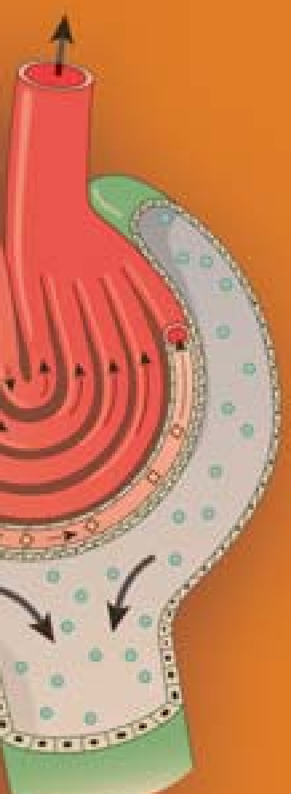
Selected Key Terms

The following terms and other boldface terms in the chapter are defined in the Glossary



anabolism
catabolism
fever
glucose
glycogen
hypothalamus
hypothermia
kilocalorie
malnutrition
metabolic rate
mineral
oxidation
pyrogen
vitamin

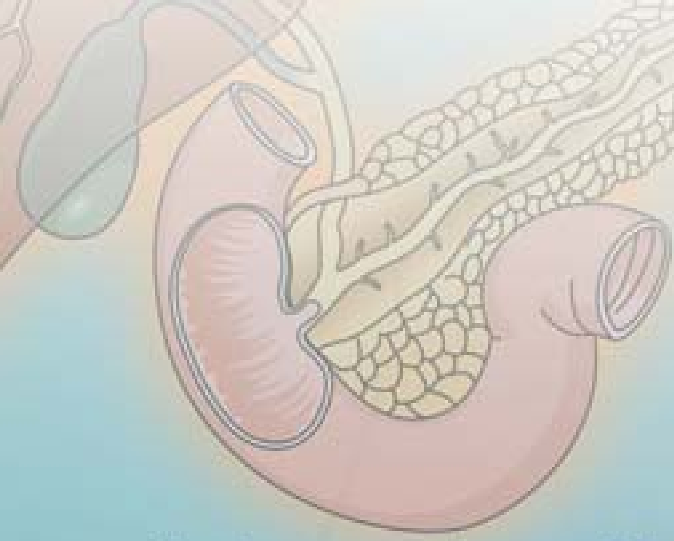
Learning Outcomes

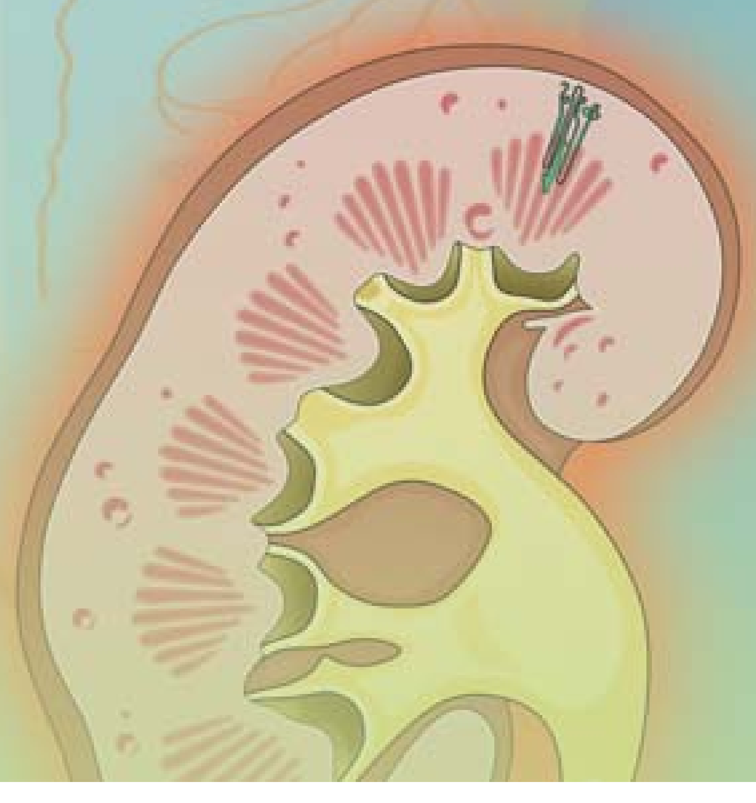
After careful study of this chapter, you should be able to:

1. Differentiate between catabolism and anabolism
2. Differentiate between the anaerobic and aerobic phases of cellular respiration and give the end products and the relative amount of energy released by each
3. Define *metabolic rate* and name several factors that affect the metabolic rate
4. Explain the roles of glucose and glycogen in metabolism
5. Compare the energy contents of fats, proteins, and carbohydrates
6. Define *essential amino acid*
7. Explain the roles of minerals and vitamins in nutrition and give examples of each
8. List the recommended percentages of carbohydrate, fat, and protein in the diet
9. Distinguish between simple and complex carbohydrates, giving examples of each
10. Compare saturated and unsaturated fats
11. List some adverse effects of alcohol consumption
12. Describe some nutritional disorders
13. Explain how heat is produced and lost in the body
14. Describe the role of the hypothalamus in regulating body temperature
15. Explain the role of fever in disease
16. Describe some adverse effects of excessive heat and cold
17. Show how word parts are used to build words related to metabolism, nutrition, and body temperature (see Word Anatomy at the end of the chapter)

chapter 20

Metabolism, Nutrition, and Body Temperature





20

Metabolism

Nutrients absorbed from the digestive tract are used for all the cellular activities of the body, which together make up **metabolism**. These activities fall into two categories:

- **Catabolism**, which is the breakdown of complex compounds into simpler compounds. Catabolism includes the digestion of food into small molecules and the release of energy from these molecules within the cell.
- **Anabolism**, which is the building of simple compounds into substances needed for cellular activities and for the growth and repair of tissues.

Through the steps of catabolism and anabolism, there is a constant turnover of body materials as energy is consumed, cells function and grow, and waste products are generated.

Checkpoint 20-1 What are the two phases of metabolism?

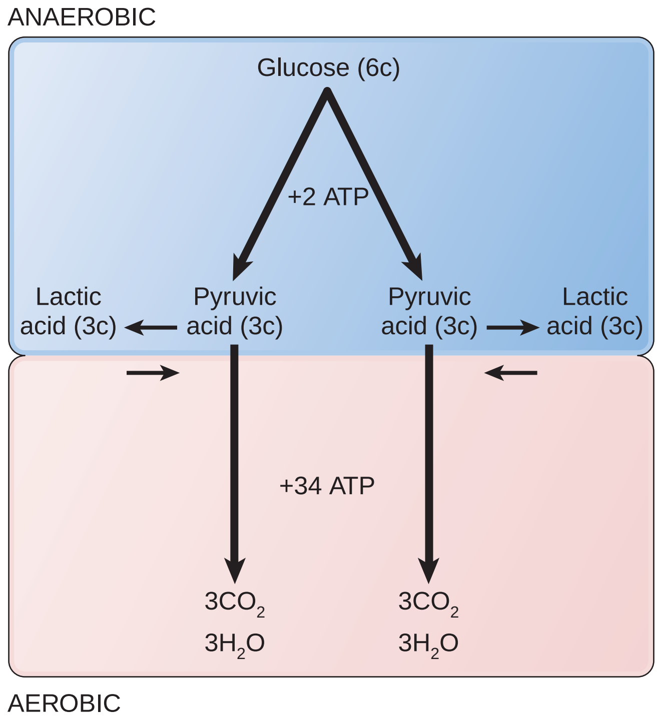


Figure 20-1 Cellular respiration. This diagram shows the catabolism of glucose without oxygen (anaerobic) and with oxygen (aerobic). (C = carbon atoms in one molecule of a substance.) In cellular respiration, glucose first yields two molecules of pyruvic acid, which will convert to lactic acid under anaerobic conditions, as during intense exercise. (Lactic acid must eventually be converted back to pyruvic acid.) Typically, however, pyruvic acid is broken down aerobically (using oxygen) to CO_2 and H_2O (aerobically). *ZOOMING IN ❖ What does pyruvic acid produce in cellular respiration under anaerobic conditions? Under aerobic conditions?*

Cellular Respiration

Energy is released from nutrients in a series of reactions called **cellular respiration** (see Table 20-1 and Fig. 20-1). Early studies on cellular respiration were done with **glucose** as the starting compound. Glucose is a simple sugar that is the main energy source for the body.

