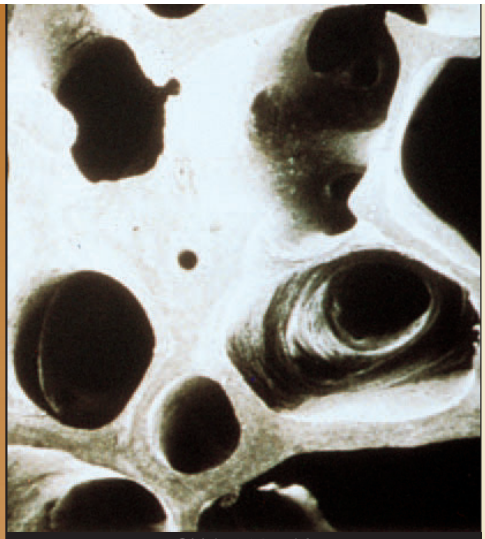


CHAPTER 19

Nutrition
Food and Diet

19

Chapter Outline

Key Concepts	Applications
Recognize the functions of the six types of nutrients.	• Understand the value of recommended dietary allowances. • Understand why deficiencies of certain nutrients result in ill health.
Understand the value of a balanced diet consisting of each of the food groups.	• Explain why grains should make up the bulk of your diet. • Recognize that some protein sources do not contain all the essential amino acids. • Describe why some nutrients should be limited in order to maintain good health.
Know that a calorie is a measure of energy.	• Recognize that exercise is important in expending the energy gained by eating. • Appreciate that some foods will have more calories than others. • Explain how metabolic rate is related to diet and weight control.
Understand that there is a great deal of individual variation in the basal metabolic rate and the voluntary activity of people.	• Understand that the food needs of people change at different points in their lives. • Recognize that overeating and under-exercising has resulted in a U.S. population in which approximately 60% of the population is overweight or obese.
Understand that eating has a strong psychological motivation.	• Identify the signs and symptoms of the common eating disorders that affect health.

19.1 Living Things as Chemical Factories: Matter and Energy Manipulators

Organisms maintain themselves by constantly processing molecules to provide building blocks for new living material and energy to sustain themselves. Autotrophs can manufacture organic molecules from inorganic molecules, but heterotrophs must consume organic molecules to get what they need. All molecules required to support living things are called **nutrients.** Some nutrients are inorganic molecules such as calcium, iron, or potassium; others are organic molecules such as carbohydrates, proteins, fats, and vitamins. All heterotrophs obtain the nutrients they need from food and each kind of heterotroph has particular nutritional requirements. This chapter deals with the nutritional requirements of humans.

The word nutrition is used in two related contexts. First, nutrition is a branch of science that seeks to understand food, its nutrients, how the nutrients are used by the body, and how inappropriate combinations or quantities of nutrients lead to ill health. The word **nutrition** is also used in a slightly different context to refer to all the processes by which we take in food and utilize it, including ingestion, digestion, absorption, and assimilation. **Ingestion** involves the process of taking food into the body through eating. **Digestion** involves the breakdown of complex food molecules to simpler molecules. **Absorption** involves the movement of simple molecules from the digestive system to the circulatory system for dispersal throughout the body. **Assimilation** involves the modification and incorporation of absorbed molecules into the structure of the organism.

Many of the nutrients that enter living cells undergo chemical changes before they are incorporated into the body. These interconversion processes are ultimately under the control of the genetic material, DNA. It is DNA that codes the information necessary to manufacture the enzymes required to extract energy from chemical bonds and to convert raw materials (nutrients) into the structure (anatomy) of the organism.

The food and drink consumed from day to day constitute a person's **diet.** It must contain the minimal nutrients necessary to manufacture and maintain the body's structure (bones, skin, tendon, muscle, etc.) and regulatory molecules (enzymes and hormones), and to supply the energy (ATP [adenosine triphosphate]) needed to run the body's machinery. If the diet is deficient in nutrients, or if a person's body cannot process nutrients efficiently, a dietary deficiency and ill health may result. A good understanding of nutrition can promote good health and involves an understanding of the energy and nutrient content in various foods.

19.2 Kilocalories, Basal Metabolism, and Weight Control

The unit used to measure the amount of energy in foods is the **kilocalorie (kcal).** The amount of energy needed to raise the temperature of 1 *kilogram* of water 1°C is 1 kilocalorie. Remember that the prefix *kilo-* means "1,000 times" the value listed. Therefore, a kilocalorie is 1,000 times more heat energy than a **calorie,** which is the amount of heat energy needed to raise the temperature of 1 *gram* of water 1°C. However, the amount of energy contained in food is usually called a Calorie with a capital C. This is unfortunate because it is easy to confuse a Calorie, which is really a kilocalorie, with a calorie. Most books on nutrition and dieting use the term Calorie to refer to *food calories*. The energy requirements in kilocalories for a variety of activities are listed in table 19.1.

Significant energy expenditure is required for muscular activity. However, even at rest, energy is required to maintain breathing, heart rate, and other normal body functions. The rate at which the body uses energy when at rest is known as the **basal metabolic rate (BMR).** The basal metabolism of

Table 19.1

TYPICAL ENERGY REQUIREMENTS FOR COMMON ACTIVITIES

Light Activities, 120–150 kcal/h	Light-to-Moderate Activities, 150–300 kcal/h	Moderate Activities, 300–400 kcal/h	Heavy Activities, 400–600 kcal/h
Dressing	Sweeping floors	Pulling weeds	Chopping wood
Typing	Painting	Walking behind lawn mower	Shoveling snow
Studying	Store clerking	Walking 3.5–4 mph on level surface	Walking 5 mph
Standing	Bowling	Calisthenics	Walking up hills
Slow walking	Walking 2–3 mph	Canoeing 4 mph	Cross-country skiing
Sitting activities	Canoeing 2.5–3 mph	Doubles tennis	Swimming
	Bicycling on level surface at 5.5 mph	Volleyball	Jogging 5 mph
		Golf (no cart)	Bicycling 11–12 mph or in hilly terrain

most people requires more energy than their voluntary muscular activity. Much of this energy is used to keep the body temperature constant. A true measurement of basal metabolic rate requires a measurement of oxygen used over a specific period under controlled conditions. There are several factors that affect an individual's basal metabolic rate. Children have higher basal metabolic rates and the rate declines throughout life. Elderly people have the lowest basal metabolic rate. In general, males have higher metabolic rates than women. Height and weight are also important. The larger a person the higher their metabolic rate. With all of these factors taken into account, most young adults would fall into the range of 1,200 to 2,200 kilocalories for a basal metabolic rate. Some other factors are: climate (cold climate = higher BMR), altitude (higher altitude = higher BMR), physical condition (regular exercise raises BMR for some time following exercise), hormones (thyroid-stimulating hormones, growth-stimulating hormones, and androgens raise BMR), previous diet (malnourished or starving persons typically have lower BMR), percent of weight that is fat (fat tissue has a lower metabolic rate than lean tissue), and time of the year (people have higher BMR during the colder part of the year).

Because few of us rest 24 hours a day, we normally require more than the energy needed for basal metabolism. One of these requirements is the amount of energy needed to process the food we eat. This is called **specific dynamic action (SDA)** and is equal to approximately 10% of your total daily kilocalorie intake.

In addition to basal metabolism and specific dynamic action, the activity level of a person determines the number of kilocalories needed. A good general indicator of the number of kilocalories needed above basal metabolism is the type of occupation a person has (table 19.2). Since most adults are relatively sedentary, they would receive adequate amounts of energy if women consumed 2,200 kilocalories and men consumed 2,900 kilocalories per day. Since approximately 60% of Americans are overweight or obese, the U.S. Department of Agriculture has developed a program aimed at educating people about the health hazards of obesity. One of the problems associated with obesity is identification—developing a good definition that can be easily understood. Table 19.3 shows guidelines for determining whether you are overweight or not. It is based on a specific method for determining *body mass index*—appropriate body weight compared to height. Body mass index (BMI) is calculated by determining a person's weight (without clothing) in kilograms and barefoot height in meters. The body mass index is their weight in kilograms divided by their height in meters squared.

$$\text{BMI} = \frac{\text{weight in kilograms}}{(\text{height in meters})^2}$$

(The inside back cover of this book gives conversions to the metric system of measurements.) For example, a person with a height of 5 feet 6 inches (1.68 meters) who weighs 165 pounds (75 kilograms) has a body mass index of 26.6 kg/m^2.

$$\text{BMI} = \frac{\text{kg}}{\text{m}^2} = \frac{75\ \text{kg}}{(1.68\ \text{m})^2} = \frac{75\ \text{kg}}{2.82\ \text{m}^2} = 26.6\ \text{kg/m}^2$$

Table 19.3 provides an easier way to determine your body mass index. Determine your weight without clothes and your height without shoes. Then go to table 19.3. to determine your body mass index.

The ideal body mass index for maintaining good health is between 18.5 and 25 kg/m^2. Therefore, the person described above would be slightly over the recommended weight. Those with a body mass index between 25 and 30 kg/m^2 are considered overweight, but there are no clear indications that there are significant health affects associated with this degree of overweight. Those with a body mass index of 30 kg/m^2 or more have a significantly increased risk of many different kinds of diseases. The higher the body mass index the more significant the risk.

