help bring these goals within reach, and food labels help to identify foods consistent with these guidelines.

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

5.1 The Chemist's View of Fatty Acids and Triglycerides (pp. 129–136)

LEARN IT Recognize the chemistry of fatty acids and triglycerides and differences between saturated and unsaturated fats.

1. Name three classes of lipids found in the body and in foods. What are some of their functions in the body? What features do fats bring to foods?
2. What features distinguish fatty acids from each other?
3. What does the term *omega* mean with respect to fatty acids? Describe the roles of the omega fatty acids in disease prevention.
4. Describe the structure of a triglyceride.
5. What does hydrogenation do to fats? What are *trans*-fatty acids, and how do they influence heart disease?
6. Saturated fatty acids:
   a. are always 18 carbons long.
   b. have at least one double bond.
   c. are fully loaded with hydrogens.
   d. are always liquid at room temperature.
7. A triglyceride consists of:
   a. three glycerols attached to a lipid.
   b. three fatty acids attached to a glucose.
   c. three fatty acids attached to a glycerol.
   d. three phospholipids attached to a cholesterol.
8. The difference between *cis*- and *trans*-fatty acids is:
   a. the number of double bonds.
   b. the length of their carbon chains.
   c. the location of the first double bond.
   d. the configuration around the double bond.

5.2 The Chemist's View of Phospholipids and Sterols (pp. 136–137)

LEARN IT Describe the chemistry, major food sources, and roles of phospholipids and sterols.

9. Which of the following is *not* true? Lecithin is:
   a. an emulsifier.
   b. a phospholipid.
   c. an essential nutrient.
   d. a constituent of cell membranes.

5.3 Digestion, Absorption, and Transport of Lipids (pp. 137–144)

LEARN IT Summarize fat digestion, absorption, and transport.

10. What do lipoproteins do? What are the differences among the chylomicrons, VLDL, LDL, and HDL?
11. Chylomicrons are produced in the:
    a. liver.
    b. pancreas.
    c. gallbladder.
    d. small intestine.
12. Transport vehicles for lipids are called:
    a. micelles.
    b. lipoproteins.
    c. blood vessels.
    d. monoglycerides.

5.4 Lipids in the Body (pp. 144–147)

LEARN IT Outline the major roles of fats in the body, including a d cussion of essential fatty acids and the omega fatty acids.

13. Which of the following is *not* true? Fats:
    a. contain glucose.
    b. provide energy.
    c. protect against organ shock.
    d. carry vitamins A, D, E, and K.
14. The essential fatty acids include:
    a. stearic acid and oleic acid.
    b. oleic acid and linoleic acid.
    c. palmitic acid and linolenic acid.
    d. linoleic acid and linolenic acid.

5.5 Health Effects and Recommended Intakes of Saturated Fats, *Trans* Fats, and Cholesterol (pp. 147–149)

LEARN IT Explain the relationships among saturated fats, *trans* and cholesterol and chronic diseases, noting recommendations.

15. How does excessive fat intake influence health? What fact influence LDL, HDL, and total blood cholesterol?
16. What are the dietary recommendations regarding fat and c lesterol intake? List ways to reduce intake.
17. The lipoprotein most associated with a high risk of heart d ease is:
    a. CHD.
    b. HDL.
    c. LDL.
    d. L

5.6 Health Effects and Recommended Intakes of Monounsaturated and Polyunsaturated Fats (pp. 149–157)

LEARN IT Explain the relationships between monounsaturated a polyunsaturated fats and health, noting recommendations.

18. List foods that are high in saturated fats and those that high in unsaturated fats.
19. What is the Daily Value for fat (for a 2000-kcalorie diet)?
20. A person consuming 2200 kcalories a day who wants to m health recommendations should limit daily fat intake to:
    a. 20 to 35 grams.
    b. 50 to 85 grams.
    c. 75 to 100 grams.
    d. 90 to 130 grams.

tiple Choice Answers

7. c 8. d 9. c 11. d 12. b 13. a 14. d 17. c 20. b

ew the key points of this chapter below, then take the practice quiz on the back of this card.

The Chemist's View of Proteins

Proteins are more chemically complex than carbohydrates or lipids; they are made of 20 different amino acids, 9 of which the body cannot make. These 9 are the essential amino acids—histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

- Each amino acid contains an amino group, an acid group, a hydrogen atom, and a distinctive side group, all attached to a central carbon atom.
- Cells link amino acids together in a series of condensation reactions to create proteins (review Figure 6-3, p. 169). The distinctive sequence of amino acids in each protein determines its unique shape and function.

2 Digestion and Absorption of Proteins

- The stomach's hydrochloric acid first denatures dietary proteins, then enzymes cleave them into smaller polypeptides and some amino acids.
- Pancreatic and intestinal enzymes split polypeptides further, to oligo-, tri-, and dipeptides, and then split most of these to single amino acids that can be absorbed into the intestinal cells (review Figure 6-6, p. 172).

3 Proteins in the Body

- Cells synthesize proteins according to the genetic information provided by the DNA in the nucleus of each cell (review Figure 6-7, p. 174). This information dictates the sequence in which amino acids are linked together to form a given protein. Sequencing errors occasionally occur, sometimes with significant consequences.
- A sampling of protein functions are summarized in Table 6-3.
- Proteins are constantly being synthesized and broken down as needed.
- The body's assimilation of amino acids into proteins and its release of amino acids via protein degradation and excretion can be tracked by measuring nitrogen balance, which should be positive during growth and steady in adulthood. An energy deficit or an inadequate protein intake may force the body to break down lean body tissue and use amino acids as fuel, creating a negative nitrogen balance.
- Protein eaten in excess of need is degraded and stored as body fat.

6.4 Protein in Foods

- High-quality proteins deliver all of the essential amino acids in adequate amounts, which ensures protein synthesis. Mixtures of foods containing complementary proteins can each supply the amino acids missing in the other.
- In addition to its amino acid content, the quality of a protein is measured by its digestibility and its ability to support growth.

6.5 Health Effects and Recommended Intakes of Protein

- Protein deficiency impairs the body's ability to grow and function optimally.
- Excess protein offers no advantage and may incur health problems as well.
- The optimal diet is adequate in energy from carbohydrate and fat and delivers 0.8 grams of protein per kilogram of healthy body weight each day.
- Healthy people do not need protein or amino acid supplements.

TABLE 6-3 Protein Functions in the Body

Structural materials	Proteins form integral parts of most body tissues and provide strength and shape to skin, tendons, membranes, muscles, organs, and bones.
Enzymes	Proteins facilitate chemical reactions.
Hormones	Proteins regulate body processes. (Some, but not all, hormones are proteins.)
Fluid balance	Proteins help to maintain the volume and composition of body fluids.
Acid-base balance	Proteins help to maintain the acid-base balance of body fluids by acting as buffers.
Transportation	Proteins transport substances, such as lipids, vitamins, minerals, and oxygen, around the body.
Antibodies	Proteins inactivate foreign invaders, thus protecting the body against diseases.
Energy and glucose	Proteins provide some fuel, and glucose if needed, for the body's energy needs.
Other	The protein fibrin creates blood clots; the protein collagen forms scars; the protein opsin participates in vision.

© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

6.1 The Chemist's View of Proteins

(pp. 168–171)

LEARN IT Recognize the chemical structures of amino acids and proteins.

1. Explain how the sequence of amino acids affects protein shape.
2. What are essential amino acids?
3. Which part of its chemical structure differentiates one amino acid from another?
   a. its side group
   b. its acid group
   c. its amino group
   d. its double bonds
4. Isoleucine, leucine, and lysine are:
   a. proteases.
   b. polypeptides.
   c. essential amino acids.
   d. complementary proteins.

6.2 Digestion and Absorption of Proteins (pp. 171–172)

LEARN IT Summarize protein digestion and absorption.

5. In the stomach, hydrochloric acid:
   a. denatures proteins and activates pepsin.
   b. hydrolyzes proteins and denatures pepsin.
   c. emulsifies proteins and releases peptidase.
   d. condenses proteins and facilitates digestion.

6.3 Proteins in the Body (pp. 173–180)

LEARN IT Describe how the body makes proteins and uses them to perform various roles.

6. What are enzymes? What roles do they play in chemical reactions? Describe the differences between enzymes and hormones.
7. How does the body use amino acids? What is deamination? Define *nitrogen balance*. What conditions are associated with zero, positive, and negative balance?
8. Proteins that maintain the acid-base balance of the blood and body fluids by accepting and releasing hydrogen ions are:
   a. buffers.
   b. enzymes.
   c. hormones.
   d. antigens.
9. If an essential amino acid that is needed to make a protei unavailable, the cells must:
   a. deaminate another amino acid.
   b. substitute a similar amino acid.
   c. break down proteins to obtain it.
   d. synthesize the amino acid from glucose and nitrogen.
10. Protein turnover describes the amount of protein:
    a. found in foods and the body.
    b. absorbed from the diet.
    c. synthesized and degraded.
    d. used to make glucose.