The Anaerobic Phase

The first steps in the breakdown of glucose do not require oxygen; that is, they are **anaerobic**. This phase of catabolism, known as **glycolysis** (gli-KOL-ih-sis), occurs in the cytoplasm of the cell. It yields a small amount of energy, which is used to make ATP (adenosine triphosphate), the cells' energy compound. Each glucose molecule yields enough energy by this process to produce 2 molecules of ATP.

The anaerobic breakdown of glucose is incomplete and ends with formation of an organic product called **pyruvic** (pi-RU-vik) **acid**. This organic acid is further metabolized in the next phase of cellular respiration, which requires oxygen. In muscle cells operating briefly under anaerobic conditions, pyruvic acid is converted to lactic acid, which accumulates as the cells build up an oxygen debt (described in Chapter 8). Lactic acid induces muscle fatigue, so the body is forced to rest and recover. During the recovery phase immediately after exercise, breathing restores the oxygen needed to convert lactic acid back to pyruvic acid, which is then metabolized further. During this recovery phase, reserves stored in muscles are also replenished. These compounds are myoglobin, which stores oxygen; glycogen, which can be broken down for glucose; and creatine phosphate, which stores energy.

The Aerobic Phase

To generate enough energy for survival, the body's cells must break pyruvic acid down more completely in the second phase of cellular respiration, which requires oxygen. These **aerobic** reactions occur within the mitochondria of the cell. They result in transfer of most of the energy remaining in the nutrients to ATP. On average, about 34 to 36 molecules of ATP can be formed aerobically per glucose molecule—quite an increase over anaerobic metabolism.

Table 20•1 Summary of Cellular Respiration of Glucose

PHASE	LOCATION IN CELL	END PRODUCT(S)	ENERGY YIELD/GLUCOSE
Anaerobic (glycolysis)	Cytoplasm	Pyruvic acid	2 ATP
Aerobic	Mitochondria	Carbon dioxide and water	34–36 ATP

During the aerobic steps of cellular respiration, the cells form carbon dioxide, which then must be transported to the lungs for elimination. In addition, water is formed by the combination of oxygen with the hydrogen that is removed from nutrient molecules. Because of the type of chemical reactions involved, and because oxygen is used in the final steps, cellular respiration is described as an **oxidation** of nutrients. Note that enzymes are required as catalysts in all the reactions of cellular respiration. Many of the vitamins and minerals described later in this chapter are parts of these enzymes.

Although the oxidation of food is often compared to the burning of fuel, this comparison is inaccurate. Burning fuel results in a sudden and often wasteful release of energy in the form of heat and light. In contrast, metabolic oxidation occurs in small steps, and much of the energy released is stored as ATP for later use by the cells; some of the energy is released as heat, which is used to maintain body temperature, as discussed later in this chapter.

For those who know how to read chemical equations, the net balanced equation for cellular respiration, starting with glucose, is as follows:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

Checkpoint 20-2 What name is given to the series of cellular reactions that releases energy from nutrients?

Metabolic Rate

Metabolic rate refers to the rate at which energy is released from nutrients in the cells. It is affected by a person's size, body fat, sex, age, activity, and hormones, especially thyroid hormone (thyroxine). Metabolic rate is high in children and adolescents and decreases with age. **Basal metabolism** is the amount of energy needed to maintain life functions while the body is at rest.

The unit used to measure energy is the kilocalorie (kcal), which is the amount of heat needed to raise 1 kilogram of water 1°C. To estimate the daily calories needed taking activity level into account, see Box 20-1.

The Use of Nutrients for Energy

As noted, glucose is the main source of energy in the body. Most of the carbohydrates in the diet are converted to glucose in the course of metabolism. Reserves of glucose are stored in liver and muscle cells as **glycogen** (GLI-ko-jen), a compound built from glucose molecules. When glucose is needed for energy, glycogen is broken down to yield glucose. Glycerol and fatty acids (from fat digestion)

Box 20-1 **A Closer Look**

Calorie Counting: Estimating Daily Energy Needs

Basal energy requirements for a day can be estimated with a simple formula. An average woman requires 0.9 kcal/kg/hour, and a man, 1.0 kcal/kg/hour. Multiplying 0.9 by body weight in kilograms* by 24 for a woman, or 1.0 by body weight in kilograms by 24 for a man, yields the daily basal energy requirement. For example, if a woman weighed 132 pounds, the equation would be as follows:

132 pounds ÷ 2.2 pounds/kg = 60 kg

0.9 kcal/kg/hour x 60 kg = 54 kcal/hour

54 kcal/hour x 24 hours/day = 1,296 kcal/day

To estimate total energy needs for a day, a percentage based on activity level ("couch potato" to serious athlete) must also be added to the basal requirement. These percentages are shown in the table below.

The equation to calculate total energy needs for a day is:

Basal energy requirement + (basal energy requirement × activity level)

Using our previous example, and assuming light activity levels, the following equations apply:

At 40% activity:

1,296 kcal/day + (1,296 kcal/day × 40%) = 1,814.4 kcal/day

At 60% activity:

1,296 kcal/day + (1,296 kcal/day × 60%) = 2,073.6 kcal/day

Therefore, the woman in our example would require between 1,814 and 2,073 Kcal/day.

ACTIVITY LEVEL	MALE	FEMALE
Little activity ("couch potato")	25–40%	25–35%
Light activity (*e.g.*, walking to and from class, but little or no intentional exercise)	50–75%	40–60%
Moderate activity (*e.g.*, aerobics several times a week)	65–80%	50–70%
Heavy activity (serious athlete)	90–120%	80–100%

*To convert pounds to kilograms, divide weight in pounds by 2.2.

and amino acids (from protein digestion) can also be used for energy, but they enter the breakdown process at different points.

Fat in the diet yields more than twice as much energy as do protein and carbohydrate (*e.g.*, it is more "fattening"); fat yields 9 kcal of energy per gram, whereas protein and carbohydrate each yield 4 kcal per gram. Calories that are ingested in excess of need are converted to fat and stored in adipose tissue.

Before they are oxidized for energy, amino acids must have their nitrogen (amine) groups removed. This removal, called **deamination** (de-am-ih-NA-shun), occurs in the liver, where the nitrogen groups are then formed into urea by combination with carbon dioxide. The blood transports urea to the kidneys to be eliminated.

There are no specialized storage forms of proteins, as there are for carbohydrates (glycogen) and fats (adipose tissue). Therefore, when one needs more proteins than are supplied in the diet, they must be obtained from body substance, such as muscle tissue or plasma proteins. Drawing on these resources becomes dangerous when needs are extreme. Fats and carbohydrates are described as "protein sparing," because they are used for energy before proteins are and thus spare proteins for the synthesis of necessary body components.