Why is weight control a problem for such a large portion of the population? There are several metabolic pathways that convert carbohydrates (glucose) or proteins to fat. Stored body fat was very important for our prehistoric ancestors because it allowed them to survive periods of food scarcity. In periods of food scarcity the stored body fat can be used to supply energy. The glycerol portion of the fat molecule can be converted to a small amount of glucose which can supply energy for red blood cells and nervous tissue that must have glucose. The fatty acid portion of the molecule can be metabolized by most other tissues directly to produce ATP. Today, however, for most of us food scarcity is not a problem, and even small amounts of excess food consumed daily tend to add to our fat stores.

Although energy doesn't weigh anything, the nutrients that contain the energy do. Weight control is a matter of balancing the kilocalories ingested as a result of dietary intake with the kilocalories of energy expended by normal daily activities and exercise. There is a limit to the rate at which a

Table 19.2

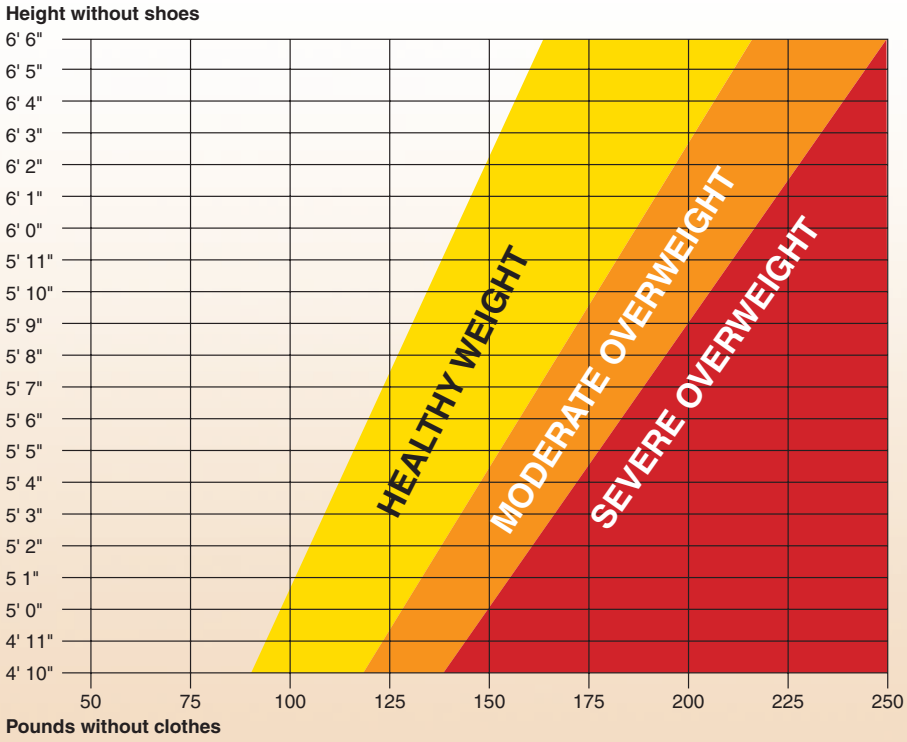
ADDITIONAL KILOCALORIES AS DETERMINED BY OCCUPATION

Occupation	Kilocalories Needed per Day Above Basal Metabolism*
Sedentary (student)	500–700
Light work (business person)	750–1,200
Moderate work (laborer)	1,250–1,500
Heavy work (professional athlete)	1,550–5,000 and up

*These are general figures and will vary from person to person depending on the specific activities performed in the job.

Table 19.3

ARE YOU OVERWEIGHT?



Source: *Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans,* 2000.

moderately active human body can use fat as an energy source. At most, 1 or 2 pounds (0.45–0.9 kilogram) of fat tissue per week are lost by an average person when dieting. Because 1 pound (0.45 kilogram) of fatty tissue contains about 3,500 kilocalories, decreasing your kilocalorie intake by 500 to 1,000 kilocalories per day while maintaining a balanced diet (including proteins, carbohydrates, and fats) will result in fat loss of 1 to 2 pounds (0.45–0.9 kilogram) per week. (A pound of pure fat contains about 4,100 kilocalories, but fat tissue contains other materials besides fat, such as water.)

Many diets promise large and rapid weight loss but in fact result only in temporary water loss. They may encourage eating and drinking foods that are diuretics, which increase the amount of urine produced and thus increase water loss. Or they may encourage exercise or other activities that cause people to lose water through sweating. Low carbohydrate diets deprive the body of glucose needed to sustain nervous tissue and red blood cells. If glucose is not available the body will begin to use protein from the liver and muscles to provide the glucose needed for these vital cells. This kind of weight loss is not healthy. Finally, just reducing the amount of food in the gut by fasting results in a temporary weight loss because the gut is empty.

For those who need to gain weight, increasing kilocalorie intake by 500 to 1,000 kilocalories per day will result in an increase of 1 or 2 pounds per week, provided the low weight is not the result of a health problem.

If you have calculated your body mass index and wish to modify your body weight, what are the steps you should take? First, you should check with your physician before making any drastic change in your eating habits. Second, you need to determine the number of kilocalories you are consuming. That means keeping an accurate diet record for at least a week. Record everything you eat and drink and determine the number of kilocalories in those nutrients. This can be done by estimating the amounts of protein, fat, and carbohydrate (including alcohol) in your foods. Roughly

speaking, 1 gram of carbohydrate is the equivalent of 4 kilocalories, 1 gram of fat is the equivalent of 9 kilocalories, 1 gram of protein is the equivalent of 4 kilocalories, and 1 gram of alcohol is 7 kilocalories. Most nutrition books have food-composition tables that tell you how much protein, fat, and carbohydrate are in a particular food. Packaged foods also have serving sizes and nutritive content printed on the package. Do the arithmetic and determine your total kilocalorie intake for the week. If your intake (from your diet) in kilocalories equals your output (from basal metabolism plus voluntary activity plus SDA), you should not have gained any weight! You can double-check this by weighing yourself before and after your week of record keeping. If your weight is constant and you want to lose weight, reduce the amount of food in your diet. To lose 1 pound each week, reduce your kilocalorie intake by 500 kilocalories per day. Be careful not to eat less than 600 kilocalories of carbohydrates or reduce your total daily intake below 1,200 kilocalories unless you are under the care of a physician. It is important to have some carbohydrate in your diet because a lack of carbohydrate leads to a breakdown of the protein that provides the cells with the energy they need. Also you may not be getting all the vitamins required for efficient metabolism and you could cause yourself harm. To gain 1 pound, increase your intake by 500 kilocalories per day.

A second ingredient valuable in a weight loss plan is an increase in exercise while keeping food intake constant. This can involve organized exercise in sports or fitness programs. It can also include simple things like walking up the stairs rather than taking the elevator, parking at the back of the parking lot so you walk farther, riding a bike for short errands, or walking down the hall to someone's office rather than using the phone. Many people who initiate exercise plans as a way of reducing weight are frustrated because they may initially gain weight rather than lose it. This is because muscle weighs more than fat. Typically they are "out of shape" and have low muscle mass. If they gain a pound of muscle at the same time they lose a pound of fat they will not lose weight. However, if the fitness program continues they will eventually reach a point where they are not increasing muscle mass and weight loss will occur. Even so, weight as muscle is more healthy than weight as fat.

If, like millions of others, you believe that you are overweight, you have probably tried numerous diet plans. Not all of these plans are the same, and not all are suitable to your particular situation. If a diet plan is to be valuable in promoting good health, it must satisfy your needs in several ways. It must provide you with needed kilocalories, proteins, fats, and carbohydrates. It should also contain readily available foods from all the basic food groups, and it should provide enough variety to prevent you from becoming bored with the plan and going off the diet too soon. A diet should not be something you follow only for a while, then abandon and regain the lost weight.

19.3 The Chemical Composition of Your Diet

Nutritionists have divided nutrients into six major classes: carbohydrates, lipids, proteins, vitamins, minerals, and water. Chapters 2 and 3 presented the fundamental structures and examples of these types of molecules. A look at each of these classes from a nutritionist's point of view should help you better understand how your body works and how you might best meet its nutritional needs.

Carbohydrates

When the word *carbohydrate* is mentioned, many people think of things like table sugar, pasta, and potatoes. The term *sugar* is usually used to refer to mono- or disaccharides, but the carbohydrate group also includes more complex polysaccharides, such as starch, glycogen, and cellulose. Starch is the primary form in which we obtain carbohydrates. Each of these has a different structural formula, different chemical properties, and plays a different role in the body (figure 19.1). Many simple carbohydrates taste sweet and stimulate the appetite. When complex carbohydrates like starch or glycogen are broken down to monosaccharides, these may then be utilized in cellular respiration to provide energy in the form of ATP molecules. Simple sugars are also used as building blocks in the manufacture of molecules such as nucleic acids. Complex carbohydrates can also be a source of **fiber** that slows the absorption of nutrients and stimulates peristalsis (rhythmic contractions) in the intestinal tract.