6.4 Protein in Foods (pp. 181–182)

LEARN IT Explain the differences between high-quality and l quality proteins, including notable food sources of each.

11. How can vegetarians meet their protein needs without ea meat?
12. Which of the following foods provides the highest qua protein?
    a. egg
    b. corn
    c. gelatin
    d. whole grains

6.5 Health Effects and Recommended Intakes of Protein (pp. 182–188)

LEARN IT Identify the health benefits of, and recommendations protein.

13. How might protein excess, or the type of protein eaten, in ence health?
14. What factors are considered in establishing recommen protein intakes?
15. What are the benefits and risks of taking protein and am acid supplements?
16. The protein RDA for a healthy adult who weighs 180 pounds
    a. 50 milligrams/day.
    b. 65 grams/day.
    c. 180 grams/day.
    d. 2000 milligrams/day.
17. Which of these foods has the least protein per ½ cup?
    a. rice
    b. broccoli
    c. pinto beans
    d. orange juice

Multiple Choice Answers
4. c 5. a 8. a 9. c 10. c 12. a 16. b 17. d

ew the key points of this chapter below, then take the practice quiz on the back of this card.

Chemical Reactions in the Body

- During digestion, the energy-yielding nutrients—carbohydrates, lipids, and proteins—are broken down to glucose (and other monosaccharides), glycerol, fatty acids, and amino acids. These compounds may enter metabolic pathways to yield energy (review Figure 7-5).
- Enzymes with their coenzymes help cells use nutrients to build compounds (anabolism) or break them down to release energy (catabolism)—review Figure 7-2, p. 200.
- ATP—a high-energy compound—captures the energy released during catabolism (review Figure 7-4, p. 201).

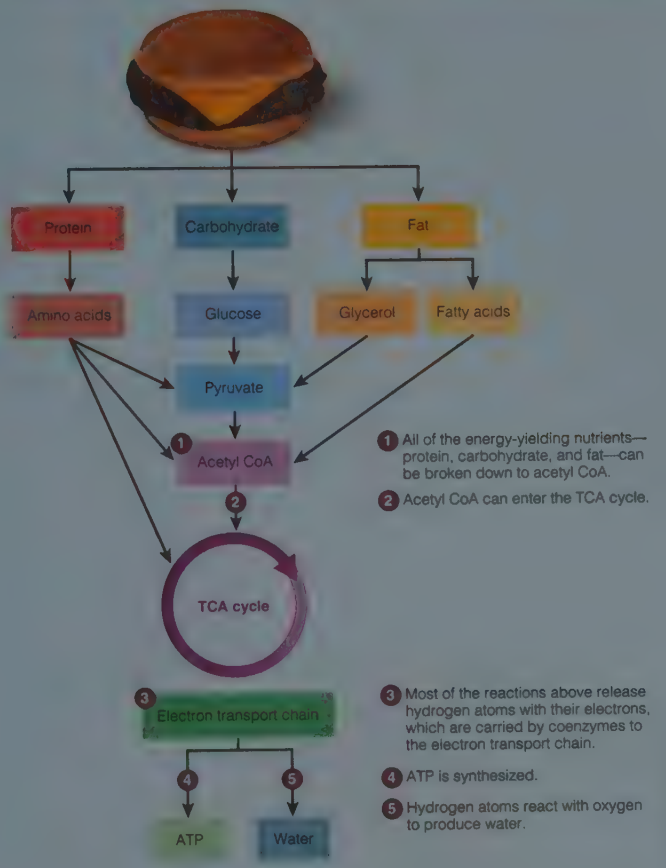
Breaking Down Nutrients for Energy

- Glucose breakdown begins with glycolysis, a pathway that produces pyruvate (review Figure 7-6, p. 204).
- Pyruvate may be converted to lactate anaerobically (without oxygen) or to acetyl CoA aerobically (with oxygen).
- Pyruvate can make glucose; acetyl CoA cannot make glucose (review Figure 7-9, p. 206).
- The glycerol part of a triglyceride can make either pyruvate (and then glucose) or acetyl CoA. The fatty acids of a triglyceride *cannot* make glucose; they can provide abundant acetyl CoA (review Figure 7-11, p. 208).
- Some amino acids can be used to make glucose; others can be used either to provide energy or to make fat. Before an amino acid enters these metabolic pathways, its nitrogen-containing amino group must be removed through deamination.
- The digestion of carbohydrate yields glucose (and other monosaccharides); some glucose is stored as glycogen, and some is broken down to pyruvate and acetyl CoA.
- The digestion of fat yields glycerol and fatty acids; some are reassembled and stored as body fat, and others are broken down to acetyl CoA.
- The digestion of protein yields amino acids; most amino acids are used to build body protein or other nitrogen-containing compounds, some are broken down to acetyl CoA, and others enter the TCA cycle directly.
- Acetyl CoA may enter the TCA cycle to release energy (review Figure 7-16, p. 212) or combine with other molecules of acetyl CoA to make body fat.

Feasting and Fasting

- If energy intake exceeds energy needs, the result will be weight gain—regardless of whether the excess is from protein, carbohydrate, or fat (review Table 7-2). The body is most efficient at storing excess energy from dietary fat.
- When fasting, the body adapts to conserve energy and minimize losses by increasing fat breakdown to fuel most cells, using glycerol and amino acids to make glucose for the brain and red blood cells, producing ketones for the brain, suppressing appetite, and slowing metabolism.

> FIGURE 7-5 Simplified Overview of Energy-Yielding Pathways



© Cengage Learning

TABLE 7-2 Review of Energy-Yielding Nutrient Endpoints

Nutrient	Yields energy	Yields glucose	Yields amino acids for body proteins	Yields fat stores?
Carbohydrates (glucose)	Yes	Yes	Yes—when nitrogen is available, can yield *nonessential* amino acids	Yes
Lipids (fatty acids)	Yes	No	No	Yes
Lipids (glycerol)	Yes	Yes—when carbohydrate is unavailable	Yes—when nitrogen is available, can yield *nonessential* amino acids	Yes
Proteins (amino acids)	Yes	Yes—when carbohydrate is unavailable	Yes	Yes

© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

7.1 Chemical Reactions in the Body

(pp. 198–201)

LEARN IT Identify the nutrients involved in energy metabolism and the high-energy compound that captures the energy released during their breakdown.

1. Define *metabolism*, *anabolism*, and *catabolism*; give an example of each.
2. What are coenzymes, and what service do they provide in metabolism?
3. Hydrolysis is an example of a(n):
   a. coupled reaction.
   b. anabolic reaction.
   c. catabolic reaction.
   d. synthesis reaction.
4. During metabolism, released energy is captured and transferred by:
   a. enzymes.
   b. pyruvate.
   c. acetyl CoA.
   d. adenosine triphosphate.

7.2 Breaking Down Nutrients for Energy

(pp. 201–213)

LEARN IT Summarize the main steps in the energy metabolism of glucose, glycerol, fatty acids, and amino acids.

5. Name the four basic units, derived from foods, that are used by the body in energy metabolism. How many carbons are in the "backbones" of each?
6. Define *aerobic* and *anaerobic*. How does insufficient oxygen influence metabolism?
7. How does the body dispose of excess nitrogen?
8. The body derives most of its energy from:
   a. proteins and fats.
   b. vitamins and minerals.
   c. glucose and fatty acids.
   d. glycerol and amino acids.
9. Glycolysis:
   a. requires oxygen.
   b. generates abundant energy.
   c. converts glucose to pyruvate.
   d. produces ammonia as a by-product.
10. The pathway from pyruvate to acetyl CoA:
    a. produces lactate.
    b. is known as gluconeogenesis.
    c. is metabolically irreversible.
    d. requires more energy than it produces.
11. For complete oxidation, acetyl CoA enters:
    a. glycolysis.
    b. the TCA cycle.
    c. the Cori cycle.
    d. the electron transport chain.
12. Deamination of an amino acid produces:
    a. vitamin B_6 and energy.
    b. pyruvate and acetyl CoA.
    c. ammonia and a keto acid.
    d. carbon dioxide and water.
13. Before entering the TCA cycle, each of the energy-yiel nutrients is broken down to:
    a. ammonia.
    b. pyruvate.
    c. electrons.
    d. acetyl CoA.

7.3 Feasting and Fasting (pp. 213–219)

LEARN IT Explain how an excess of any of the three energy-yiel nutrients contributes to body fat and how an inadequate intake of of them shifts metabolism.