Checkpoint 20-3 What is the main energy source for the cells?

Anabolism

Nutrient molecules are built into body materials by anabolic steps, all of which are catalyzed by enzymes.

Essential Amino Acids Eleven of the 20 amino acids needed to build proteins can be synthesized internally by metabolic reactions. These 11 amino acids are described as *nonessential* because they need not be taken in as food (Table 20-2). The remaining 9 amino acids cannot be made by the body and therefore must be taken in as part of the diet; these are the **essential amino acids**. Note that some nonessential amino acids may become essential under certain conditions, as during extreme physical stress, or in certain hereditary metabolic diseases.

Essential Fatty Acids There are also two essential fatty acids (linoleic acid and linolenic acid) that must be taken in as food. These are easily obtained through a healthful, balanced diet.

Checkpoint 20-4 What is meant when an amino acid or a fatty acid is described as essential?

Minerals and Vitamins

In addition to needing fats, proteins, and carbohydrates, the body requires minerals and vitamins.

Minerals are chemical elements needed for body structure, fluid balance, and such activities as muscle contraction, nerve impulse conduction, and blood clotting. Some minerals are components of vitamins. A list of the main minerals needed in a proper diet is given in Table 20-3. Some additional minerals not listed are also required for good health. Minerals needed in extremely small amounts are referred to as **trace elements**.

Vitamins are complex organic substances needed in very small quantities. Vitamins are parts of enzymes or other substances essential for metabolism, and vitamin deficiencies lead to a variety of nutritional diseases.

The water-soluble vitamins are the B vitamins and vitamin C. These are not stored and must be taken in regularly with food. The fat-soluble vitamins are A, D, E, and K. These vitamins are kept in reserve in fatty tissue. Excess intake of the fat-soluble vitamins can lead to toxicity. A list of vitamins is given in Table 20-4.

Certain substances are valuable in the diet as **antioxidants**. They defend against the harmful effects of **free radicals**, highly reactive and unstable molecules produced from oxygen in the normal course of metabolism (and also from UV radiation, air pollution and tobacco smoke). Free radicals contribute to aging and disease. Antioxidants react with free radicals to stabilize them and minimize their harmful effects on cells. Vitamins C and E and beta carotene, an orange pigment found in plants that is converted to vitamin A, are

Table 20•2 Amino acids

NONESSENTIAL AMINO ACIDS*		ESSENTIAL AMINO ACIDS**	
Name	**Pronunciation**	**Name*** **	**Pronunciation**
Alanine	AL-ah-nene	Histidine	HIS-tih-dene
Arginine	AR-jih-nene	Isoleucine	i-so-LU-sene
Asparagine	ah-SPAR-ah-jene	Leucine	LU-sene
Aspartic acid	ah-SPAR-tik AH-sid	Lysine	LI-sene
Cysteine	SIS-teh-ene	Methionine	meh-THI-o-nene
Glutamic acid	glu-TAM-ik AH-sid	Phenylalanine	fen-il-AL-ah-nene
Glutamine	GLU-tah-mene	Threonine	THRE-o-nene
Glycine	GLY-sene	Tryptophan	TRIP-to-fane
Proline	PRO-lene	Valine	VA-lene
Serine	SERE-ene		
Tyrosine	TI-ro-sene		

**Nonessential amino acids can be synthesized by the body.*
***Essential amino acids cannot be synthesized by the body; they must be taken in as part of the diet.*
****If you are ever called upon to memorize the essential amino acids, the mnemonic (memory device) Pvt. T. M. Hill gives the first letter of each name.*

Table 20•3 Minerals

MINERAL	FUNCTIONS	SOURCES	RESULTS OF DEFICIENCY
Calcium (Ca)	Formation of bones and teeth, blood clotting, nerve conduction, muscle contraction	Dairy products, eggs, green vegetables, legumes (peas and beans)	Rickets, tetany, osteoporosis
Phosphorus (P)	Formation of bones and teeth; found in ATP, nucleic acids	Meat, fish, poultry, egg yolk, dairy products	Osteoporosis, abnormal metabolism
Sodium (Na)	Fluid balance; nerve impulse conduction, muscle contraction	Most foods, especially processed foods, table salt	Weakness, cramps, diarrhea, dehydration
Potassium (K)	Fluid balance, nerve and muscle activity	Fruits, meats, seafood, milk, vegetables, grains	Muscular and neurologic disorders
Chloride (Cl)	Fluid balance, hydrochloric acid in stomach	Meat, milk, eggs, processed foods, table salt	Rarely occurs
Iron (Fe)	Oxygen carrier (hemoglobin, myoglobin)	Meat, eggs, fortified cereals, legumes, dried fruit	Anemia, dry skin, indigestion
Iodine (I)	Thyroid hormones	Seafood, iodized salt	Hypothyroidism, goiter
Magnesium (Mg)	Catalyst for enzyme reactions, carbohydrate metabolism	Green vegetables, grains, nuts, legumes	Spasticity, arrhythmia, vasodilation
Manganese (Mn)	Catalyst in actions of calcium and phosphorus; facilitator of many cell processes	Many foods	Possible reproductive disorders
Copper (Cu)	Necessary for absorption and use of iron in formation of hemoglobin; part of some enzymes	Meat, water	Anemia
Chromium (Cr)	Works with insulin to regulate blood glucose levels	Meat, unrefined food, fats and oils	Inability to use glucose
Cobalt (Co)	Part of vitamin B12	Animal products	Pernicious anemia
Zinc (Zn)	Promotes carbon dioxide transport and energy metabolism; found in enzymes	Meat, fish, poultry, grains, vegetables	Alopecia (baldness); possibly related to diabetes
Fluoride (F)	Prevents tooth decay	Fluoridated water, tea, seafood	Dental caries

antioxidants. There are also many compounds found in plants (e.g., soybeans and tomatoes) that are antioxidants.

Checkpoint 20-5 Both vitamins and minerals are needed in metabolism. What is the difference between vitamins and minerals?

Nutritional Guidelines

The relative amounts of carbohydrates, fats and proteins that should be in the daily diet vary somewhat with the individual. Typical recommendations for the number of calories derived each day from the three types of food are as follows:

- Carbohydrate: 55-60%
- Fat: 30% or less
- Protein: 15-20%

It is important to realize that the type as well as the amount of each is a factor in good health. A weight loss diet should follow the same proportions as given above, but with a reduction in portion sizes.

Carbohydrates

Carbohydrates in the diet should be mainly complex, naturally occurring carbohydrates, and simple sugars should be kept to a minimum. Simple sugars are monosaccharides, such as glucose and fructose (fruit sugar), and disaccharides, such as sucrose (table sugar) and lactose (milk sugar). Simple sugars are a source of fast energy because they are metabolized rapidly. However, they boost pancreatic insulin output, and as a result, they cause blood glucose levels to rise and fall rapidly. It is healthier to maintain steady glucose levels, which normally range from approximately 85 to125 mg/dL throughout the day.

The **glycemic effect** is a measure of how rapidly a particular food raises the blood glucose level and stimulates the release of insulin. The effect is generally low for whole grains, fruit and dairy products and high for sweets and refined ("white") grains. Note, however, that the glycemic effect of a food also depends on when it is eaten during the day, and if or how it is combined with other foods.