A diet deficient in carbohydrates results in fats being oxidized and converted to ATP. Unfortunately protein is also metabolized to provide cells with the glucose they need for survival. In situations where carbohydrates are absent, most of the fats are metabolized to keto acids. Large numbers of keto acids may be produced in extreme cases of fasting, resulting in a potentially dangerous change in the body's pH. If a person does not have stored fat to metabolize, a carbohydrate deficiency will result in an even greater use of the body's proteins as a source of energy. This is usually only encountered in starvation or extreme cases of fasting or in association with eating disorders. In extreme cases this can be fatal because the oxidation of protein results in an increase in toxic, nitrogen-containing compounds.

A more typical situation for us is the consumption of too much food. As with other nutrients, if there is an excess of carbohydrates in the diet, they are converted to lipids and stored by the body in fat cells—and you gain weight.

Lipids

The class of nutrients technically known as *lipids* is often called *fat* by many people. This is unfortunate and may lead to some confusion because fats are only one of three subclasses of lipids. Each subclass of lipids—phospholipids,

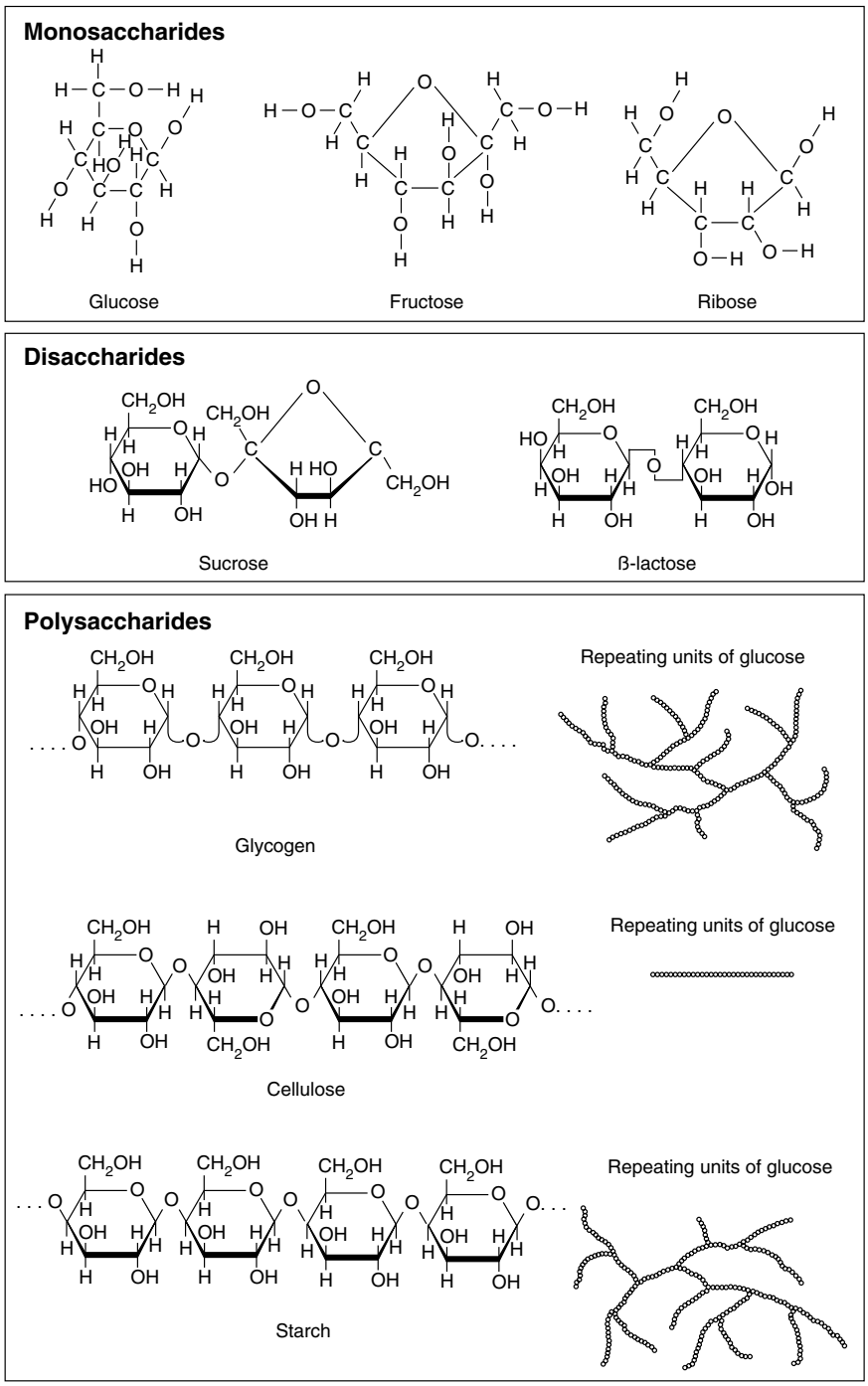


Figure 19.1

The Structure and Role of Various Carbohydrates
The diet includes a wide variety of carbohydrates. Some are monosaccharides (simple sugars); others are more complex disaccharides, trisaccharides, and polysaccharides. The complex carbohydrates differ from one another depending on the type of monosaccharides that are linked together by dehydration synthesis. Notice that the complex carbohydrates shown are primarily from plants. With the exception of milk, animal products are not a good nutritional source of carbohydrates because animals do not store them in great quantities or use large amounts of them as structural materials.

steroids, and true fats—plays an important role in human nutrition. Phospholipids are essential components of all cell membranes. Although various kinds of phospholipids are sold as dietary supplements they are unnecessary because all food composed of cells contains phospholipids. Many steroids are hormones that help regulate a variety of body processes. With the exception of vitamin D, it is not necessary to specifically include steroids as a part of the diet. Cholesterol is a steroid commonly found in certain food and may cause health problems in some people. The *true fats* (also called *triglycerides*) are an excellent source of energy. They are able to release 9 kilocalories of energy per gram compared to 4 kilocalories per gram of carbohydrate or protein. Some fats contain the **essential fatty acids,** linoleic acid and linolenic acid. Neither is synthesized by the human body and, therefore, must be a part of the diet. These essential fatty acids are required by the body for such things as normal growth, blood clotting, and maintaining a healthy skin. Most diets that incorporate a variety of foods including meats and vegetable oils have enough of these essential fatty acids. A diet high in linoleic acid has also been shown to help in reducing the amount of the steroid cholesterol in the blood. Some vitamins, such as vitamins A, D, E, and K do not dissolve in water but dissolve in fat and, therefore, require fat for their absorption from the gut.

Fat is an insulator against outside cold and internal heat loss and is an excellent shock absorber. Deposits in the back of the eyes serve as cushions when the head suffers a severe blow. During starvation, these deposits are lost, and the eyes become deep-set in the eye sockets, giving the person a ghostly appearance.

The pleasant taste and "mouth feel" of many foods is the result of fats. Their ingestion provides that full feeling after a meal because they leave the stomach more slowly than other nutrients. You may have heard people say, "When you

eat Chinese food, you're hungry a half hour later." Because Chinese foods contain very little animal fat, it's understandable that after such a meal, the stomach will empty soon and people won't have that full feeling very long. Conversely, a buffet breakfast of sausages, bacon, eggs, fried potatoes, and pastries contains a great deal of fat and will remain in the stomach for four to five hours. Excess kilocalories obtained directly from fats are stored more efficiently than excess kilocalories obtained from carbohydrates and protein because the body does not need to expend energy to convert the molecules to fat. The fat molecules can simply be disassembled in the gut and reassembled in the cells.

Proteins

Proteins are composed of amino acids linked together by peptide bonds; however, not all proteins contain the same amino acids. Proteins can be divided into two main groups, the **complete proteins** and the **incomplete proteins.** Complete proteins contain all the amino acids necessary for good health, whereas incomplete proteins lack certain amino acids that the body must have to function efficiently. Table 19.4 lists the **essential amino acids,** those that cannot be synthesized by the human body. Without adequate amounts of these amino acids in the diet, a person may develop a protein-deficiency disease. Proteins are essential components of hemoglobin and cell membranes, as well as antibodies, enzymes, some hormones, hair, muscle, and the connective tissue fiber, collagen. Plasma proteins are important because they can serve as buffers and help retain water in the bloodstream. Proteins also provide a last-ditch source of energy during starvation when carbohydrate and fat consumption falls below protective levels.

Unlike carbohydrates and fats, proteins cannot be stored for later use. Because they are not stored and because they serve many important functions in the body, it is important that adequate amounts of protein be present in the daily diet. However, a high-protein diet is not necessary. Only small amounts of protein are metabolized and lost from the body each day. This amounts to about 20 to 30 grams per day. Therefore, it is important to replace this with small amounts of protein in the diet. Any protein in excess of that needed to rebuild lost molecules is metabolized to provide the body with energy. Protein is the most expensive but least valuable energy source. Carbohydrate and fat are much better sources.

The body has several mechanisms that tend to protect protein from being metabolized to provide cells with energy. This relationship is called **protein-sparing.** During fasting or starvation many of the cells of the body can use fat as their primary source of energy, thus protecting the more valuable protein. However, red blood cells and nervous tissue must have glucose to supply their energy needs. Small amounts of carbohydrates can supply the glucose needed. Because very little glucose is stored, after a day or two of fasting the body begins to convert some of the amino acids from protein into glucose to supply these vital cells. Although fat can be used to supply energy for many cells during fasting or starvation it is not able to completely protect the proteins if there is no carbohydrate in the diet. With prolonged starvation the fat stores are eventually depleted and structural proteins are used for all the energy needs of the body.