14. What adaptations does the body make during a fast? What ketone bodies? Define *ketosis*.
15. Distinguish between a loss of *fat* and a loss of *weight*, describe how each might happen.
16. The body stores energy for future use in:
    a. proteins.
    b. acetyl CoA.
    c. triglycerides.
    d. ketone bodies.
17. During a fast, when glycogen stores have been depleted, body begins to synthesize glucose from:
    a. acetyl CoA.
    b. amino acids.
    c. fatty acids.
    d. ketone bodies.
18. During a fast, the body produces ketone bodies by:
    a. hydrolyzing glycogen.
    b. condensing acetyl CoA.
    c. transaminating keto acids.
    d. converting ammonia to urea.

Multiple Choice Answers

4. d 8. c 9. c 10. c 11. b 12. c 13. d 16. c 17. b 18. b

iew the key points of this chapter below, then take the practice quiz on the back of this card.

1 Energy Balance

- When energy consumed equals energy expended, a person is in energy balance and body weight is stable.
- If more energy is taken in than is expended, a person gains weight. If more energy is expended than is taken in, a person loses weight.

2 Energy In: The kCalories Foods Provide

- Scientists use a bomb calorimeter to estimate the potential energy of foods by measuring the heat energy released when foods are burned.
- Hunger and appetite initiate eating, whereas satiation and satiety stop and delay eating, respectively (review Figure 8-2, p. 234). Each responds to messages from the nervous and hormonal systems. Superimposed on these signals are complex factors involving emotions, habits, and other aspects of human behavior.

3 Energy Out: The kCalories e Body Expends

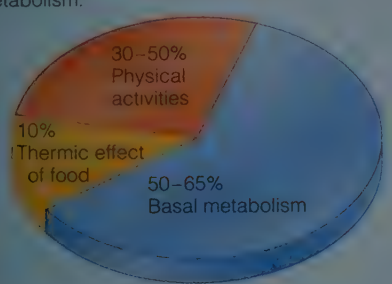
- A person in energy balance takes in energy from food and expends much of it on basal metabolic activities, some of it on physical activities, and a little on the thermic effect of food (review Figure 8-4).
- Energy requirements vary from person to person based on such factors as gender, age, weight, and height as well as the intensity and duration of physical activity.

4 Body Weight and Body Composition

- Body weight standards are based on a person's weight in relation to height, called the body mass index (BMI), and reflect disease risks. BMI does not identify body fat or its distribution, and it may misclassify muscular people as overweight.

> FIGURE 8-4 Components of Energy Expenditure

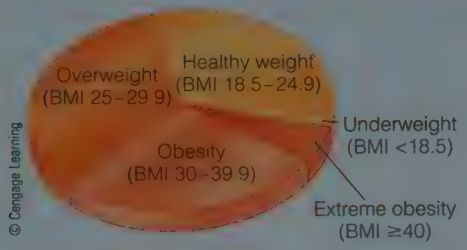
The amount of energy expended in voluntary physical activities has the greatest variability, depending on a person's activity patterns. For a sedentary person, physical activities may account for less than half as much energy as basal metabolism, whereas an extremely active person may expend as much on activity as for basal metabolism.



© Cengage Learning

The amount of energy expended in a day differs for each individual, but in general, basal metabolism is the largest component of energy expenditure and thermic effect of food is the smallest.

> FIGURE 8-7 Distribution of Body Weights in US Adults



© Cengage Learning

- $\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$ or $\frac{\text{weight (lb)}}{\text{height (in)}^2} \times 703.$

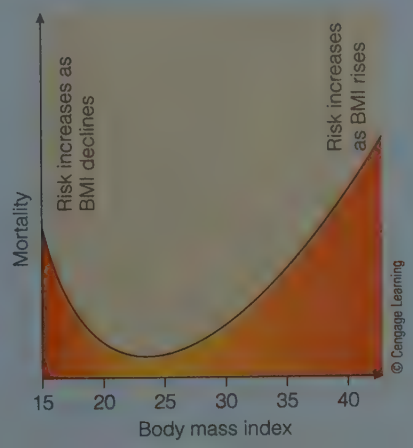
  Underweight: BMI <18.5
  Healthy: BMI 18.5 to 24.9
  Overweight: BMI 25 to 29.9
  Obese: BMI ≥30
- Two-thirds of US adults have a BMI greater than 25 (review Figure 8-7).
- The ideal amount of body fat varies from person to person, but excess body fat poses health risks.
- Central obesity—excess abdominal fat distributed around the trunk of the body—presents greater health risks than excess fat distributed on the lower body (review Figure 8-8 and Figure 8-9, p. 245).
- Women with a waist circumference greater than 35 inches and men with a waist circumference greater than 40 inches have a high risk of central obesity–related health problems.

8.5 Health Risks Associated with Body Weight and Body Fat

- The healthiest weight for an individual depends on personal factors such as body fat distribution, family health history, and current health status. At the extremes, both overweight and underweight impose health risks (review Figure 8-11).

> FIGURE 8-11 BMI and Mortality

This J-shaped curve describes the relationship between body mass index (BMI) and mortality and shows that both underweight and overweight present risks of a premature death.



© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

8.1 Energy Balance (p. 232)

LEARN IT Describe energy balance and the consequences of not being in balance.

1. A person who consistently consumes 1700 kcalories a day and expends 2200 kcalories a day for a month would be expected to:
   a. lose ½ to 1 pound.
   b. gain ½ to 1 pound.
   c. lose 4 to 5 pounds.
   d. gain 4 to 5 pounds.

8.2 Energy In: The kCalories Foods Provide (pp. 232–236)

LEARN IT Discuss some of the physical, emotional, and environmental influences on food intake.

2. A bomb calorimeter measures:
   a. physiological fuel.
   b. energy available from foods.
   c. kcalories a person derives from foods.
   d. heat a person releases in basal metabolism.
3. The psychological desire to eat that accompanies the sight, smell, or thought of food is known as:
   a. hunger.
   b. satiety.
   c. appetite.
   d. palatability.
4. A person watching television after dinner reaches for a snack during a commercial in response to:
   a. external cues.
   b. hunger signals.
   c. stress arousal.
   d. satiety factors.

8.3 Energy Out: The kCalories the Body Expends (pp. 236–240)

LEARN IT List the components of energy expenditure and factors that might influence each.

5. The largest component of energy expenditure is:
   a. basal metabolism.
   b. physical activity.
   c. indirect calorimetry.
   d. thermic effect of food.
6. A major factor influencing BMR is:
   a. hunger.
   b. food intake.
   c. body composition.
   d. physical activity.
7. The thermic effect of an 800-kcalorie meal is about:
   a. 8 kcalories.
   b. 80 kcalories.
   c. 160 kcalories.
   d. 200 kcalories.

8.4 Body Weight and Body Composition (pp. 241–246)

LEARN IT Distinguish between body weight and body compositio including methods to assess each.

8. What problems are involved in defining "ideal" body weight
9. What is central obesity, and what is its relationship to diseas
10. For health's sake, a person with a BMI of 21 might want to:
    a. lose weight.
    b. maintain weight.
    c. gain weight.
11. Which of the following reflects height and weight?
    a. body mass index
    b. central obesity
    c. waist circumference
    d. body composition

8.5 Health Risks Associated with Body Weight and Body Fat (pp. 246–249)

LEARN IT Identify relationships between body weight and chron diseases.

12. Which of the following increases disease risks?
    a. BMI 19–21
    b. BMI 22–25
    c. lower-body fat
    d. central obesity

Multiple Choice Answers
1. b 2. b 3. c 4. a 5. a 6. c 7. b 10. b 11. a 12. d

ew the key points of this chapter below, then take the practice quiz on the back of this card.

Overweight and Obesity

- Fat cells develop by increasing in number and size (review Figure 9-2, p. 263).
- Preventing weight gain depends on limiting the number of fat cells; weight loss depends on decreasing the size of fat cells.
- Lipoprotein lipase (LPL) removes triglycerides from the blood for storage in both adipose tissue and muscle cells. LPL activity is influenced by weight and gender.
- With weight gains or losses, the body adjusts in an attempt to return to its previous weight (set point theory).

Causes of Overweight and Obesity

- Obesity has multiple causes and different combinations of causes in different people.
- Some environmental causes, such as overeating and physical inactivity, may be within a person's control, and some, such as genetics, may be beyond it.
- Proteins such as ghrelin and leptin regulate food intake and energy homeostasis.

Problems of Overweight and Obesity

- Whether a person should lose weight depends on factors such as the extent of overweight, age, health risks, and genetics.
- Not all obesity will cause disease or shorten life expectancy. Just as there are unhealthy, normal-weight people, there are healthy, overweight people.
- Some people risk more in the process of losing weight than in remaining overweight.
- Fad diets and weight-loss supplements can be as physically and psychologically damaging as excess body weight.