Complex carbohydrates are polysaccharides. Examples are:

Table 20•4 Vitamins

VITAMINS	FUNCTIONS	SOURCES	RESULTS OF DEFICIENCY
A (retinol)	Required for healthy epithelial tissue and for eye pigments; involved in reproduction and immunity	Orange fruits and vegetables, liver, eggs, dairy products, dark green vegetables	Night blindness; dry, scaly skin; decreased immunity
B1 (thiamin)	Required for enzymes involved in oxidation of nutrients; nerve function	Pork, cereal, grains, meats, legumes, nuts	Beriberi, a disease of nerves
B2 (riboflavin)	In enzymes required for oxidation of nutrients	Milk, eggs, liver, green leafy vegetables, grains	Skin and tongue disorders
B3 (niacin, nicotinic acid)	Involved in oxidation of nutrients	Yeast, meat, liver, grains, legumes, nuts	Pellagra with dermatitis, diarrhea, mental disorders
B6 (pyridoxine)	Amino acid and fatty acid metabolism; formation of niacin; manufacture of red blood cells	Meat, fish, poultry, fruit, grains, legumes, vegetables	Anemia, irritability, convulsions, muscle twitching, skin disorders
Pantothenic acid	Essential for normal growth; energy metabolism	Yeast, liver, eggs, and many other foods	Sleep disturbances, digestive upset
B12 (cyanocobalamin)	Production of cells; maintenance of nerve cells; fatty acid and amino acid metabolism	Animal products	Pernicious anemia
Biotin	Involved in fat and glycogen formation, amino acid metabolism	Peanuts, liver, tomatoes, eggs, and many other foods	Lack of coordination, dermatitis, fatigue
Folate (folic acid)	Required for amino acid metabolism, DNA synthesis, maturation of red blood cells	Vegetables, liver, legumes, seeds	Anemia, digestive disorders, neural tube defects in the embryo
C (ascorbic acid)	Maintains healthy skin and mucous membranes; involved in synthesis of collagen; antioxidant	Citrus fruits, green vegetables, potatoes, orange fruits	Scurvy, poor wound healing, anemia, weak bones
D (calciferol)	Aids in absorption of calcium and phosphorus from intestinal tract	Fatty fish, liver, eggs, fortified milk	Rickets, bone deformities
E (tocopherol)	Protects cell membranes; antioxidant	Seeds, green vegetables, nuts, grains, oils,	Anemia, muscle and liver degeneration, pain
K	Synthesis of blood clotting factors, bone formation	Bacteria in digestive tract, liver, cabbage, and leafy green vegetables	Hemorrhage

- Starches, found in grains, legumes, and potatoes.
- Fibers, such as cellulose, pectins, and gums, which are the structural materials of plants.

Fiber adds bulk to the stool and promotes elimination of toxins and waste. It also slows the digestion and absorption of carbohydrates, thus regulating the release of glucose. It helps in weight control by providing a sense of fullness and limiting caloric intake. Adequate fiber in the diet lowers cholesterol and helps to prevent diabetes, colon cancer, hemorrhoids, appendicitis, and diverticulitis.

Box 20-2 • Health Maintenance

Dietary Fiber: Bulking Up

Dietary fiber is best known for its ability to improve bowel habits and ease weight loss. But fiber may also help to prevent diabetes, heart disease, and certain digestive disorders such as diverticulitis and gallstones.

Dietary fiber is an indigestible type of carbohydrate found in fruit, vegetables, and whole grains. The amount of fiber recommended for a 2,000-calorie diet is 25 grams per day, but most people in the United States tend to get only half this amount. One should eat fiber-rich foods throughout the day to meet the requirement. It is best to increase fiber in the diet gradually to avoid unpleasant symptoms, such as intestinal bloating and flatulence. If your diet lacks fiber, try adding the following foods over a period of several weeks:

- Whole grain breads, cereals, pasta, and brown rice. These add 1 to 3 more grams of fiber per serving than the "white" product.
- Legumes, which include beans, peas, and lentils. These add 4 to 12 grams of fiber per serving.
- Fruits and vegetables. Whole, raw, unpeeled versions contain the most fiber, and juices, the least. Apple juice has no fiber, whereas a whole apple has 3 grams.
- Unprocessed bran. This can be sprinkled over almost any food: cereal, soups, and casseroles. One tablespoon adds 2 grams of fiber. Be sure to take adequate fluids with bran.

Foods high in fiber, such as whole grains, fruits, and vegetables, are also rich in vitamins and minerals (see Box 20-2).

Checkpoint 20-6 What is the normal range of blood glucose?

Fats

Fats are subdivided into saturated and unsaturated forms based on their chemical structure. The fatty acids in **saturated fats** have more hydrogen atoms in their molecules and fewer double bonds between carbons atoms than do those of unsaturated fats (Fig. 20-2). Most saturated fats are from animal sources and are solid at room temperature, such as butter and lard. Also included in this group are the so-called "tropical oils": coconut oil and palm oil. **Unsaturated fats** are derived from plants. They are liquid at room temperature and are generally referred to as oils, such as corn, peanut, olive and canola oils.

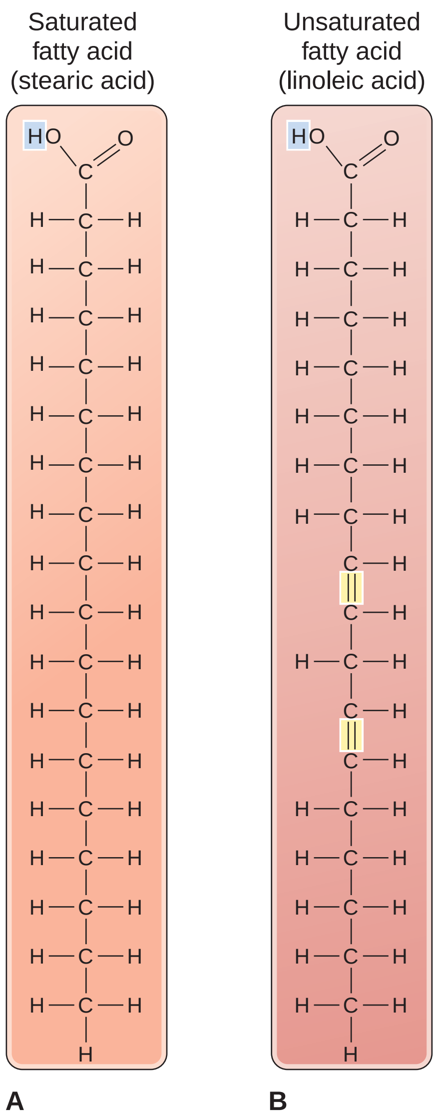


Figure 20-2 Saturated and unsaturated fats. (A) Saturated fatty acids contain the maximum numbers of hydrogen atoms attached to carbons and no double bonds between carbon atoms. **(B)** Unsaturated fatty acids have less than the maximum number of hydrogen atoms attached to carbons and one or more double bonds between carbon atoms (highlighted).

Saturated fats should make up less than one third of the fat in the diet (less than 10% of total calories). Diets high in saturated fats are associated with a higher than normal incidence of cancer, heart disease, and cardiovascular problems, although the relation between these factors is not fully understood.

Many commercial products contain fats that are artificially saturated to prevent rancidity and provide a more solid consistency. These are listed on food labels as partially hydrogenated (HI-dro-jen-a-ted) vegetable oils and are found in baked goods, processed peanut butter, vegetable shortening, and solid margarine. Evidence shows that components of hydrogenated fats, known as *trans-fatty acids*, may be just as harmful, if not more so, than natural saturated fats and should be avoided.