Table 19.4

SOURCES OF ESSENTIAL AMINO ACIDS

Essential Amino Acids*	Food Sources
Threonine	Dairy products, nuts, soybeans, turkey
Lysine	Dairy products, nuts, soybeans, green peas, beef, turkey
Methionine	Dairy products, fish, oatmeal, wheat
Arginine (essential to infants only)	Dairy products, beef, peanuts, ham, shredded wheat, poultry
Valine	Dairy products, liverwurst, peanuts, oats
Phenylalanine	Dairy products, peanuts, calves' liver
Histidine (essential to infants only)	Human and cow's milk and standard infant formulas
Leucine	Dairy products, beef, poultry, fish, soybeans, peanuts
Tryptophan	Dairy products, sesame seeds, sunflower seeds, lamb, poultry, peanuts
Isoleucine	Dairy products, fish, peanuts, oats, lima beans

*The essential amino acids are required in the diet for protein building and, along with the nonessential amino acids, allow the body to metabolize all nutrients at an optimum rate. Combinations of different plant foods can provide essential amino acids even if complete protein foods (e.g., meat, fish, and milk) are not in the diet.

Most people have a misconception with regard to the amount of protein necessary in their diets. The total amount necessary is actually quite small (about 50 grams/day) and can be easily met. The equivalent of ¼ pound of hamburger, a half chicken breast, or a fish sandwich contains the daily amount of protein needed for the majority of people.

Vitamins

Vitamins are the fourth class of nutrients. **Vitamins** are organic molecules needed in minute amounts to maintain essential metabolic activities. Like essential amino acids and fatty acids, vitamins cannot be manufactured by the body. Table 19.5 lists vitamins for which there are recommended daily intake data. Contrary to popular belief vitamins do not serve as a source of energy, but play a role in assisting specific enzymes that bring about essential biochemical changes.

Table 19.5

VITAMINS: SOURCES AND FUNCTIONS

Name	Recommended Daily Intake for Adults (female; male)	Physiological Value	Readily Available Sources	Other Information
Vitamin A	800–1,000 µg RE	Important in vision; maintain skin and intestinal lining	Orange, red, and dark green vegetables	Fat soluble, stored in liver Children have little stored.
Vitamin B_1 (thiamin)	1.1–1.2 mg	Maintain nerves and heart; involved in carbohydrate metabolism	Whole grain foods, legumes, pork	Larger amounts needed during pregnancy and lactation
Vitamin B_2 (riboflavin)	1.1–1.3 mg	Central role in energy metabolism; maintain skin and mucous membranes	Dairy products, green vegetables, whole grain foods, meat	
Vitamin B_3 (niacin)	14–16 mg NE	Energy metabolism	Whole grain foods, meat	
Vitamin B_6 (pyridoxine pyridoxol, pyradoxamine)	1.3 mg	Form red blood cells; maintain nervous system	Whole grain foods, milk, green leafy vegetables, meats, legumes, nuts	
Vitamin B_{12} (cobalamin)	2.4 µg	Protein and fat metabolism; form red blood cells; maintain nervous system	Animal products only: dairy products, meats, and seafood	Stored in liver Pregnant and lactating women and vegetarians need larger amounts.
Vitamin C	60 mg	Maintain connective tissue, bones, and skin	Citrus fruits, leafy green vegetables, tomatoes, potatoes	Toxic in high doses
Vitamin D	5 µg	Needed to absorb calcium for strong bones and teeth	Vitamin D–fortified milk; exposure of skin to sunlight	Fat soluble
Vitamin E	8–10 µg TE	Antioxidant; protects cell membranes	Whole grain foods, seeds and nuts, vegetables, vegetable oils	Fat soluble Only two cases of deficiency ever recorded
Vitamin K	60–70 µg	Blood clotting	Dark green vegetables	Fat soluble; small amount of fat needed for absorption
Folate (folic acid)	400 µg DFE	Coenzyme in metabolism	Most foods: beans, fortified cereals	Important in pregnancy
Pantothenic acid	5 mg	Involved in many metabolic reactions; formation of hormones, normal growth	All foods	Typical diet provides adequate amounts.
Biotin	30 µg	Maintain skin and nervous system	All foods	Typical diet provides adequate amounts. Added to intravenous feedings
Choline (lecithin)	425–550 mg	Component of cell membranes	All foods	Only important in people unable to consume food normally.

HOW SCIENCE WORKS 19.1

Preventing Scurvy

Scurvy is a nutritional disease caused by the lack of vitamin C in the diet. This lack results in the general deterioration of health because vitamin C is essential to the formation of collagen, a protein important in most tissues. Disease symptoms include poor healing of wounds, fragile blood vessels resulting in bleeding, lack of bone growth, and loosening of the teeth.

Although this is not a common disease today, lack of fresh fruits and vegetables was a common experience for people who were on long sea voyages in previous centuries. This was such a common problem that the disease was often called sea scurvy. Many ship's captains and ship's doctors observed a connection between the lack of fresh fruits and vegetables and the increased incidence of scurvy. Excerpts from a letter by a Dr. Harness to the First Lord of the Admiralty of the British navy give a historical background to the practice of using lemons to prevent scurvy on British ships.

"During the blockade of Toulon in the summer of 1793, many of the ships' companies were afflicted with symptoms of scurvy; . . . I was induced to propose . . . the sending a vessel into port for the express purpose of obtaining lemons for the fleet; . . . and the good effects of its use were so evident. . . that an order was soon obtained from the commander in chief, that no ship under his lordship's command should leave port without being previously furnished with an ample supply of lemons. And to this circumstance becoming generally known may the use of lemon juice, the effectual means of subduing scurvy, while at sea, be traced."

A common term applied to British seamen during this time was "limey."

In some cases the vitamin is actually incorporated into the structure of the enzyme. Such vitamins are called *coenzymes*. For example, a B-complex vitamin (niacin) helps enzymes in the respiration of carbohydrates.

Most vitamins are acquired from food; however, vitamin D may be formed when ultraviolet light strikes a cholesterol molecule already in your skin, converting this cholesterol to vitamin D. This means that vitamin D is not really a vitamin at all. It came to be known as a vitamin because of the mistaken idea that it is only acquired through food rather than being formed in the skin on exposure to sunshine. It would be more correct to call vitamin D a hormone, but most people do not. Most people can get all the vitamins they need from a well-balanced diet. However, because vitamins are inexpensive, and people think they may not be getting the vitamins they need from their diets, many people take vitamin supplements.

Because many vitamins are inexpensive and their functions are poorly understood, there are many who advocate large doses of vitamins (megadoses) to prevent a wide range of diseases. Often the benefits advertised are based on fragmentary evidence and lack a clearly defined mechanism of action. Consumption of high doses of vitamins is unwise because high doses of many vitamins have been shown to be toxic. For example, fat-soluble vitamins such as vitamin A and vitamin D are stored in the fat of the body and the liver. Excess vitamin A is known to cause joint pain, loss of hair, and jaundice. Excess vitamin D results in calcium deposits in the kidneys, high amounts of calcium in the blood, and bone pain. Even high doses of some of the water-soluble vitamins may have toxic effects. Vitamin B_6 (pyridoxine) in high concentrations has been shown to cause nervous symptoms such as unsteady gait and numbness in the hands.

However, inexpensive multivitamins that provide 100% of the recommended daily allowance can prevent or correct deficiencies caused by poor diet without danger of toxic consequences. Most people have no need of vitamins *if they eat a well-balanced diet* (How Science Works 19.1).

Minerals

All **minerals** are inorganic elements found throughout nature and cannot be synthesized by the body. Table 19.6 lists the sources and functions of several common minerals. Because they are elements, they cannot be broken down or destroyed by metabolism or cooking. They commonly occur in many foods and in water. Minerals retain their characteristics whether they are in foods or in the body and each plays a different role in metabolism. Minerals can function as regulators, activators, transmitters, and controllers of various enzymatic reactions. For example, sodium ions (Na^+) and potassium ions (K^+) are important in the transmission of nerve impulses, whereas magnesium ions (Mg^{++}) facilitate energy release during reactions involving ATP. Without iron, not enough hemoglobin would be formed to transport oxygen, a condition called *anemia,* and a lack of calcium may result in *osteoporosis*. **Osteoporosis** is a condition that results from calcium loss leading to painful, weakened bones. There are many minerals that are important in your diet. In addition to those just mentioned, you need chlorine, cobalt, copper, iodine, phosphorus, potassium, sulfur, and zinc to remain healthy. With few exceptions, adequate amounts of minerals are obtained in a normal diet. Calcium and iron supplements may be necessary, particularly in women.