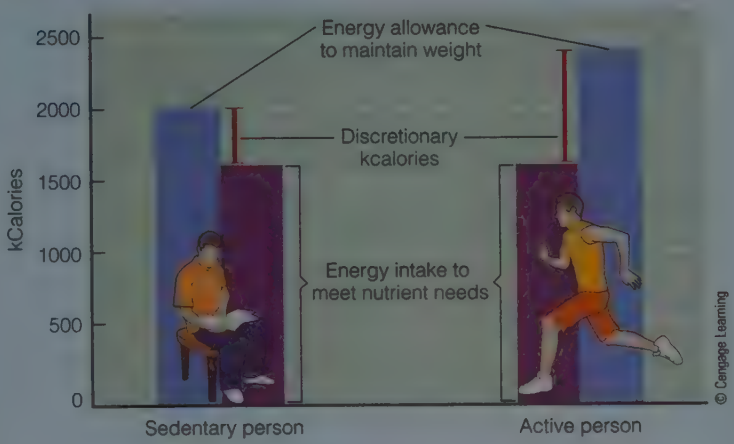
Aggressive Treatments for Obesity

- Obese people with high risks of medical problems may need aggressive treatment, including drugs or surgery.
- Others may benefit most from improving eating and physical activity habits.

Weight-Loss Strategies

- A person who adopts a lifelong "eating plan for good health" rather than a "diet for weight loss" will be more likely to keep the lost weight off.
- Table 9-3 (p. 277) provides several tips for successful weight management.

> FIGURE 9-8 *Animated* **Influence of Physical Activity on Discretionary kCalories**



- Physical activity can increase energy expenditure (review Figure 9-8), improve body composition, help control appetite, reduce stress and stress eating, and enhance physical and psychological well-being.
- A surefire remedy for obesity has yet to be found; a combination of approaches is most effective.
- Weight loss depends on adjusting diet and physical activity so that more energy is expended than is taken in.
- For weight loss, energy intake should be reduced by 500 to 1000 kcalories per day, depending on starting body weight and usual food intake.
- Safe rate for weight loss is ½ to 2 pounds per week or 10 percent body weight per 6 months.
- Behavior modification and cognitive restructuring retrain habits to support a healthy eating and activity plan.
- Treatment requires time, individualization, and sometimes the assistance of a registered dietitian or support group.
- Preventing weight gains and maintaining weight losses require vigilant attention to diet and physical activity; taking care of oneself is a lifelong responsibility.

9.6 Underweight

- Both the incidence of underweight and the health problems associated with it are less prevalent than overweight and its associated problems.
- To gain weight, a person must train physically and increase energy intake by selecting energy-dense foods, eating regular meals, taking larger portions, and consuming extra snacks and beverages.
- Table 9-5 (p. 287) includes a summary of weight-gain strategies.

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

9.1 Overweight and Obesity (pp. 261–263)

LEARN IT Describe how body fat develops and why it can be difficult to maintain weight gains and losses.

1. With weight loss, fat cells:
   a. decrease in size only.
   b. decrease in number only.
   c. decrease in both number and size.
   d. decrease in number, but increase in size.
2. Describe the role of lipoprotein lipase (LPL).

9.2 Causes of Overweight and Obesity (pp. 264–267)

LEARN IT Review some of the causes of obesity.

3. Obesity is caused by:
   a. overeating.
   b. inactivity.
   c. defective genes.
   d. multiple factors.
4. The protein produced by the fat cells under the direction of the *ob* gene is called:
   a. leptin.
   b. serotonin.
   c. sibutramine.
   d. phentermine.

9.3 Problems of Overweight and Obesity (pp. 268–270)

LEARN IT Discuss the physical, social, and psychological consequences of overweight and obesity.

5. Which of the following is *not* used to evaluate the risks to health from obesity?
   a. body mass index
   b. blood leptin levels
   c. waist circumference
   d. disease risk profiles

9.4 Aggressive Treatments for Obesity (pp. 270–272)

LEARN IT Explain the risks and benefits, if any, of several aggressive ways to treat obesity.

6. Gastric bypass surgery:
   a. is the best noninvasive treatment for obesity.
   b. limits food intake by reducing the capacity of the stomach.
   c. allows a person to eat unlimited amounts of food without weight gain.
   d. suppresses hunger by increasing production of gastrointestinal hormones.

9.5 Weight-Loss Strategies (pp. 272–285)

LEARN IT Outline reasonable strategies for achieving and maintaining a healthy body weight.

7. What are the benefits of increased physical activity in a weight-loss program?
8. Describe the behavioral strategies for changing an individual's dietary habits. What role does personal attitude play?
9. A realistic goal for weight loss is to reduce body weight:
   a. down to the weight a person was at age 25.
   b. down to the ideal weight in the weight-for-height tables.
   c. by 10 percent over 6 months.
   d. by 15 percent over 3 months.
10. A nutritionally sound weight-loss diet might restrict daily energy intake to create a:
    a. 1000-kcalorie-per-month deficit.
    b. 500-kcalorie-per-month deficit.
    c. 500-kcalorie-per-day deficit.
    d. 3500-kcalorie-per-day deficit.
11. Successful weight loss depends on:
    a. avoiding fats and limiting water.
    b. taking supplements and drinking water.
    c. increasing proteins and restricting carbohydrates.
    d. reducing energy intake and increasing physical activity.
12. Physical activity does *not* help a person to:
    a. lose weight.
    b. retain muscle.
    c. maintain weight loss.
    d. lose fat in trouble spots.
13. Which strategy would *not* help an overweight person to lose weight?
    a. Exercise.
    b. Eat slowly.
    c. Limit high-fat foods.
    d. Eat energy-dense foods regularly.

9.6 Underweight (pp. 285–287)

LEARN IT Summarize strategies for gaining weight.

14. Which strategy would *not* help an underweight person to g weight?
    a. Exercise.
    b. Drink plenty of water.
    c. Eat snacks between meals.
    d. Eat large portions of foods.

tiple Choice Answers

3. d 4. a 5. b 6. b 9. c 10. c 11. d 12. d 13. d 14. b

10 The Water-Soluble Vitamins: B Vitamins and Vitamin C

view the key points of this chapter below, then take the practice quiz on the back of this card.

10.1 The Vitamins—An Overview

- The vitamins are organic, essential nutrients needed in tiny amounts in the diet both to prevent deficiency diseases and to support optimal health. The body handles the vitamins differently depending on whether they are water- or fat-soluble (review Table 10-2).
- The water-soluble vitamins are the B vitamins and vitamin C; the fat-soluble vitamins are vitamins A, D, E, and K. The B vitamins include thiamin, niacin, riboflavin, vitamin B_6, folate, vitamin B_{12}, pantothenic acid, and biotin.

10.2 The B Vitamins

- The B vitamins serve as coenzymes—small organic molecules closely associated with enzymes that facilitate the work of cells (review Figure 10-2).
- Thiamin is part of the coenzyme TPP, which assists in energy metabolism. Deficiency can result in beriberi. Thiamin occurs in small quantities in many nutritious foods; pork is an exceptionally good source.
- Riboflavin is part of the coenzymes FMN and FAD that accept and donate hydrogens during energy metabolism. Milk and milk products are good sources.
- Niacin is part of the coenzymes NAD and NADP that participate in many metabolic reactions. The deficiency disease, pellagra, causes diarrhea, dermatitis, dementia, and eventually death ("the 4 Ds"). Toxicity produces "niacin flush"—a tingling, painful sensation. The amino acid tryptophan can be converted to niacin in the body: 60 mg tryptophan = 1 NE (niacin equivalent). Good sources of niacin are protein-rich foods.
- Biotin plays a critical role in energy metabolism, replenishing oxaloacetate in the TCA cycle. Biotin is widespread in foods; deficiencies and toxicities are rare.
- Pantothenic acid is part of coenzyme A that forms acetyl CoA in many metabolic pathways. Pantothenic acid is widespread in foods; deficiencies and toxicities are rare.
- Vitamin B_6 occurs as pyridoxal, pyridoxine, and pyridoxamine; all can become part of the coenzyme PLP, which is active in amino acid metabolism. Deficiency causes convulsions; toxicity causes nerve damage.
- Folate is part of the coenzyme THF that activates vitamin B_{12}, synthesizes DNA, and regenerates the amino acid methionine from homocysteine. Folate helps prevent neural tube defects. Excessive folate can mask the anemia of a vitamin B_{12} deficiency, but it will not prevent the associated nerve damage. Folate is abundant in legumes, fruits, and vegetables.