Proteins

Because proteins, unlike carbohydrates and fats, are not stored in special reserves, protein foods should be taken in on a regular basis, with attention to obtaining the essential amino acids. Most animal proteins supply all of the essential amino acids and are described as complete proteins. Most vegetables are lacking in one or more of the essential amino acids. People on strict vegetarian diets must learn to combine foods, such as legumes (*e.g.*, beans and peas) with grains (*e.g.*, rice, corn, or wheat), to obtain all the essential amino acids each day. Table 20-5 demonstrates the principles of combining two foods, legumes and grains, to supply essential amino acids that might be missing in one food or the other. Legumes are rich in isoleucine and lysine but poor in methonine and tryptophan, while grains are just the opposite. For illustration purposes, the table includes only the 4 missing essential amino acids (there are 9 total). Traditional ethnic diets reflect these healthy combinations, for example, beans with corn or rice in Mexican dishes or chickpeas and lentils with wheat in Middle Eastern fare.

Vitamin and Mineral Supplements

The need for mineral and vitamin supplements to the diet is a subject of controversy. Some researchers maintain that adequate amounts of these substances can be obtained from a varied, healthful diet. Many commercial foods, including milk, cereal and bread, are already fortified with minerals and vitamins. Others hold that pollution, depletion of the soils, and the storage, refining, and processing of foods make additional supplementation beneficial. Most agree, however, that children, elderly people, pregnant and lactating women, and teenagers, who often do not get enough of the proper foods, would profit from additional minerals and vitamins.

Table 20•5 Combining Foods for Essential Amino Acids

	ESSENTIAL AMINO ACIDS*			
	ISOLEUCINE	LYSINE	METHIONINE	TRYPTOPHAN
Legumes	x	x		
Grains			x	x
Legumes and grains combined	x	x	x	x

**There are 9 essential amino acids; the table includes 4 for the purposes of illustration.*

When required, supplements should be selected by a physician or nutritionist to fit an individual's particular needs. Megavitamin dosages may cause unpleasant reactions and in some cases are hazardous. Vitamins A and D have both been found to cause serious toxic effects when taken in excess.

The Food Guide Pyramid

In 1992, the USDA (United States Department of Agriculture) developed a pyramid to represent the quantities of foods in the different food groups recommended each day for good health (Fig. 20-3). This symbol is under revision, and some suggested improvements include:

- Distinguish between unrefined and refined carbohydrates.
- Distinguish between healthful unsaturated fats, which can be eaten in moderation, and less healthful saturated and processed (trans-) fats, which should be restricted.
- Accommodate vegetarians, who may avoid not only meats, but dairy products and eggs as well.

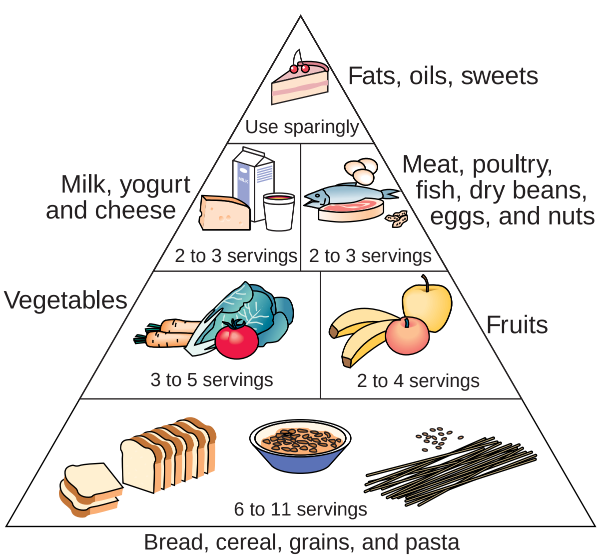


Figure 20-3 **The Food Guide Pyramid.** (From U.S. Department of Agriculture/U.S. Department of Health and Human Services.)

- Specify portion sizes, which are smaller than most people think.
- Include the need for water.
- Indicate possible need for vitamin supplements.

Governments in the U.S. and other countries will continue to study this topic with input from nutritionists and other scientists. The best nutrition guidelines, however, will be of no benefit unless people are educated and motivated to follow them.

Alcohol

Alcohol yields energy in the amount of 7 kcal per gram, but it is not considered a nutrient because it does not yield useful end products. In fact, alcohol interferes with metabolism and contributes to a variety of disorders.

The body can metabolize about one-half ounce of pure alcohol (ethanol) per hour. This amount translates into one glass of wine, one can of beer, or one shot of hard liquor. Consumed at a more rapid rate, alcohol enters the bloodstream and affects many cells, notably in the brain.

Alcohol is rapidly absorbed through the stomach and small intestine and is detoxified by the liver. When delivered in excess to the liver, alcohol can lead to the accumulation of fat as well as inflammation and scarring of liver tissue. It can eventually cause cirrhosis (*sih-RO-sis*), which involves irreversible changes in liver structure. Alcohol metabolism ties up enzymes needed for oxidation of nutrients and also results in byproducts that acidify body fluids. Other effects of alcoholism include obesity, malnutrition, cancer, ulcers, and fetal alcohol syndrome. Pregnant women are advised not to drink any alcohol. In addition, alcohol impairs judgment and leads to increased involvement in accidents.

Although alcohol consumption is compatible with good health and may even have a beneficial effect on the cardiovascular system, alcohol should be consumed only in moderation.

Checkpoint 20-7 What are typical recommendations for the relative amounts of carbohydrates, fats, and proteins in the diet?

Nutritional Disorders

Diet-related problems may originate from an excess or shortage of necessary nutrients. Another issue in the news today is weight control. Food allergies may also affect some people.

Food Allergies

Some people develop clear allergic (hypersensitive) symptoms if they eat certain foods. Common food allergens are wheat, nuts, milk, shellfish, and eggs, but almost any food might cause an allergic reaction in a given individual. People may also have allergic reactions to food additives, such as flavorings, colorings, or preservatives. Signs of allergic reactions usually involve the skin, respiratory tract, or gastrointestinal tract. Food allergies may provoke potentially fatal anaphylactic shock in extremely sensitive individuals.

Malnutrition

If any vital nutrient is missing from the diet, the body will suffer from malnutrition. One commonly thinks of a malnourished person as someone who does not have enough to eat, but malnutrition can also occur from eating too much of the wrong foods. Factors that contribute to malnutrition are poverty, old age, chronic illness, anorexia, poor dental health, and drug or alcohol addiction.

In poor and underdeveloped countries, many children suffer from protein and energy malnutrition (PEM). **Marasmus** (mah-RAZ-mus) is a term used for severe malnutrition in infancy (from Greek meaning "dying away").

Kwashiorkor (kwash-e-OR-kor) typically affects older children when they are weaned because another child is born (and the name means just that). A low protein level in the blood plasma interferes with fluid return to the capillaries, resulting in edema. Often excess fluid accumulates in the abdomen as ascites (ah-SI-teze) fluid, causing the stomach to bulge.

Overweight and Obesity

The causes of obesity are complex, involving social, economic, genetic, psychological and metabolic factors. It is common knowledge that overweight and obesity have increased in the past several decades in many countries. In the U.S., 35% of adults are overweight and an additional 30% are obese (see "Body Mass Index" below.) Obesity shortens the life span and is associated with cardiovascular disease, diabetes, some cancers, and other diseases. The incidence of type II diabetes, once considered to have an adult onset, has increased greatly among children. Some researchers hold that obesity has a closer correlation to chronic disease than poverty, smoking, or drinking alcohol.