Water

Water is crucial to all life and plays many essential roles. You may be able to survive weeks without food, but you would die in a matter of days without water. It is known as

Table 19.6

MINERALS: SOURCES AND FUNCTIONS

Name	Recommended Daily Intake for Adults (female; male)	Physiological Value	Readily Available Sources	Other Information
Calcium	1,000 mg	Build and maintain bones and teeth	Dairy products	Children need 1,300 mg. Vitamin D needed for absorption.
Fluoride	3.1–3.8 mg	Maintain bones and teeth; reduce tooth decay	Fluoridated drinking water, seafood	
Iodine	150 µg	Necessary to make hormone thyroxine	Iodized table salt, seafood	The soils in some parts of the world are low in iodine so iodized salt in very important.
Iron	15–10 mg	Necessary to make hemoglobin	Grains, meat, seafood, poultry, legumes, dried fruits	Women need more than men; pregnant women need two times the normal dose.
Magnesium	320–420 mg	Bone mineralization; muscle and nerve function	Dark green vegetables, whole grains, legumes	
Phosphorus	700 mg	Acid/base balance; enzyme cofactor	Found in all foods	Children need 1,250 mg. Most people get more than recommended.
Selenium	55–70 µg	Involved in many enzymatic reactions	Meats, grains, seafood	
Zinc	12–15 mg	Wound healing; fetal development; involved in many enzymatic and hormonal activities	Meat, fish, poultry	

the universal solvent because so many types of molecules are soluble in it. The human body is about 65% water. Even dense bone tissue consists of 33% water. All the chemical reactions in living things take place in water. It is the primary component of blood, lymph, and body tissue fluids. Inorganic and organic nutrients and waste molecules are also dissolved in water. Dissolved inorganic ions, such as sodium (Na^+), potassium (K^+), and chloride (Cl^-), are called **electrolytes** because they form a solution capable of conducting electricity. The concentration of these ions in the body's water must be regulated in order to prevent electrolyte imbalances.

Excesses of many types of wastes are eliminated from the body dissolved in water; that is, they are excreted from the kidneys as urine or in small amounts from the lungs or skin through evaporation. In a similar manner, water acts as a conveyor of heat. Water molecules are also essential reactants in all the various hydrolytic reactions of metabolism. Without it, the breakdown of molecules such as starch, proteins, and lipids would be impossible. With all these important roles played by water, it's no wonder that nutritionists recommend that you drink the equivalent of at least eight glasses each day. This amount of water can be obtained from tap water, soft drinks, juices, and numerous food items, such as lettuce, cucumbers, tomatoes, and applesauce.

19.4 Amounts and Sources of Nutrients

In order to give people some guidelines for planning a diet that provides adequate amounts of the six classes of nutrients, nutritional scientists in the United States and many other countries have developed nutrient standards. In the United States, these guidelines are known as the **recommended dietary allowances,** or **RDAs.** RDAs are dietary recommendations, not requirements or minimum standards. They are based on the needs of a healthy person already eating an adequate diet. RDAs do not apply to persons with medical problems who are under stress or suffering from malnutrition. The amount of each nutrient specified by the RDAs has

been set relatively high so that most of the population eating those quantities will be meeting their nutritional needs. Keep in mind that everybody is different and eating the RDA amounts may not meet your personal needs if you have an unusual metabolic condition.

General sets of RDAs have been developed for four groups of people: infants, children, adults, and pregnant and lactating women. The U.S. RDAs are used when preparing product labels. The federal government requires by law that labels list ingredients from the greatest to the least in quantity. The volume in the package must be stated along with the weight, and the name of the manufacturer or distributor. If any nutritional claim is made, it must be supported by factual information.

A product label that proclaims, for example, that a serving of cereal provides 25% of the RDA for vitamin A means that you are getting at least one-fourth of your RDA of vitamin A from a single serving of that cereal. To figure your total RDA of vitamin A, consult a published RDA table for adults. It tells you that an adult male requires 1,000 and a female 800 micrograms (μg) of vitamin A per day. Of this, 25% is 250 and 200 micrograms, respectively—the amount you are getting in a serving of that cereal. You will need to get the additional amounts (750 for men and 600 for women) by having more of that cereal or eating other foods that contain vitamin A. If a product claims to have 100% of the RDA of a particular nutrient, that amount must be present in the product. However, restricting yourself to that one product will surely deprive you of many of the other nutrients necessary for good health. Ideally, you should eat a variety of complex foods containing a variety of nutrients to ensure that all your health requirements are met.

19.5 The Food Guide Pyramid with Five Food Groups

Using RDAs and product labels is a pretty complicated way for a person to plan a diet. Planning a diet around basic food groups is generally easier. The basic food groups first developed and introduced in 1953 have been modified and updated several times to serve as guidelines in maintaining a balanced diet (figure 19.2). In May 1992, the U.S.

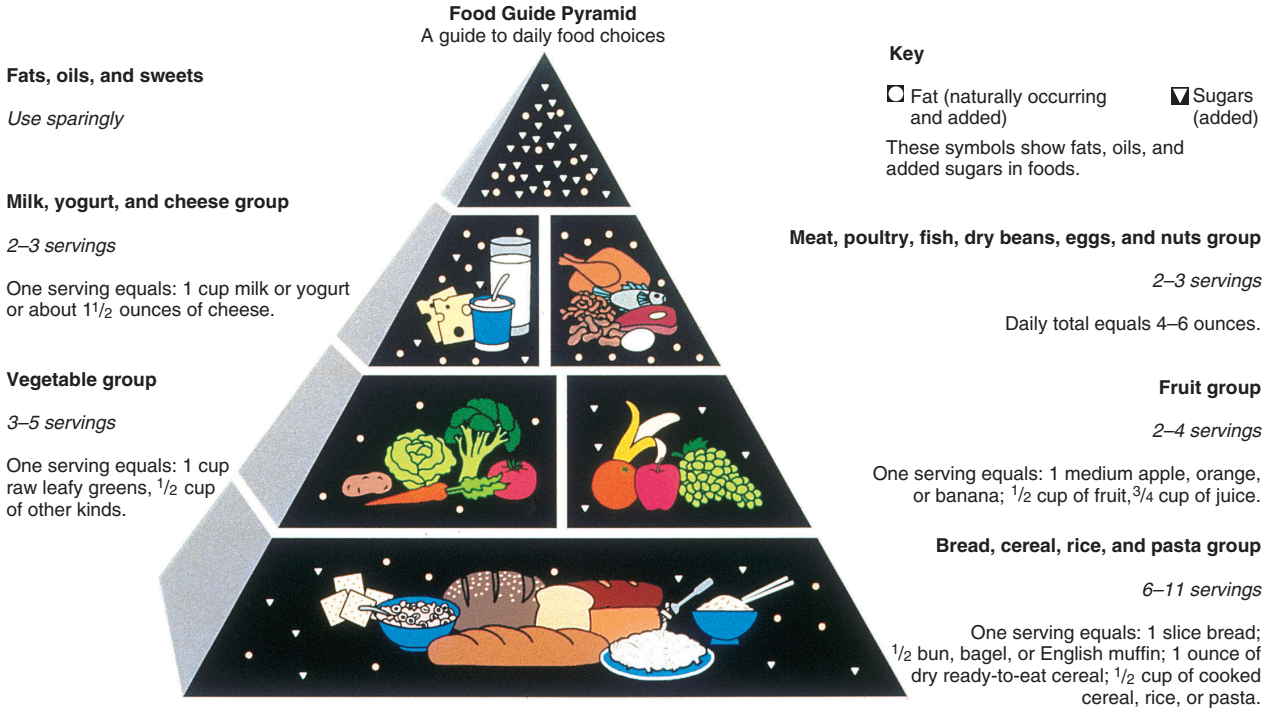


Figure 19.2

The Food Guide Pyramid
In May 1992, the Department of Agriculture released a new guide to good eating. This Food Guide Pyramid suggests that we eat particular amounts of five different food groups while decreasing our intake of fats and sugars. This guide should simplify our menu planning and help ensure that we get all the recommended amounts of basic nutrients.

Source: U.S. Department of Agriculture, 1992.

Department of Agriculture released the results of its most recent study on how best to educate the public about daily nutrition. The federal government adopted the **Food Guide Pyramid** of the Department of Agriculture as one of its primary tools to help the general public plan for good nutrition. The Food Guide Pyramid contains five basic groups of foods with guidelines for the amounts one needs daily from each group for ideal nutritional planning. The Food Guide Pyramid differs from previous federal government information in than it encourages a reduction in the amount of fats and sugars in the diet and an increase in our daily servings of fruits and vegetables. In addition, the new guidelines suggest significantly increasing the amount of grain products we eat each day. Figure 19.3 shows typical serving sizes for each of the categories in the Food Guide Pyramid (Outlooks 19.1).

Grain Products Group

Grains include vitamin-enriched or whole-grain cereals and products such as breads, bagels, buns, crackers, dry and cooked cereals, pancakes, pasta, and tortillas. Items in this group are typically dry and seldom need refrigeration. They should provide most of your kilocalorie requirements in the form of complex carbohydrates like starch, which is the main ingredient in most grain products. You should have 6 to 11 servings from this group each day. This is a major change from previous recommendations of four servings each day. A serving is considered about ½ cup, or 1 ounce, or the equivalent of about 100 kilocalories. Using product labels will help determine the appropriate serving size.*

In addition to their energy content, cereals and grains provide fiber and are rich sources of the B vitamins in your diet. Cereals are also important sources of minerals, iron, magnesium, and selenium. As you decrease the intake of proteins in the meat and poultry group, you should increase your intake of items from this group. These foods help you feel you have satisfied your appetite, and many of them are very low in fat.