TABLE 10-2 Water-Soluble and Fat-Soluble Vitamins Compared

	Water-Soluble Vitamins: B Vitamins and Vitamin C	Fat-Soluble Vitamins: Vitamins A, D, E, and K
Absorption	Directly into the blood	First into the lymph, then the blood
Transport	Travel freely	Many require transport proteins
Storage	Circulate freely in water-filled parts of the body	Stored in the cells associated with fat
Excretion	Kidneys detect and remove excess in urine	Less readily excreted; tend to remain in fat-storage sites
Toxicity	Possible to reach toxic levels when consumed from supplements	Likely to reach toxic levels when consumed from supplements
Requirements	Needed in frequent doses (perhaps 1 to 3 days)	Needed in periodic doses (perhaps weeks or even months)

NOTE: Exceptions occur, but these differences between the water-soluble and fat-soluble vitamins are valid generalizations.

© Cengage Learning

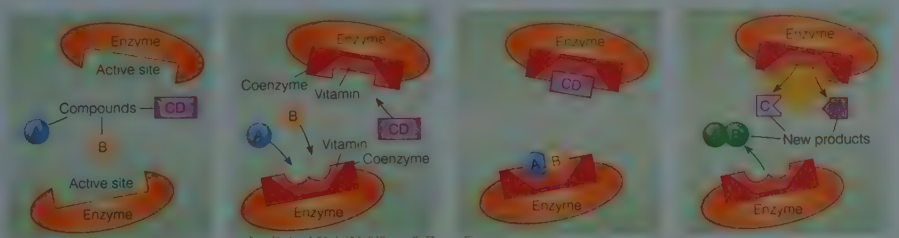
- Vitamin B_{12} activates folate, synthesizes DNA, regenerates methionine from homocysteine, and maintains the sheath that protects nerve fibers. Deficiencies typically occur when either hydrochloric acid or intrinsic factor is lacking. Vitamin B_{12} is found primarily in foods derived from animals.
- Many substances that people claim as B vitamins are not. Fortunately, a variety of foods from each food group provides an adequate supply of all B vitamins.

10.3 Vitamin C

- Vitamin C acts as an antioxidant—a substance that decreases the adverse effects of free radicals in the body.
- Vitamin C works as a cofactor in the synthesis of collagen, neurotransmitters (serotonin and norepinephrine), hormones (thyroxin), and other compounds.
- Vitamin C deficiency causes scurvy.

> FIGURE 10-2 Coenzyme Action

Some vitamins form part of the coenzymes that enable enzymes either to synthesize compounds (as illustrated by the lower enzymes in this figure) or to dismantle compounds (as illustrated by the upper enzymes).



Without coenzymes, compounds A, B, and CD don't respond to their enzymes.

With the coenzymes in place, compounds are attracted to their sites on the enzymes . . .

. . . and the reactions proceed instantaneously. The coenzymes often donate or accept electrons, atoms, or groups of atoms.

The reactions are completed with either the formation of a new product, AB, or the breaking apart of a compound into two new products, C and D, and the release of energy.

© Cengage Learning

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

10.1 The Vitamins—An Overview

(pp. 297–300)

LEARN IT Describe how vitamins differ from the energy nutrients and how fat-soluble vitamins differ from water-soluble vitamins.

1. Vitamins:
   a. are inorganic compounds.
   b. yield energy when broken down.
   c. are soluble in either water or fat.
   d. perform best when linked in long chains.

2. The rate at and the extent to which a vitamin is absorbed and used in the body is known as its:
   a. bioavailability.
   b. intrinsic factor.
   c. physiological effect.
   d. pharmacological effect.

10.2 The B Vitamins (pp. 300–322)

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the B vitamins (thiamin, riboflavin, niacin, biotin, pantothenic acid, vitamin B_6, folate, and vitamin B_{12}).

3. Which B vitamins are involved in energy metabolism? Protein metabolism? Cell division?

4. What is the relationship of tryptophan to niacin?

5. Describe the relationship between folate and vitamin B_{12}.

6. What risks are associated with high doses of niacin? Vitamin B_6? Vitamin C?

7. Many of the B vitamins serve as:
   a. coenzymes.
   b. antagonists.
   c. antioxidants.
   d. serotonin precursors.

8. With respect to thiamin, which of the following is the most nutrient dense?
   a. 1 slice whole-wheat bread (69 kcalories and 0.1 milligram thiamin)
   b. 1 cup yogurt (144 kcalories and 0.1 milligram thiamin)
   c. 1 cup snow peas (69 kcalories and 0.22 milligram thiamin)
   d. 1 chicken breast (141 kcalories and 0.06 milligram thiamin)

9. The body can make niacin from:
   a. tyrosine.
   b. serotonin.
   c. carnitine.
   d. tryptophan.

10. The vitamin that protects against neural tube defects is:
    a. niacin.
    b. folate.
    c. riboflavin.
    d. vitamin B_{12}.

11. A lack of intrinsic factor may lead to:
    a. beriberi.
    b. pellagra.
    c. pernicious anemia.
    d. atrophic gastritis.

12. Which of the following is a B vitamin?
    a. inositol
    b. carnitine
    c. vitamin B_{15}
    d. pantothenic acid

10.3 Vitamin C (pp. 322–327)

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin C.

13. Vitamin C serves as a(n):
    a. coenzyme.
    b. antagonist.
    c. antioxidant.
    d. intrinsic factor.

14. The requirement for vitamin C is highest for:
    a. smokers.
    b. athletes.
    c. alcoholics.
    d. the elderly.

See p. 328 for a summary of the water-soluble vitamins.

Multiple Choice Answers
1. c 2. a 7. a 8. c 9. d 10. b 11. c 12. d 13. c 14. a

11 The Fat-Soluble Vitamins: A, D, E, and K

View the key points of this chapter below, then take the practice quiz on the back of this card.

11.1 Vitamin A and Beta-Carotene

- Vitamin A is found in the body in three forms: retinol, retinal, and retinoic acid. Together, they are essential to vision, healthy epithelial tissues, and growth.
- Vitamin A deficiency is a major health problem worldwide, leading to infections, blindness, and keratinization.
- Toxicity can also cause problems and is most often associated with supplement abuse.
- Animal-derived foods such as liver and whole or fortified milk provide retinoids, whereas brightly colored plant-derived foods such as spinach, carrots, and pumpkins provide beta-carotene and other carotenoids.
- In addition to serving as a precursor for vitamin A, beta-carotene may act as an antioxidant in the body.

11.2 Vitamin D

- Vitamin D can be synthesized in the body with the help of sunlight (see Figure 11-9) or obtained from fortified milk.
- Vitamin D sends signals to three primary target sites: the GI tract to absorb more calcium and phosphorus, the bones to release more, and the kidneys to retain more. These actions maintain blood calcium concentrations and support bone formation.
- A vitamin D deficiency causes rickets in childhood and osteomalacia in later life.

11.3 Vitamin E

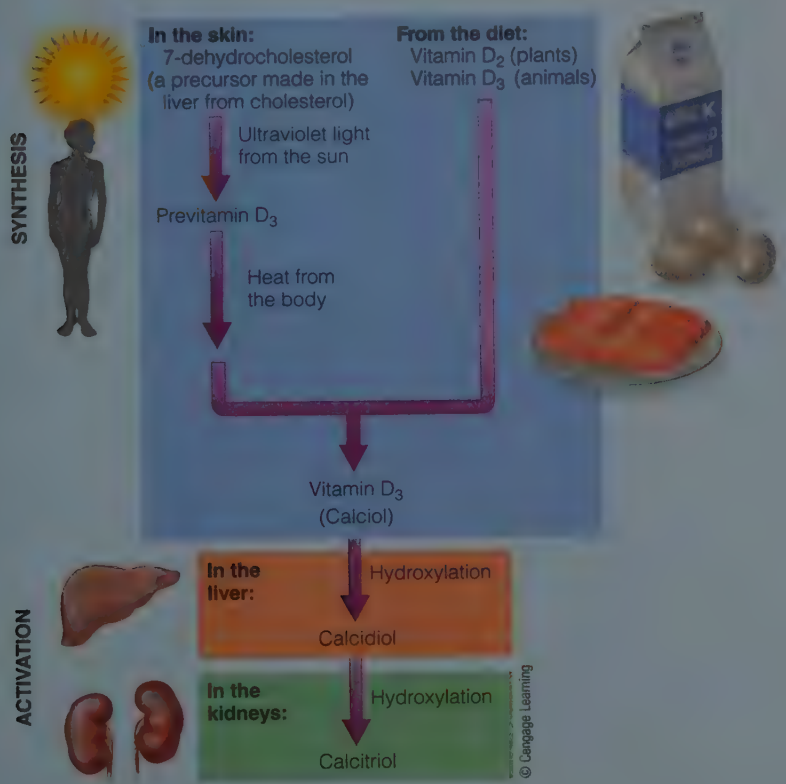
- Vitamin E (alpha-tocopherol) acts as an antioxidant, defending lipids and other components of the cells against oxidative damage.
- Deficiencies are rare, but they do occur in premature infants, the primary symptom being erythrocyte hemolysis (red blood cell breakage).
- Vitamin E is found predominantly in vegetable oils and appears to be one of the least toxic of the fat-soluble vitamins.