Scientists are studying the nervous and hormonal controls over weight, but so far they have not found any effective and safe drugs for weight control. For most people, a varied diet eaten in moderation and regular exercise are the surest ways to avoid obesity. One-half hour of vigorous exercise at least four times a week is recommended for health and weight control.

Body Mass Index **Body mass index** (BMI) is a measurement used to evaluate body size. It is based on the ratio of weight to height (Fig. 20-4). BMI is calculated by dividing weight in kilograms by height in meters squared. (For those not accustomed to using the metric system, an alternate method is to divide weight in pounds by the square of height in inches and multiply by 703.) A healthy range for this measurement is 19-24. Overweight is defined as a BMI of 25-30, and obesity as a BMI greater than 30. However, BMI does not take into account the relative amount of muscle and fat in the body. For example, a bodybuilder might be healthy with a higher than typical BMI because muscle has a higher density than fat.

Calculation of body mass index (BMI)

Formula:

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$$

Conversion:

Kilograms = pounds ÷ 2.2

Meters = inches ÷ 39.4

Example:

A woman who is 5'4" tall and weighs 134 pounds has a BMI of 23.5.

Weight: 134 pounds ÷ 2.2 = 61kg

Height: 64 inches ÷ 39.4 = 1.6m; $(1.6)^2 = 2.6$

$$\text{BMI} = \frac{61\text{kg}}{2.6\text{m}} = 23.5$$

Figure 20-4 Calculation of body mass index (BMI). *ZOOMING IN ◆ What is the BMI of a male 5'10" in height who weighs 170 pounds? (Round off to one decimal place.)*

Underweight

People who are underweight have as much difficulty gaining weight as others have losing it. The problem of underweight may result from rapid growth, eating disorders, allergies, illness, or psychological factors. It is associated with low reserves of energy, reproductive disturbances, and nutritional deficiencies. A BMI of less than 18.5 is defined as underweight. To gain weight, people have to increase their intake of calories, but they should also exercise to add muscle tissue and not just fat.

Nutrition and Aging

With age, a person may find it difficult to maintain a balanced diet. Often, the elderly lose interest in buying and preparing food or are unable to do so. Because metabolism generally slows, and less food is required to meet energy needs, nutritional deficiencies may develop. Medications may interfere with appetite and with the absorption and use of specific nutrients.

It is important for older people to seek out foods that are "nutrient dense," that is, foods that have a high proportion of nutrients in comparison with the number of calories they provide. Exercise helps to boost appetite and

Box 20-3 • Health Professions

Dietitians and Nutritionists

Dietitians and nutritionists specialize in planning and supervising food programs for institutions such as hospitals, schools, and nursing care facilities. They assess their clients' nutritional needs and design individualized meal plans. Dietitians and nutritionists also work in community settings, educating the public about disease prevention through healthy eating. Increased public awareness about food and nutrition has also led to new opportunities in the food manufacturing industry. To perform their duties, dietitians and nutritionists need a thorough understanding of anatomy and physiology. Most dietitians and nutritionists in the United States receive their training from a college or university and take a licensing exam.

Job prospects for dietitians and nutritionists are good. As the American population continues to age, the need for nutritional planning in hospital and nursing care settings is expected to rise. In addition, many people now place an emphasis on healthy eating and may consult nutritionists privately. For more information about this career, contact the American Dietetic Association.

maintains muscle tissue, which is more active metabolically. Box 20-3 describes how dietitians and nutritionists can help in planning a healthful diet for people of all ages.

Body Temperature

Heat is an important byproduct of the many chemical activities constantly occurring in body tissues. At the same time, heat is always being lost through a variety of outlets. Under normal conditions, a number of regulatory devices keep body temperature constant within quite narrow limits. Maintenance of a constant temperature despite both internal and external influences is one phase of homeostasis, the tendency of all body processes to maintain a normal state despite forces that tend to alter them.

Heat Production

Heat is a byproduct of the cellular oxidations that generate energy. The amount of heat produced by a given organ varies with the kind of tissue and its activity. While at rest, muscles may produce as little as 25% of total body heat, but when muscles contract, heat production is greatly multiplied, owing to the increase in metabolic rate. Under basal conditions (at rest), the liver and other abdominal organs produce about 50% of total body heat. The brain produces only 15% of body heat at rest, and an increase in nervous tissue activity produces little increase in heat production.

Although it would seem from this description that some parts of the body would tend to become much warmer than others, the circulating blood distributes the heat fairly evenly.

Factors Affecting Heat Production The rate at which heat is produced is affected by a number of factors, including exercise, hormone production, food intake, and age. Hormones, such as thyroxine from the thyroid gland and epinephrine (adrenaline) from the adrenal medulla, increase the rate of heat production.

The intake of food is also accompanied by increased heat production. The nutrients that enter the blood after digestion are available for increased cellular metabolism. In addition, the glands and muscles of the digestive system generate heat as they set to work. These responses do not account for all the increase, however, nor do they account for the much greater increase in metabolism after a meal containing a large amount of protein. Although the reasons are not entirely clear, the intake of food definitely increases metabolism and thus adds to heat production.

Checkpoint 20-8 What are some factors that affect heat production in the body?

Heat Loss

More than 80% of heat loss occurs through the skin. The remaining 15% to 20% is dissipated by the respiratory system and with the urine and feces. Networks of blood vessels in the skin's dermis (deeper part) can bring considerable quantities of blood near the surface, so that heat can be dissipated to the outside. This release can occur in several ways.

- Heat can be transferred directly to the surrounding air by means **conduction**.
- Heat also travels from its source as heat waves or rays, a process termed **radiation**.
- If the air is moving, so that the layer of heated air next to the body is constantly being carried away and replaced with cooler air (as by an electric fan), the process is known as **convection**.
- Finally, heat may be lost by **evaporation**, the process by which liquid changes to the vapor state.

To illustrate evaporation, rub some alcohol on your skin; it evaporates rapidly, using so much heat from the skin that your arm feels cold. Perspiration does the same thing, although not as quickly. The rate of heat loss through evaporation depends on the humidity of the surrounding air. When it exceeds 60% or so, perspiration does not evaporate so readily, making one feel generally miserable unless some other means of heat loss is available, such as convection caused by a fan.

Prevention of Heat Loss Factors that play a part in heat loss through the skin include the volume of tissue compared with the amount of skin surface. A child loses heat more rapidly than does an adult. Such parts as fingers and toes are affected most by exposure to cold because they have a great amount of skin compared with total tissue volume.

If the temperature of the surrounding air is lower than that of the body, excessive heat loss is prevented by both natural and artificial means. Clothing checks heat loss by trapping "dead air" in both its material and its layers. This noncirculating air is a good insulator. An effective natural insulation against cold is the layer of fat under the skin. Even when skin temperature is low, this fatty tissue prevents the deeper tissues from losing much heat. On the average, this layer is slightly thicker in females than in males. Naturally, there are individual variations, but as a rule, the degree of insulation depends on the thickness of this subcutaneous fat layer.

Temperature Regulation

Given that body temperature remains almost constant despite wide variations in the rate of heat production or loss, there must be internal mechanisms for regulating temperature.

The Role of the Hypothalamus Many areas of the body take part in heat regulation, but the most important center is the hypothalamus, the area of the brain located just above the pituitary gland. Some of the cells in the hypothalamus control heat production in body tissues, whereas another group of cells controls heat loss. Regulation is based on the temperature of the blood circulating through the brain and also on input from temperature receptors in the skin.