Fruits Group

You probably can remember discussions of whether a tomato is a vegetable or a fruit. This controversy arises from the fact that the term *vegetable* is not scientifically precise but means a plant material eaten during the main part of the

*The measurement of ingredients during food preparation varies throughout the world. Some people measure by weight (e.g., grams), others by volume (e.g., cups); some use the metric system (grams), others the English system (pounds). Still others use units of measure that are even less uniform (e.g., "pinches"). This chapter describes quantities of nutrients using the units of measure most familiar to people in the United States.

(a) Meat group

(b) Fruit group

(c) Vegetable group

(d) Cereal group

(e) Dairy group

(f) Fats, sugars, and alcohol

Figure 19.3

Serving Sizes of Basic Foods
These photos show typical serving sizes for many types of foods. Each item in each photo is equivalent to one serving. On a daily basis, an average adult should eat 6 to 11 servings of cereals, 2 to 3 servings from the meat group, 3 to 5 servings from the vegetable group, 2 to 4 servings from the fruit group, and 2 to 3 servings from the dairy group. Fats, sugars, and alcohol should be used sparingly.

OUTLOOKS 19.1

The Dietary Habits of Americans

The U.S. Department of Agriculture has provided Americans with information about diet and nutrition for many years. While there have been some changes in eating habits, there are still a great number of people who do not eat well, nor do they participate in other activities that have the potential to improve their health. The following statements about the dietary and exercise habits of Americans in 2000 illustrate that there are many changes that still need to be made.

- The quantity of fat consumed has increased in the past ten years.
- Fat consumption provides about 33% of Calories for the average American. It is recommended that less than 30% of Calories come from fat.
- Only 17% of the population eat the recommended amount of fruits.
- Only 31% of the population eats the recommended amount of vegetables.
- Only 26% of the population consumes the recommended amount of dairy products.
- 60% of the adult population is overweight or obese.
- 10% of children are overweight or obese.
- 25% of the adult population is obese.
- Less that 30% of the population gets the recommended amount of exercise.
- 25% of the population does not exercise at all.
- Less than 50% of meals eaten in the United States are cooked at home.
- Typical restaurant and fast-food outlets serve enormous portions compared to the serving sizes suggested by the Food Guide Pyramid.
- The proportion of overweight and obese persons has increased over the past 40 years.

In 2000 the U.S. Department of Agriculture responded by publishing a revised set of recommendations regarding food and exercise. The 2000 edition of *Dietary Guidelines for Americans* lists several criteria for maintaining a healthy lifestyle.

Aim for fitness

- Aim for a healthy weight.
- Be physically active each day—30 minutes five times a week.

Build a healthy base

- Let the Food Guide Pyramid guide your food choices.
- Choose a variety of grains daily, especially whole grains.
- Choose a variety of fruits and vegetables daily.
- Keep food safe to eat.

Choose sensibly

- Choose a diet that is low in saturated fat and cholesterol and moderate in total fat—less than 30% of Calories from fat and less than 10% from saturated fats.
- Choose beverages and foods to moderate your intake of sugars.
- Choose and prepare foods with less salt.
- If you drink alcoholic beverages, do so in moderation.

meal. *Fruit,* on the other hand, is a botanical term for the structure that is produced from the female part of the flower that surrounds the ripening seeds. Although, botanically, green beans, peas, and corn are all fruits, nutritionally speaking, they are placed in the vegetable category because they are generally eaten during the main part of the meal. Nutritionally speaking, fruits include such sweet plant products as melons, berries, apples, oranges, and bananas. The Food Guide Pyramid suggests two to four servings of fruit per day. However, because these foods tend to be high in natural sugars, consumption of large amounts of fruits can add significant amounts of kilocalories to your diet. A small apple, half a grapefruit, 1/2 cup of grapes, or 6 ounces of fruit juice is considered a serving. Fruits provide fiber, carbohydrate, water, and certain of the vitamins, particularly vitamin C.

Vegetables Group

The Food Guide Pyramid suggests three to five servings from this group each day. Items in this group include nonsweet plant materials, such as broccoli, carrots, cabbage, corn, green beans, tomatoes, potatoes, lettuce, and spinach. A serving is considered 1 cup of raw leafy vegetables or 1/2 cup of other types. It is wise to include as much variety as possible in this group. If you eat only carrots, several cups each day can become very boring. There is increasing evidence indicating that cabbage, broccoli, and cauliflower can provide some protection from certain types of cancers. This is a good reason to include these foods in your diet.

Foods in this group provide vitamins A and C as well as water and minerals. Leafy green vegetables are good sources of vitamin B_2 (riboflavin), vitamin B_6, vitamin K, and the mineral, magnesium. They also provide fiber, which assists in the proper functioning of the digestive tract.

Dairy Products Group

All of the cheeses, ice cream, yogurt, and milk are in this group. Two servings from this group are recommended each day. Each of these servings should be about 1 cup of ice cream, yogurt, or milk, or 2 ounces of cheese. Using product labels will help you determine the appropriate serving size of

individual items. This group provides not only minerals, such as calcium, in your diet, but also water, vitamins, carbohydrates, and protein. Several of the B vitamins are present in milk and vitamin D and A often are added to the milk. You must remember that many cheeses contain large amounts of cholesterol and fat for each serving. Low-fat dairy products are increasingly common as manufacturers seek to match their products with the desire of the public for less fat in the diet.

Meat, Poultry, Fish, and Dry Beans Group

This group contains most of the things we eat as a source of protein; for example, nuts, peas, tofu, and eggs are considered members of this group. It is recommended that we include 5 to 7 ounces (140–200 grams) of these items in our daily diet. (A typical hamburger patty contains 60 grams of meat.) In general, people in the economically developed world eat at least this quantity and frequently much more. Because many sources of protein also include significant fat, and health recommendations suggest reduced fat, more attention is being paid to the quantity of protein-rich foods in the diet. We have not only decreased our intake of items from this group, but also shifted from the high-fat-content foods, such as beef and pork, to foods that are high in protein but lower in fat content, such as fish and poultry. Beans (except for the oil-rich soybean) are also excellent ways to get needed protein without unwanted fat. Modern food preparers tend to use smaller portions and cook foods in ways that reduce the fat content. Broiled fish, rather than fried, and baked, skinless portions of chicken or turkey (the fat is attached to the skin) are seen more and more often on restaurant menus and on dining room tables at home.

Remember that the recommended daily portion from this group is only 5 to 7 ounces (140–200 grams). This means that one double cheeseburger meets this recommendation for the daily intake. Actually the RDA for protein in the diet is about 60 grams for adults so the Food Guide Pyramid provides a generous amount of protein. Eating excessive amounts of protein can stress the kidneys by causing higher concentrations of calcium in the urine, increase the demand for water to remove toxic keto acids produced from the breakdown of amino acids, and lead to weight gain because of the fat normally associated with many sources of protein. It should be noted, however, that vegetarians must pay particular attention to acquiring adequate sources of protein because they have eliminated a major source from their diet. Although nuts and soybeans are high in protein they should not be consumed in large quantities because they are also high in fats.

19.6 Eating Disorders

The three most common eating disorders are obesity, bulimia, and anorexia nervosa. All three disorders are related to the prevailing perceptions and values of the culture in which we live. In many cases there is a strong psychological component as well.

Obesity

People who have a body mass index of 30 kg/m^2 or greater are considered **obese,** and suffer from a disease condition known as obesity. Approximately 25% of adults in the U.S. population are obese. Obesity is the condition of being overweight to the extent that a person's health and life span are adversely affected. Obesity occurs when people consistently take in more food energy than is necessary to meet their daily requirements.

On the surface it would appear that obesity is a simple problem to solve. To lose weight all that people must do is consume fewer kilocalories, exercise more, or do both.

Although all obese people have an imbalance between their need for kilocalories and the amount of food they eat, the reasons for this imbalance are complex and varied. It is clear that the prevailing culture has much to do with the incidence of obesity. For example, rates of obesity have increased over time, which strongly suggests that most cases of obesity are due to changes in lifestyle, not inherent biological factors. Furthermore, immigrants from countries with low rates of obesity show increased rates of obesity when they integrate into the American culture.

Many people attempt to cope with the problems they face by overeating. Overeating to solve problems is encouraged by our culture. Furthermore, food consumption is central to most kinds of celebrations. Social gatherings of almost every type are considered incomplete without some sort of food and drink. If snacks (usually high-calorie foods) are not made available by the host, many people feel uneasy or even unwelcome. It is also true that Americans and people of other cultures show love and friendship by sharing a meal. Many photographs in family albums have been taken at mealtime. In addition, less than half the meals consumed in the United States are prepared in the home. Under these conditions the consumer has reduced choices in the kind of food available, no control over the way foods are prepared, and little control over serving size. Meals prepared in restaurants and fast-food outlets emphasize meat and minimize the fruit, vegetable, and cereal portions of a person's diet, in direct contrast to the Food Guide Pyramid. The methods of preparation also typically involve cooking with oils and serving with dressings or fat-containing condiments. In addition, portion sizes are generally much larger than recommended.