11.4 Vitamin K

- Vitamin K helps with blood clotting (review Figure 11-12, p. 355), and its deficiency causes hemorrhagic disease (uncontrolled bleeding).
- Bacteria in the GI tract can make vitamin K; people typically receive about half of their requirements from bacterial synthesis and half from foods such as green vegetables and vegetable oils.
- Because people depend on bacterial synthesis for vitamin K, deficiency is most likely in newborn infants and in people taking antibiotics.

> FIGURE 11-9 Vitamin D Synthesis and Activation

The final activation step in the kidneys is tightly regulated by hormones.



TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

11.1 Vitamin A and Beta-Carotene

(pp. 340–347)

LEARN IT Identify the main roles, deficiency symptoms, and food sources for vitamin A.

1. What are vitamin precursors? Name the precursors of vitamin A, and tell in what classes of foods they are located. Give examples of foods with high vitamin A activity.

2. The form of vitamin A active in vision is:
   a. retinal.
   b. retinol.
   c. rhodopsin.
   d. retinoic acid.

3. Vitamin A–deficiency symptoms include:
   a. rickets and osteomalacia.
   b. hemorrhaging and jaundice.
   c. night blindness and keratomalacia.
   d. fibrocystic breast disease and erythrocyte hemolysis.

4. Good sources of vitamin A include:
   a. oatmeal, pinto beans, and ham.
   b. apricots, turnip greens, and liver.
   c. whole-wheat bread, green peas, and tuna.
   d. corn, grapefruit juice, and sunflower seeds.

11.2 Vitamin D (pp. 347–352)

LEARN IT Identify the main roles, deficiency symptoms, and sources for vitamin D.

5. How is vitamin D unique among the vitamins?

6. To keep minerals available in the blood, vitamin D targets:
   a. the skin, the muscles, and the bones.
   b. the kidneys, the liver, and the bones.
   c. the intestines, the kidneys, and the bones.
   d. the intestines, the pancreas, and the liver.

7. Vitamin D can be synthesized from a precursor that the body makes from:
   a. bilirubin.
   b. tocopherol.
   c. cholesterol.
   d. beta-carotene.

11.3 Vitamin E (pp. 353–354)

LEARN IT Identify the main roles, deficiency symptoms, and fo sources for vitamin E.

8. Vitamin E's most notable role is to:
   a. protect lipids against oxidation.
   b. activate blood-clotting proteins.
   c. support protein and DNA synthesis.
   d. enhance calcium deposits in the bones.

9. The classic sign of vitamin E deficiency is:
   a. rickets.
   b. xeropthalmia.
   c. muscular dystrophy.
   d. erythrocyte hemolysis.

11.4 Vitamin K (pp. 354–356)

LEARN IT Identify the main roles, deficiency symptoms, and sourc for vitamin K.

10. What conditions may lead to vitamin K deficiency?

11. Without vitamin K:
    a. muscles atrophy.
    b. bones become soft.
    c. skin rashes develop.
    d. blood fails to clot.

12. A significant amount of vitamin K comes from:
    a. vegetable oils.
    b. sunlight exposure.
    c. bacterial synthesis.
    d. fortified grain products.

See p. 357 for a summary of the fat-soluble vitamins.

Multiple Choice Answers
a. 3.c 4.b 6.c 7.c 8.a 9.d 11.d 12.c

12 Water and the Major Minerals

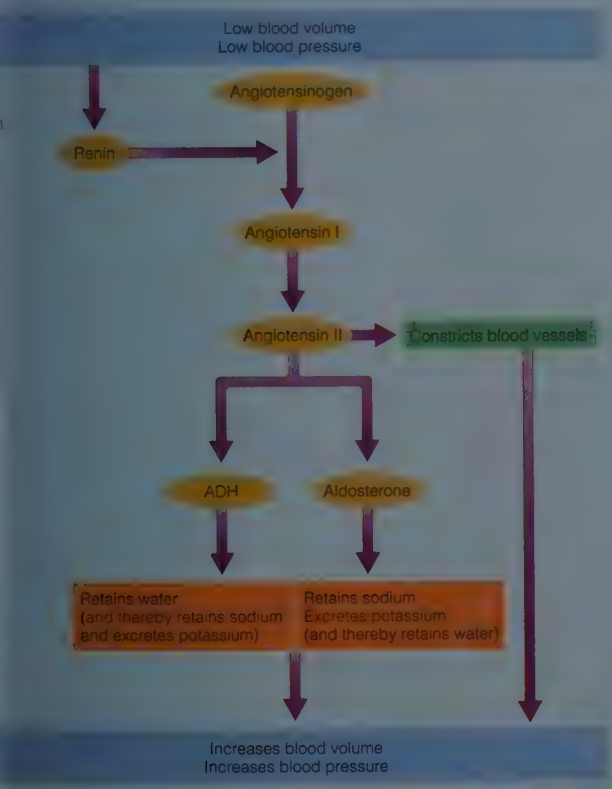
view the key points of this chapter below, then take the practice quiz on the back of this card.

.1 Water and the Body Fluids

- Water makes up about 60 percent of an adult's body weight.
- Water assists with the transport of nutrients and waste products throughout the body, participates in chemical reactions, acts as a solvent, serves as a shock absorber, and regulates body temperature.
- To maintain water balance, intake from liquids, foods, and metabolism must equal losses from the kidneys, skin, lungs, and GI tract (review Table 12-3, p. 370).
- Whenever the body experiences low blood volume, low blood pressure, or highly concentrated body fluids, the actions of ADH, renin, angiotensin, and aldosterone restore homeostasis (review Figure 12-3).
- Electrolytes (charged minerals) in the fluids help distribute the fluids inside and outside the cells, thus ensuring the appropriate water balance and acid-base balance to support all life processes.
- Excessive losses of fluids and electrolytes upset these balances, and the kidneys play a key role in restoring homeostasis.

IGURE 12-3 ***Animated*** **How the Body Regulates Blood lume and Blood Pressure**

e renin-angiotensin-aldosterone system helps regulate blood volume and erefore blood pressure.



© Cengage Learning

12.2 The Minerals—An Overview

- The major minerals are needed in the diet and found in the body in larger quantities than the trace minerals (review Figure 12-9, p. 378).
- Minerals are inorganic elements that retain their chemical identities; receive special handling and regulation in the body; and may bind with other substances or interact with other minerals, thus limiting their absorption.
- The major minerals, especially sodium, chloride, and potassium, influence the body's fluid balance; whenever an anion moves, a cation moves—always maintaining homeostasis.
- Sodium, chloride, potassium, calcium, and magnesium are key members of the team of nutrients that direct nerve impulse transmission and muscle contraction. They are also the primary nutrients involved in regulating blood pressure.
- Phosphorus and magnesium participate in many reactions involving glucose, fatty acids, amino acids, and the vitamins. Calcium, phosphorus, and magnesium combine to form the structure of the bones and teeth. Each major mineral also plays other specific roles in the body.

12.3 The Major Minerals

- Sodium is the main cation outside cells and one of the primary electrolytes responsible for maintaining fluid balance. Dietary deficiency is rare; excesses seem to aggravate hypertension, and so health professionals advise a diet moderate in salt and sodium.
- Chloride is the major anion outside cells, and it associates closely with sodium. In addition to its role in fluid balance, chloride is part of the stomach's hydrochloric acid.
- Potassium is the primary cation inside cells and plays an important role in maintaining fluid balance. Fresh foods, notably fruits and vegetables, are its best sources.
- Calcium is found primarily in the bones where it provides a rigid structure and a reservoir of calcium for the blood. Blood calcium participates in muscle contraction, blood clotting, and nerve impulses, and it is closely regulated by a system of hormones and vitamin D (review Figure 12-12, p. 386). Milk and milk products are good sources of calcium, but certain vegetables and tofu also provide calcium. Even when calcium intake is inadequate, blood calcium remains normal, but at the expense of bone loss, which can lead to osteoporosis.
- Phosphorus accompanies calcium both in the crystals of bone and in many foods such as milk. Phosphorus is also important in energy metabolism, as part of phospholipids, and as part of the genetic materials DNA and RNA.
- Magnesium supports bone mineralization and participates in numerous enzyme systems and in heart function. It is found abundantly in legumes and dark green, leafy vegetables and, in some areas, in water.
- Sulfate is found in all protein-containing foods. Its primary role in amino acids is to stabilize proteins by forming disulfide bridges.

TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

12.1 Water and the Body Fluids (pp. 368–377)

LEARN IT Explain how the body regulates fluid balance.