If these two factors indicate that too much heat is being lost, impulses are sent quickly from the hypothalamus to the autonomic (involuntary) nervous system, which in turn causes constriction of the skin blood vessels to reduce heat loss. Other impulses are sent to the muscles to cause shivering, a rhythmic contraction of many muscles, which results in increased heat production. Furthermore, the output of epinephrine may be increased if necessary. Epinephrine increases cell metabolism for a short period, and this in turn increases heat production.

If there is danger of overheating, the hypothalamus stimulates the sweat glands to increase their activity. Impulses from the hypothalamus also cause blood vessels in the skin to dilate, so that increased blood flow to the skin will result in greater heat loss. The hypothalamus may also promote muscle relaxation to minimize heat production.

Muscles are especially important in temperature regulation because variations in the activity of these large tissue masses can readily increase or decrease heat generation. Because muscles form roughly one-third of the body, either an involuntary or an intentional increase in their activity can form enough heat to offset a considerable decrease in the temperature of the environment.

Checkpoint 20-9 What part of the brain is responsible for regulating body temperature?

Age Factors Very young and very old people are limited in their ability to regulate body temperature when exposed to environmental extremes. A newborn infant's body temperature decreases if the infant is exposed to a cool environment for a long period. Elderly people also are not able to produce enough heat to maintain body temperature in a cool environment.

With regard to overheating in these age groups, heat loss mechanisms are not fully developed in the newborn. The elderly do not lose as much heat from their skin as do younger people. Both groups should be protected from extreme temperatures.

Normal Body Temperature The normal temperature range obtained by either a mercury or an electronic thermometer may extend from 36.2°C to 37.6°C (97°F to 100°F). Body temperature varies with the time of day. Usually, it is lowest in the early morning because the muscles have been relaxed and no food has been taken in for several hours. Temperature tends to be higher in the late afternoon and evening because of physical activity and consumption of food.

Normal temperature also varies in different parts of the body. Skin temperature obtained in the axilla (armpit) is lower than mouth temperature, and mouth temperature is a degree or so lower than rectal temperature. It is believed that, if it were possible to place a thermometer inside the liver, it would register a degree or more higher than rectal temperature. The temperature within a muscle might be even higher during activity.

Although the Fahrenheit scale is used in the United States, in most parts of the world, temperature is measured with the **Celsius** (SEL-se-us) thermometer. On this scale, the ice point is at 0° and the normal boiling point of water is at 100°, the interval between these two points being divided into 100 equal units. The Celsius scale is also called the **centigrade scale** (think of 100 cents in a dollar). See Appendix 2 for a comparison of the Celsius and Fahrenheit scales and formulas for converting from one to the other.

Checkpoint 20-10 What is normal body temperature?

Fever

Fever is a condition in which the body temperature is higher than normal. An individual with a fever is described as **febrile** (FEB-ril). Usually, the presence of fever is due to an infection, but there can be many other causes, such as malignancies, brain injuries, toxic reactions, reactions to vaccines, and diseases involving the central nervous system (CNS). Sometimes, emotional upsets can bring on a fever. Whatever the cause, the effect is to reset the body's thermostat in the hypothalamus.

Curiously enough, fever usually is preceded by a chill—that is, a violent attack of shivering and a sensation of cold that blankets and heating pads seem unable to relieve. As a result of these reactions, heat is generated and stored, and when the chill subsides, the body temperature is elevated.

The old adage that a fever should be starved is completely wrong. During a fever, there is an increase in metabolism that is usually proportional to the degree of fever. The body uses available sugars and fats, and there is an increase in the use of protein. During the first week or so of a fever, there is definite evidence of protein destruction, so a high-calorie diet with plenty of protein is recommended.

When a fever ends, sometimes the drop in temperature to normal occurs very rapidly. This sudden fall in temperature is called the **crisis**, and it is usually accompanied by symptoms indicating rapid heat loss: profuse perspiration, muscular relaxation, and dilation of blood vessels in the skin. A gradual drop in temperature, in contrast, is known as **lysis**. A drug that reduces fever is described as **antipyretic** (an-ti-pi-RET-ik).

The mechanism of fever production is not completely understood, but we might think of the hypothalamus as a thermostat that is set higher during fever than normally. This change in the heat-regulating mechanism often follows the injection of a foreign protein or the entrance into the bloodstream of bacteria or their toxins. Substances that produce fever are called **pyrogens** (PI-ro-jens).

Up to a point, fever may be beneficial because it steps up phagocytosis (the process by which white blood cells destroy bacteria and other foreign material), inhibits the growth of certain organisms, and increases cellular metabolism, which may help recovery from disease.

Responses to Excessive Heat

The body's heat-regulating devices are efficient, but there is a limit to what they can accomplish. High outside temperature may overcome the body's heat loss mechanisms, in which case body temperature rises and cellular metabolism with accompanying heat production increases. When body temperature rises, the affected person is apt to suffer from a series of disorders: heat cramps are followed by heat exhaustion, which, if untreated, is followed by heat stroke.

In **heat cramps**, there is localized muscle cramping of the extremities and occasionally of the abdomen. The condition abates with rest in a cool environment and adequate fluids.

With further heat retention and more fluid loss, **heat exhaustion** occurs. Symptoms of this disorder include headache, tiredness, vomiting, and a rapid pulse. The victim feels hot, but the skin is cool due to evaporation of sweat. There may be a decrease in circulating blood volume and lowered blood pressure. Heat exhaustion is also treated by rest and fluid replacement.

Heat stroke (also called sunstroke) is a medical emergency. Heat stroke can be recognized by a body temperature of up to 41°C (105°F); hot, dry skin; and CNS symptoms, including confusion, dizziness, and loss of consciousness. The body has responded to the loss of circulating fluid by reducing blood flow to the skin and sweat glands.

It is important to lower the heatstroke victim's body temperature immediately by removing the individual's clothing, placing him or her in a cool environment, and cooling the body with cold water or ice. The patient should be treated with appropriate fluids containing necessary electrolytes, including sodium, potassium, calcium, and chloride. Supportive medical care is also needed to avoid fatal complications.

Checkpoint 20-11 What are some conditions brought on by excessive heat?

Responses to Excessive Cold

The body is no more capable of coping with prolonged exposure to cold than with prolonged exposure to heat. If, for example, the body is immersed in cold water for a time, the water (a better heat conductor than air) removes more heat from the body than can be replaced, and temperature falls. Cold air can produce the same result, particularly when clothing is inadequate. The main effects of an excessively low body temperature, termed **hypothermia** (hi-po-THER-me-ah), are uncontrolled shivering, lack of coordination, and decreased heart and respiratory rates. Speech becomes slurred, and there is overpowering sleepiness, which may lead to coma and death. Outdoor activities in cool, not necessarily cold, weather cause many unrecognized cases of hypothermia. Wind, fatigue, and depletion of water and energy stores all play a part.

When the body is cooled below a certain point, cellular metabolism slows, and heat production is inadequate to maintain a normal temperature. The person must then be warmed gradually by heat from an outside source. The best first aid measure is to remove the person's clothing and put him or her in a warmed sleeping bag with an unclothed companion until shivering stops. Administration of warm, sweetened fluids also helps.

Exposure to cold, particularly to moist cold, may result in **frostbite**, which can cause permanent local tissue damage. The areas most likely to be affected by frostbite are the face, ears, and extremities. Formation of ice crystals and reduction of blood supply to an area leads to necrosis (death) of tissue and possible gangrene. The very young, the very old, and those who suffer from disease of the circulatory system are particularly susceptible to cold injuries.