Recent discoveries of genes in mice suggest that there are genetic components to obesity. Mice without a crucial gene gained an extraordinary amount of weight. There is some suggestion that there may be similar genes in humans. It is clear also that some people have much lower metabolic rates than the majority of the population and, therefore, need much less food than is typical. Still other obese individuals have a chemical imbalance of the nervous system that prevents them from feeling "full" until they have eaten an excessive amount of food. This imbalance prevents the brain from "turning off" the desire to eat after a reasonable amount of food has been eaten. Research into the nature and action of this brain chemical indicates that if obese people

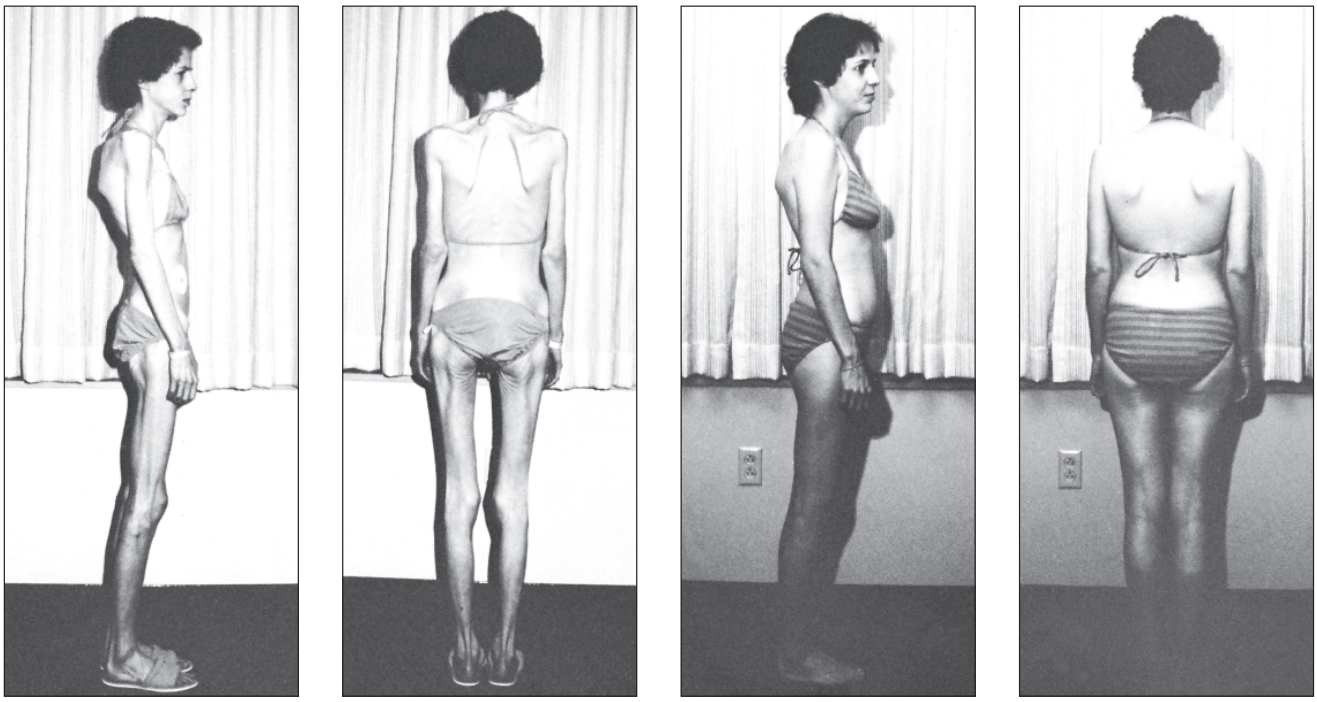


Figure 19.4

Anorexia Nervosa
Anorexia nervosa is a psychological eating disorder afflicting many Americans. These photographs were taken of an individual before and after treatment. Restoring a person with this disorder requires both medical and psychological efforts.

lacking this chemical receive it in pill form, they can feel "full" even when their food intake is decreased by 25%.

Health practitioners are changing their view of obesity from one of blaming the obese person for lack of self-control to one of treating the condition as a chronic disease that requires a varied approach to control. For the majority of people dietary counseling and increased exercise is all that is needed. But others need psychological counseling and some may need drug therapy or surgery. Regardless, controlling obesity can be very difficult because it requires basic changes in a person's eating habits, lifestyle, and value system.

Bulimia

Bulimia ("hunger of an ox" in Greek) is a disease condition in which the person has a cycle of eating binges followed by purging the body of the food by inducing vomiting or using laxatives. Many bulimics also use diuretics that cause the body to lose water and, therefore, reduce weight. It is often called the silent killer because it is difficult to detect. Bulimics are usually of normal body weight or are overweight. The cause is thought to be psychological, stemming from depression, low self-esteem, displaced anger, a need to be in control of one's body, or a personality disorder. Many bulimics have other compulsive behaviors such as drug abuse as well and are often involved in incidences of theft and suicide.

Vomiting may be induced physically or by the use of some nonprescription drugs. Case studies have shown that bulimics may take 40 to 60 laxatives a day to rid themselves of food. For some, the laxative becomes addictive. The binge-purge cycle and associated use of diuretics result in a variety of symptoms that can be deadly. The following is a list of the major symptoms observed in many bulimics:

Excessive water loss
Diminished blood volume
Extreme potassium, calcium, and sodium deficiencies
Kidney malfunction
Increase in heart rate
Loss of rhythmic heartbeat
Lethargy
Diarrhea
Severe stomach cramps
Damage to teeth and gums
Loss of body proteins
Migraine headaches
Fainting spells
Increased susceptibility to infections

Anorexia Nervosa

Anorexia nervosa (figure 19.4) is a nutritional deficiency disease characterized by severe, prolonged weight loss as a result of a voluntary severe restriction in food intake. An anorexic person's fear of becoming overweight is so intense that even though weight loss occurs, it does not lessen the fear of obesity, and the person continues to diet, often even refusing to maintain the optimum body weight for his or her age, sex, and height. This nutritional deficiency disease is thought to stem from sociocultural factors. Our society's preoccupation with weight loss and the desire to be thin strongly influences this disorder.

Just turn on your television or radio, or look at newspapers, magazines, or billboards, and you can see how our culture encourages people to be thin. Male and female models are thin. Muscular bodies are considered healthy and any stored body fat unhealthy. Unless you are thin, so the advertisements imply, you will never be popular, get a date, or even marry. Our culture's constant emphasis on being thin has influenced many people to become anorexic and lose too much weight. Anorexic individuals frequently starve themselves to death. Individuals with anorexia are mostly adolescent and preadolescent females, although the disease does occur in males. Here are some of the symptoms of anorexia nervosa:

Thin, dry, brittle hair
Degradation of fingernails
Constipation
Amenorrhea (lack of menstrual periods)
Decreased heart rate
Loss of body proteins
Weaker-than-normal heartbeat
Calcium deficiency
Osteoporosis
Hypothermia (low body temperature)
Hypotension (low blood pressure)
Increased skin pigmentation
Reduction in size of uterus
Inflammatory bowel disease
Slowed reflexes
Fainting
Weakened muscles

19.7 Deficiency Diseases

Without minimal levels of the essential amino acids in the diet, a person may develop health problems that could ultimately lead to death. In many parts of the world, large populations of people live on diets that are very high in carbohydrates and fats but low in complete protein. This is easy to understand because carbohydrates and fats are inexpensive to grow and process in comparison to proteins. For example, corn, rice, wheat, and barley are all high-carbohydrate foods. Corn and its products (meal, flour) contain protein, but it is an incomplete protein that has very low amounts of the amino acids tryptophan and lysine. Without enough of these amino acids, many necessary enzymes cannot be made in sufficient amounts to keep a person healthy. One protein-deficiency disease is called **kwashiorkor,** and the symptoms are easily seen (figure 19.5). A person with this deficiency has a distended belly, slow growth, slow movement, and is emotionally depressed. If the disease is caught in time, brain damage may be prevented and death averted. This requires a change in diet that includes expensive protein, such as poultry, fish, beef, shrimp, or milk. As the world food problem increases, these expensive foods will be in even shorter supply and will become more and more costly.

Figure 19.5

Kwashiorkor
This starving child shows the symptoms of kwashiorkor, a protein-deficiency disease. If treated with a proper diet containing all amino acids, the symptoms can be reduced.