1. List the roles of water in the body.
2. List the sources of water intake and routes of water excretion.
3. What is ADH? Where does it exert its action? What is aldosterone? How does it work?
4. How does the body use electrolytes to regulate fluid balance?
5. The body generates water during the:
   a. buffering of acids.
   b. dismantling of bone.
   c. metabolism of minerals.
   d. oxidation of energy nutrients through the electron transport chain.
6. Regulation of fluid and electrolyte balance and acid-base balance depends primarily on the:
   a. kidneys.
   b. intestines.
   c. sweat glands.
   d. specialized tear ducts.

12.2 The Minerals—An Overview

(pp. 377–378)

LEARN IT List some of the ways minerals differ from vitamins and other nutrients.

7. What do the terms *major* and *trace* mean when describing the minerals in the body?
8. Describe some characteristics of minerals that distinguish them from vitamins.
9. The distinction between the major and trace minerals reflects the:
   a. ability of their ions to form salts.
   b. amounts of their contents in the body.
   c. importance of their functions in the body.
   d. capacity to retain their identity after absorption.

12.3 The Major Minerals (pp. 379–394)

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the major minerals (sodium, chloride, potassium, calcium, phosphorus, magnesium, and sulfate).

10. What is the major function of sodium in the body? Describe how the kidneys regulate blood sodium. Is a dietary deficiency of sodium likely? Why or why not?
11. List calcium's roles in the body. How does the body keep blood calcium constant regardless of intake?
12. Name significant food sources of calcium. What are the co sequences of inadequate intakes?
13. List the roles of phosphorus in the body. Discuss the relationsh between calcium and phosphorus. Is a dietary deficiency phosphorus likely? Why or why not?
14. State the major functions of chloride, potassium, magnesiu and sulfur in the body. Are deficiencies of these nutrients lik to occur in your own diet? Why or why not?
15. The principal cation in extracellular fluids is:
    a. sodium.
    b. chloride.
    c. potassium.
    d. phosphorus.
16. The role of chloride in the stomach is to help:
    a. support nerve impulses.
    b. convey hormonal messages.
    c. maintain a strong acidity.
    d. assist in muscular contractions.
17. Which would provide the most potassium?
    a. bologna
    b. potatoes
    c. pickles
    d. whole-wheat bread
18. Calcium homeostasis depends on:
    a. vitamin K, aldosterone, and renin.
    b. vitamin K, parathyroid hormone, and renin.
    c. vitamin D, aldosterone, and calcitonin.
    d. vitamin D, calcitonin, and parathyroid hormone.
19. Calcium absorption is hindered by:
    a. lactose.
    b. oxalates.
    c. vitamin D.
    d. stomach acid.
20. Phosphorus assists in many activities in the body, but *not*:
    a. energy metabolism.
    b. the clotting of blood.
    c. the transport of lipids.
    d. bone and teeth formation.
21. Most of the body's magnesium can be found in the:
    a. bones.
    b. nerves.
    c. muscles.
    d. extracellular fluids.

See p. 394 for a summary of the major minerals.

Multiple Choice Answers
1. a 2. b 3. a 4. c 5. b 6. d 7. b 8. b 9. a 10. b 11. a

13 The Trace Minerals

view the key points of this chapter below, then take the practice quiz on the back of this card.

3.1 The Trace Minerals—An Overview

- The body needs tiny amounts of the trace minerals.
- The trace minerals can be toxic at levels not far above estimated requirements—a consideration for supplement users (review Figure 13-1, p. 404).
- Like the other nutrients, the trace minerals are best obtained by eating a variety of foods.

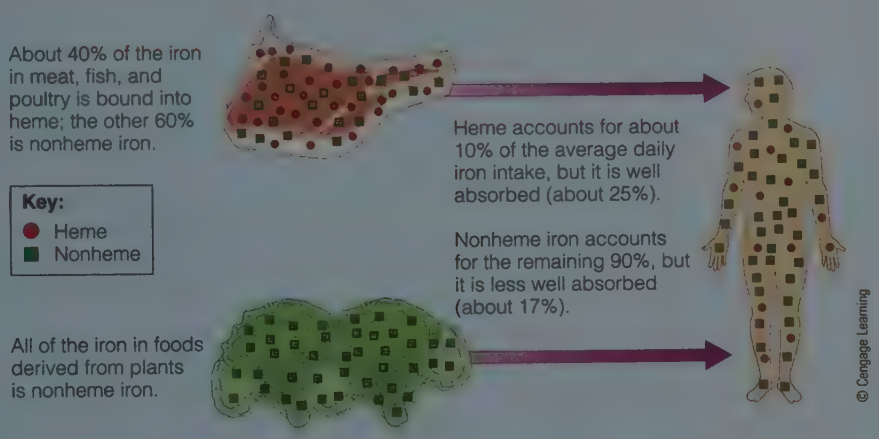
3.2 The Trace Minerals—As Individuals

- Iron is found in hemoglobin and myoglobin where it carries oxygen for energy metabolism; iron also acts as a cofactor for some enzymes. Iron deficiency is most common among infants and young children, teenagers, women of childbearing age, and pregnant women. Symptoms include fatigue and anemia. Iron overload is most common in men. Heme iron, which is found only in meat, fish, and poultry, is better absorbed than nonheme iron, which occurs in most foods (review Figure 13-4). Nonheme iron absorption is improved by eating iron-containing foods with foods containing the MFP factor and vitamin C; absorption is limited by phytates and oxalates.
- Zinc-requiring enzymes participate in reactions affecting growth, vitamin A activity, and pancreatic digestive enzyme synthesis. Both dietary zinc and zinc-rich pancreatic secretions (via enteropancreatic circulation) are available for absorption. Absorption is monitored by a special binding protein (metallothionein) in the small intestine. Protein-rich foods derived from animals are the best sources of bioavailable zinc. Fiber and phytates in cereals bind zinc, limiting absorption. Symptoms of deficiency include growth retardation and sexual immaturity.
- Iodide, the iodine ion, is an essential component of the thyroid hormone. A deficiency can lead to goiter (enlargement of the thyroid gland) and can impair fetal development, causing cretinism. Iodization of salt has largely eliminated iodine deficiency in the United States and Canada.
- Selenium is an antioxidant nutrient that works closely with the glutathione peroxidase enzyme and vitamin E. Selenium is found with protein in foods. Deficiencies are associated with a predisposition to a type of heart abnormality known as Keshan disease.
- Copper is a component of several enzymes, all of which are involved with oxygen or oxidation. Some act as antioxidants; others are essential to iron metabolism. Legumes, whole grains, and shellfish are good sources of copper.
- Manganese-dependent enzymes are involved in bone formation and various metabolic processes. Because manganese is widespread in plant foods, deficiencies are rare, although regular use of calcium and iron supplements may limit manganese absorption.
- Fluoride makes teeth more resistant to decay. Fluoridation of public water reduces the incidence of dental caries; excess fluoride during tooth development can discolor and pit tooth enamel (fluorosis).
- Chromium enhances insulin's action. Deficiency can result in a diabetes-like condition. Chromium is widely available in unrefined foods including brewer's yeast, whole grains, and liver.
- Molybdenum is a part of many metalloenzymes. Deficiencies are unknown and toxicity is rare. It is found in a variety of foods.

13.3 Contaminant Minerals

- Contaminant minerals include the heavy metals lead, mercury, and cadmium that enter the food supply by way of soil, water, and air pollution.
- Lead typifies the ways all heavy metals behave in the body: they interfere with nutrients that are trying to do their jobs. The "good guy" nutrients are shoved aside by the "bad guy" contaminants. Then, when the contaminants cannot perform the role of the nutrients, health diminishes.
- To safeguard our health, we must defend ourselves against contamination by eating nutrient-rich foods and preserving a clean environment.

> FIGURE 13-4 **Heme and Nonheme Iron in Foods**



TEST IT

Take the quiz below to test your mastery of the key chapter concepts.

13.1 The Trace Minerals—An Overview

(pp. 403–405)

LEARN IT Summarize key factors unique to the trace minerals.

1. Discuss the importance of balanced and varied diets in obtaining the essential minerals and avoiding toxicities.
2. Describe some of the ways trace minerals interact with one another and with other nutrients.

13.2 The Trace Minerals (pp. 405–424)

LEARN IT Identify the main roles, deficiency symptoms, and food sources for each of the trace minerals (iron, zinc, iodine, selenium, copper, manganese, fluoride, chromium, and molybdenum).