A frostbitten area should never be rubbed; rather, it should be thawed by application of warm towels or immersion in circulating lukewarm (not hot) water for 20 to 30 minutes. The affected area should be treated gently; a person with frostbitten feet should not be permitted to walk. People with cold-damaged extremities frequently have some lowering of body temperature. The whole body should be warmed at the same time that the affected part is warmed.

Hypothermia is employed in certain types of surgery. In these circumstances, drugs are used to depress the hypothalamus and reduce the body temperature to as low as 25°C (77°F) before the surgeon begins the operation. In heart surgery, the blood is cooled further 20°C (68°F) as it goes through the heart-lung machine. This method has been successful even in infants.

Checkpoint 20-12 What is the term for excessively low body temperature?

Word Anatomy

Medical terms are built from standardized word parts (prefixes, roots, and suffixes). Learning the meanings of these parts can help you remember words and interpret unfamiliar terms.

WORD PART	MEANING	EXAMPLE
Metabolism		
glyc/o	sugar, sweet	*Glycogen* yields glucose molecules when it breaks down.
-lysis	separating, dissolving	*Glycolysis* is the breakdown of glucose for energy.
Body Temperature		
pyr/o	fire, fever	An *antipyretic* drug reduces fever.
therm/o	heat	*Hypothermia* is an excessively low body temperature.

Summary

I. Metabolism—life-sustaining reactions that occur in the living cell

1. Catabolism—breakdown of complex compounds into simpler compounds
2. Anabolism—building of simple compounds into substances needed for cellular activities, growth, and repair

A. Cellular respiration—a series of reactions in which food is oxidized for energy
   1. Anaerobic phase—does not require oxygen
      a. Location—cytoplasm
      b. Yield—2 ATP per glucose
      c. End product—organic (i.e., pyruvic acid)
   2. Aerobic phase—requires oxygen
      a. Location—mitochondria
      b. Yield—34-36 ATP per glucose
      c. End products—carbon dioxide and water
   3. Metabolic rate—rate at which energy is released from food in the cells
      a. Basal metabolism—amount of energy needed to maintain life functions while at rest

B. Use of nutrients for energy
   1. Glucose—main energy source
   2. Fats—highest energy yield
   3. Proteins—can be used for energy after removal of nitrogen (deamination)

C. Anabolism
   1. Essential amino acids and fatty acids must be taken in as part of diet

D. Minerals and vitamins
   1. Minerals—elements needed for body structure and cell activities
      a. Trace elements—elements needed in extremely small amounts
   2. Vitamins—organic substances needed in small amounts
      a. Antioxidants (*e.g.*, vitamins C and E) protect against free radicals

II. Nutritional guidelines

A. Carbohydrates
   1. 55-60% of calories
   2. Should be complex (unrefined) not simple (sugars)
      a. Glycemic effect—how quickly a food raises blood glucose and insulin
      b. Plant fiber important

B. Fats
   1. 30% or less of calories
   2. Unsaturated healthier than saturated
      a. Hydrogenated fats artificially saturated

C. Proteins
   1. 15-20% of calories
   2. Complete—all essential amino acids
      a. Need to combine plant foods

D. Mineral and vitamin supplements

E. Food Guide Pyramid (USDA)—under revision

F. Alcohol—metabolized in liver

III. Nutritional disorders

A. Food allergies
B. Malnutrition
C. Overweight and obesity
  1. Body mass index (BMI)—weight (kg) ÷ **(height [m])^2**
D. Underweight

IV. Nutrition and aging

V. Body temperature

A. Heat production
  1. Most heat produced in muscles and glands
  2. Distributed by the circulation
  3. Affected by exercise, hormones, food, age
B. Heat loss
  1. Avenues—skin, urine, feces, respiratory system
  2. Mechanisms—conduction, radiation, convection, evaporation
  3. Prevention of heat loss—clothing, subcutaneous fat
C. Temperature regulation
  1. Hypothalamus—main temperature-regulating center
    a. Responds to temperature of blood in brain and temperature receptors in skin
  2. Conservation of heat
    a. Constriction of blood vessels in skin
    b. Shivering
    c. Increased release of epinephrine
  3. Release of heat
    a. Dilation of skin vessels
    b. Sweating
    c. Relaxation of muscles
  4. Age factors
  5. Normal body temperature—ranges from 36.2°C to 37.68C; varies with time of day and location measured
D. Fever—higher than normal body temperature resulting from infection, injury, toxin, damage to CNS, etc.
  1. Pyrogen—substance that produces fever
  2. Antipyretic—drug that reduces fever
E. Response to excessive heat—heat cramps, heat exhaustion, heat stroke
F. Response to excessive cold
  1. Hypothermia—low body temperature
    a. Results—coma and death
    b. Uses—surgery
  2. Frostbite—reduction of blood supply to areas such as face, ears, toes, fingers
    a. Results—necrosis and gangrene

Questions for Study and Review

Building Understanding

Fill in the blanks

1. Building glycogen from glucose is an example of ______.
2. The amount of energy needed to maintain life functions while at rest is ______.
3. Reserves of glucose are stored in liver and muscle as ______.
4. The most important area of the brain for temperature regulation is the ______.
5. A drug that reduces fever is described as ______.

Matching

Match each numbered item with the most closely related lettered item.

___ 6. Main energy source for the body
___ 7. Chemical element required for normal body function
___ 8. Complex organic substance required for normal body function
___ 9. Energy storage molecule with only single bonds between carbon atoms
___ 10. Energy storage molecule with one or more double bonds between carbon atoms

a. saturated fat
b. vitamin
c. mineral
d. unsaturated fat
e. glucose

Multiple choice

___ 11. During amino acid catabolism, nitrogen is removed by
  a. oxidation
  b. the glycemic effect
  c. lysis
  d. deamination

___ 12. Which of the following would have the lowest glycemic effect?
  a. glucose
  b. sucrose
  c. lactose
  d. starch

___ 13. Alcohol is catabolized by the
  a. small intestine
  b. liver
  c. pancreas
  d. spleen

___ 14. Amino acids that cannot be made by metabolism are said to be
  a. essential
  b. nonessential

c. antioxidants
d. free radicals

Understanding Concepts

15. In what part of the cell does anaerobic respiration occur and what are its end products? In what part of the cell does aerobic respiration occur? What are its end products?
16. About how many kilocalories are released from a tablespoon of butter (14 grams)? a tablespoon of sugar (12 grams)? a tablespoon of egg white (15 grams)?
17. If you eat 2000 kcal a day, how many kilocalories should come from carbohydrates? from fats? from protein?
18. How is heat produced in the body? What structures produce the most heat during increased activity?
19. Emily's body temperature increased from 36.2 °C to 36.5 °C and then decreased to 36.2°C Describe the feedback mechanism regulating Emily's body temperature.
20. Define *fever*. Name some aspects of the course of fever, and list some of its beneficial and harmful effects.
21. What is hypothermia? Under what circumstances does it usually occur? List some of its effects.
22. Differentiate between the terms in the following pairs:
    a. conduction and convection
    b. radiation and evaporation
    c. marasmus and kwashiorkor
    d. lysis and crisis
    e. heat exhaustion and heat stroke

Conceptual Thinking

23. The oxidation of glucose to form ATP is often compared to the burning of fuel. Why is this analogy inaccurate?
24. Richard M, a self-described couch potato, is six feet tall and weighs 240 pounds. Calculate Richard's body mass index. Is Richard overweight or obese? List some diseases associated with obesity.