3. Distinguish between heme and nonheme iron. Discuss the factors that enhance iron absorption.
4. Iron absorption is impaired by:
   a. heme.
   b. phytates.
   c. vitamin C.
   d. MFP factor.
5. Which of these people is *least* likely to develop an iron deficiency?
   a. 3-year-old boy
   b. 52-year-old man
   c. 17-year-old girl
   d. 24-year-old woman
6. Which of the following would *not* describe the blood cells of a severe iron deficiency?
   a. anemic
   b. microcytic
   c. pernicious
   d. hypochromic
7. Which provides the most absorbable iron?
   a. 1 apple
   b. 1 cup milk
   c. 3 ounces steak
   d. ½ cup spinach
8. What causes iron overload? What are its symptoms?
9. Describe the similarities and differences in the absorption and regulation of iron and zinc.
10. Discuss possible reasons for a low intake of zinc. What factors affect the bioavailability of zinc?
11. The intestinal protein that helps to regulate zinc absorption is:
    a. albumin.
    b. ferritin.
    c. hemosiderin.
    d. metallothionein.
12. A classic sign of zinc deficiency is:
    a. anemia.
    b. goiter.
    c. mottled teeth.
    d. growth retardation.
13. What public health measure has been used in preventi simple goiter?
14. Cretinism is caused by a deficiency of:
    a. iron.
    b. zinc.
    c. iodine.
    d. selenium.
15. The mineral best known for its role as an antioxidant is:
    a. copper.
    b. selenium.
    c. manganese.
    d. molybdenum.
16. What measure has been recommended for protection agai tooth decay?
17. Fluorosis occurs when fluoride:
    a. is excessive.
    b. is inadequate.
    c. binds with phosphorus.
    d. interacts with calcium.
18. Which mineral enhances insulin activity?
    a. zinc
    b. iodine
    c. chromium
    d. manganese

See p. 425 for a summary of the trace minerals.

13.3 Contaminant Minerals (p. 424)

LEARN IT Describe how contaminant minerals disrupt body process and impair nutrition status.

19. Which of the following does lead *not* compete with?
    a. iron
    b. zinc
    c. fluoride
    d. calcium

Multiple Choice Answers
5. b 6. c 7. c 11. d 12. d 14. c 15. b 17. a 18. c 19. c

Daily Values for Food Labels

The Daily Values are standard values developed by the Food and Drug Administration (FDA) for use on food labels. The values are based on 2000 kcalories a day for adults and children over 4 years old. Chapter 2 provides more details.

Nutrient	Amount
Protein[a]	50 g
Thiamin	1.5 mg
Riboflavin	1.7 mg
Niacin	20 mg NE
Biotin	300 µg
Pantothenic acid	10 mg
Vitamin B_6	2 mg
Folate	400 µg
Vitamin B_{12}	6 µg
Vitamin C	60 mg
Vitamin A	5000 IU[b]
Vitamin D	400 IU[b]
Vitamin E	30 IU[b]
Vitamin K	80 µg
Calcium	1000 mg
Iron	18 mg
Zinc	15 mg
Iodine	150 µg
Copper	2 mg
Chromium	120 µg
Selenium	70 µg
Molybdenum	75 µg
Manganese	2 mg
Chloride	3400 mg
Magnesium	400 mg
Phosphorus	1000 mg

[a]The Daily Values for protein vary for different groups of people: pregnant women, 60 g; nursing mothers, 65 g; infants under 1 year, 14 g; children 1 to 4 years, 16 g.
[b]Equivalent values for nutrients expressed as IU are: vitamin A, 1500 RAE (assumes a mixture of 40% retinol and 60% beta-carotene); vitamin D, 10 µg; vitamin E, 20 mg.

Food Component	Amount	Calculation Factors
Fat	65 g	30% of kcalories
Saturated fat	20 g	10% of kcalories
Cholesterol	300 mg	Same regardless of kcalories
Carbohydrate (total)	300 g	60% of kcalories
Fiber	25 g	11.5 g per 1000 kcalories
Protein	50 g	10% of kcalories
Sodium	2400 mg	Same regardless of kcalories
Potassium	3500 mg	Same regardless of kcalories

GLOSSARY OF NUTRIENT MEASURES

kcal: kcalories; a unit by which energy is measured (Chapter 1 provides more details).

g: grams; a unit of weight equivalent to about 0.03 ounces.

mg: milligrams; one-thousandth of a gram.

µg: micrograms; one-millionth of a gram.

IU: international units; an old measure of vitamin activity determined by biological methods (as opposed to new measures that are determined by direct chemical analyses). Many fortified foods and supplements use IU on their labels.

- For vitamin A, 1 IU = 0.3 µg retinol, 3.6 µg β-carotene, or 7.2 µg other vitamin A carotenoids
- For vitamin D, 1 IU = 0.02 µg cholecalciferol
- For vitamin E, 1 IU = 0.67 natural α-tocopherol (other conversion factors are used for different forms of vitamin E)

mg NE: milligrams niacin equivalents; a measure of niacin activity (Chapter 10 provides more details).

- 1 NE = 1 mg niacin
  = 60 mg tryptophan (an amino acid)

µg DFE: micrograms dietary folate equivalents; a measure of folate activity (Chapter 10 provides more details).

- 1 µg DFE = 1 µg food folate
  = 0.6 µg fortified food or supplement folate taken with food
  = 0.5 µg supplement folate taken on an empty stomach

µg RAE: micrograms retinol activity equivalents; a measure of vitamin A activity (Chapter 11 provides more details).

- 1 µg RAE = 1 µg retinol
  = 12 µg β-carotene
  = 24 µg other vitamin A carotenoids

mmol: millimoles; one-thousanth of a mole, the molecular weight of a substance. To convert mmol to mg, multiply by the atomic weight of the substance.

- For sodium, mmol × 23 = mg Na
- For chloride, mmol × 35.5 = mg Cl
- For sodium chloride, mmol × 58.5 = mg NaCl

Body Mass Index (BMI)

Find your height along the left-hand column and look across the row until you find the number that is closest to your weight. The number at the top of that column identifies your BMI. Chapter 8 describes how BMI correlates with disease risks and defines obesity, and Chapter 16 presents BMI for children and adolescents. The area shaded in blue represents healthy weight ranges.

	Underweight (<18.5)	Healthy Weight (18.5–24.9)						Overweight (25–29.9)					Obese (≥30)										
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Height	Body weight (pounds)																						
4'10"	86	91	96	100	105	110	115	119	124	129	134	138	143	148	153	158	162	167	172	177	181	186	191
4'11"	89	94	99	104	109	114	119	124	128	133	138	143	148	153	158	163	168	173	178	183	188	193	198
5'0"	92	97	102	107	112	118	123	128	133	138	143	148	153	158	163	168	174	179	184	189	194	199	204
5'1"	95	100	106	111	116	122	127	132	137	143	148	153	158	164	169	174	180	185	190	195	201	206	211
5'2"	98	104	109	115	120	126	131	136	142	147	153	158	164	169	175	180	186	191	196	202	207	213	218
5'3"	102	107	113	118	124	130	135	141	146	152	158	163	169	175	180	186	191	197	203	208	214	220	225
5'4"	105	110	116	122	128	134	140	145	151	157	163	169	174	180	186	192	197	204	209	215	221	227	232
5'5"	108	114	120	126	132	138	144	150	156	162	168	174	180	186	192	198	204	210	216	222	228	234	240
5'6"	112	118	124	130	136	142	148	155	161	167	173	179	186	192	198	204	210	216	223	229	235	241	247
5'7"	115	121	127	134	140	146	153	159	166	172	178	185	191	198	204	211	217	223	230	236	242	249	255
5'8"	118	125	131	138	144	151	158	164	171	177	184	190	197	203	210	216	223	230	236	243	249	256	262
5'9"	122	128	135	142	149	155	162	169	176	182	189	196	203	209	216	223	230	236	243	250	257	263	270
5'10"	126	132	139	146	153	160	167	174	181	188	195	202	209	216	222	229	236	243	250	257	264	271	278
5'11"	129	136	143	150	157	165	172	179	186	193	200	208	215	222	229	236	243	250	257	265	272	279	286
6'0"	132	140	147	154	162	169	177	184	191	199	206	213	221	228	235	242	250	258	265	272	279	287	294
6'1"	136	144	151	159	166	174	182	189	197	204	212	219	227	235	242	250	257	265	272	280	288	295	302
6'2"	141	148	155	163	171	179	186	194	202	210	218	225	233	241	249	256	264	272	280	287	295	303	311
6'3"	144	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	279	287	295	303	311	319
6'4"	148	156	164	172	180	189	197	205	213	221	230	238	246	254	263	271	279	287	295	304	312	320	328
6'5"	151	160	168	176	185	193	202	210	218	227	235	244	252	261	269	277	286	294	303	311	319	328	336
6'6"	155	164	172	181	190	198	207	216	224	233	241	250	259	267	276	284	293	302	310	319	328	336	345



ISBN-13: 978-1-285-14475-7
ISBN-10: 1-285-14475-9

CENGAGE Learning®

For your lifelong learning solutions, visit **custom.cengage.com**
Visit our corporate website at **cengage.com**