Starvation is also a common problem in many parts of the world. Very little carbohydrate is stored in the body. If you starve yourself, this small amount will last as a stored form of energy only for about two days. Even after a few hours of fasting the body begins to use its stored fat deposits as a source of energy; as soon as the carbohydrates are gone proteins will begin to be used to provide a source of glucose. Some of the keto acids produced during the breakdown of fats and amino acids are released in the breath and can be detected as an unusual odor. People who are fasting, anorexic, diabetic, or have other metabolic problems often have this "ketone breath." During the early stages of starvation, the amount of fat in the body steadily decreases, but the amount of protein drops only slightly (20–30 grams

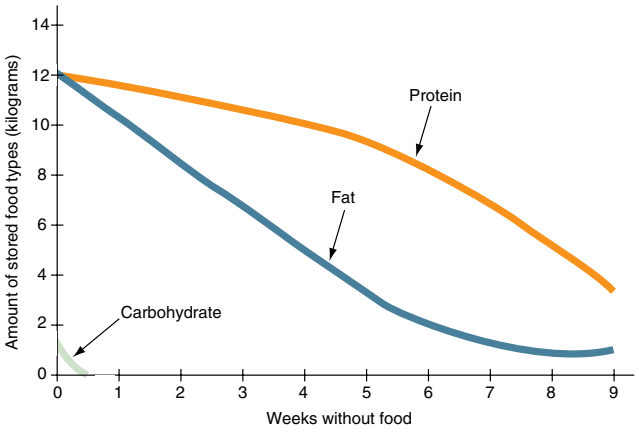


Figure 19.6

Starvation and Stored Foods
Starving yourself results in a very selective loss of the kinds of nutrients stored in the body. Notice how the protein level in the body has the slowest decrease of the three nutrients. This protein-conservation mechanism enables the body to preserve essential amounts of enzymes and other vital proteins.

per day) (figure 19.6). This can continue only up to a certain point. After several weeks of fasting, so much fat has been lost from the body that proteins are no longer protected, and cells begin to use them as a primary source of energy (as much as 125 grams per day). This results in a loss of proteins from the cells that prevents them from carrying out their normal functions. When starvation gets to this point it is usually fatal. When not enough enzymes are available to do the necessary cellular jobs, the cells die. People who are chronically undernourished and lack fat do not have the protective effect of fat and experience the effects of starvation much more quickly than those who have stored fat. Children are particularly at risk because they also have a great need for nutrients to serve as building blocks for growth.

The lack of a particular vitamin in the diet can result in a **vitamin-deficiency disease.** A great deal has been said about the need for vitamin and mineral supplements in diets. Some people claim that supplements are essential; others claim that a well-balanced diet provides adequate amounts of vitamins and minerals. Supporters of vitamin supplements have even claimed that extremely high doses of certain vitamins can prevent poor health or even create "superhumans." It is very difficult to substantiate many of these claims, however. Because the function of vitamins and minerals and their regulation in the body is not completely understood, the RDAs are, at best, estimates by experts who have looked at the data from a variety of studies. In fact, the minimum daily requirement of a number of vitamins has not been determined. Vitamin-deficiency diseases that show recognizable symptoms are extremely rare except in cases of extremely poor nutrition.

19.8 Nutrition Through the Life Cycle

Nutritional needs vary throughout life and are related to many factors, including age, sex, reproductive status, and level of physical activity. Infants, children, adolescents, adults, and the elderly all require essentially the same types of nutrients but have special nutritional needs related to their stages of life, which may require slight adjustments in the kinds and amounts of nutrients consumed.

Infancy

A person's total energy requirements per kilogram are highest during the first 12 months of life: 100 kilocalories per kilogram of body weight per day. Fifty percent of this energy is required for an infant's basal metabolic rate. Infants (birth to 12 months) triple their weight and increase their length by 50% during that first year; this is their so-called first growth spurt. Because they are growing so rapidly they require food that contains adequate proteins, vitamins, minerals, and water. They also need food that is high in kilocalories. For many reasons, the food that most easily meets these needs is human breast milk (table 19.7). Even with breast milk's many nutrients, many physicians strongly recommend multivitamin supplements as part of an infant's diet.

Childhood

As infants reach childhood, their dietary needs change. The rate of growth generally slows between 1 year of age and puberty, and girls increase in height and weight slightly faster than boys. During childhood, the body becomes more lean, bones elongate, and the brain reaches 100% of its adult size between the ages of 6 and 10. To adequately meet growth and energy needs during childhood, protein intake should be high enough to take care of the development of new tissues. Minerals, such as calcium, zinc, and iron, as well as vitamins, are also necessary to support growth and prevent anemia. Although many parents continue to provide their children with multivitamin supplements, such supplements should be given only after a careful evaluation of their children's diets. There are four groups of children who are at particular risk and should receive such supplements:

1. Children from deprived families and those suffering from neglect or abuse
2. Children who have anorexia or poor eating habits, or who are obese
3. Pregnant teens
4. Children who are strict vegetarians

During childhood, eating habits are very erratic and often cause parental concern. Children often limit their intake of milk, meat, and vegetables while increasing their intake of sweets. To get around these problems, parents can

Table 19.7

A COMPARISON OF HUMAN BREAST MILK AND COW'S MILK*

Nutrient	Human Milk	Cow's Milk
Energy (kilocalories/1,000 grams)	690	660 (whole milk)
Protein (grams per liter)	9	35
Fat (grams per liter)	40	38
Lactose (grams per liter)	68	49
Vitamins		
A (international units)	1,898	1,025
C (micrograms)	44	17
D (activity units)	40	14
E (international units)	3.2	0.4
K (micrograms)	34	170
Thiamin (B_1) (micrograms)	150	370
Riboflavin (B_2) (micrograms)	380	1,700
Niacin (B_3) (milligrams)	1.7	0.9
Pyridoxine (B_6) (micrograms)	130	460
Cobalamin (B_{12}) (micrograms)	0.5	4
Folic acid (micrograms)	41–84.6	2.9–68
Minerals (all in milligrams)		
Calcium	241–340	1,200
Phosphorus	150	920
Sodium	160	560
Potassium	530	1,570
Iron	0.3–0.56	0.5
Iodine	200	80

*All milks are not alike. Each milk is unique to the species that produces it for its young, and each infant has its own special growth rate. Humans have one of the slowest infant growth rates, and human milk contains the least amount of protein. Because cow's milk is so different, many pediatricians recommend that human infants be fed either human breast milk or formulas developed to be comparable to breast milk during the first 12 months of life. The use of cow's milk is discouraged. This table lists the relative amounts of different nutrients in human breast milk and cow's milk.

provide calcium by serving cheeses, yogurt, and soups as alternatives to milk. Meats can be made more acceptable if they are in easy-to-chew, bite-sized pieces, and vegetables may be more readily accepted if smaller portions are offered on a more frequent basis. Steering children away from sucrose by offering sweets in the form of fruits can help reduce dental caries. You can better meet the dietary needs of children by making food available on a more frequent basis, such as every three to four hours. Obesity is an increasing problem among children. Parents sometimes encourage this by insisting that children eat everything served to them. Most children automatically regulate the food they eat to an appropriate amount; parents should be more concerned about the kinds of food children eat rather than the amounts.

Adolescence

The nutrition of an adolescent is extremely important because, during this period, the body changes from nonreproductive to reproductive. Puberty is usually considered to last between five and seven years. Before puberty, males and females tend to have similar proportions of body fat and muscle. Both body fat and muscle make up between 15% and 19% of the body's weight. Lean body mass, primarily muscle, is about equal in males and females. During puberty, female body fat increases to about 23%, and in males it decreases to about 12%. Males double their muscle mass in comparison to females.

The changes in body form that take place during puberty constitute the second growth spurt. Because of their more rapid rate of growth and unique growth patterns, males require more of certain nutrients than females (protein, vitamin A, magnesium, and zinc). During adolescence, youngsters will gain as much as 20% of their adult height and 50% of their adult weight, and many body organs will double in size. Nutritionists have taken these growth patterns and spurts into account by establishing RDAs for males and females 10 to 20 years old, including requirements at the peaks of growth spurts. RDAs at the peak of the growth spurt are much higher than they are for adults and children.

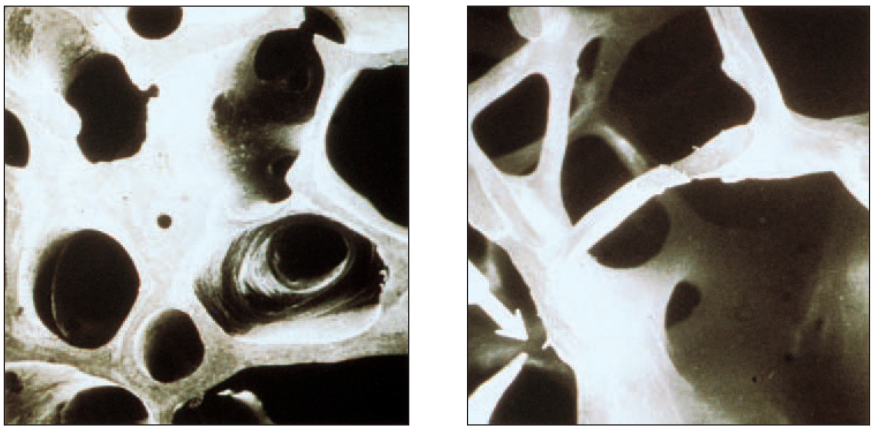
Adulthood

People who have completed the changes associated with adolescence are considered to have entered adulthood. Most of the information available to the public through the press, television, and radio focuses on this stage in the life cycle. During adulthood, the body enters a plateau phase, and diet and nutrition focus on maintenance and disease prevention. Nutrients are used primarily for tissue replacement and repair, and changes such as weight loss occur slowly. Because the BMR slows, as does physical activity, the need for food energy decreases from about 2,900 kilocalories in average young adult males (ages 20 to 40) to about 2,300 for elderly men. For women, the corresponding numbers decrease from 2,200 to 1,900 kilocalories. Protein intake for most U.S. citizens is usually in excess of the recommended amount. The RDA standard for protein is about 63 grams for men and 50 grams for women each day. About 25% to 50% should come from animal foods to ensure intake of the essential amino acids. The rest should be from plant-protein foods such as whole grains, legumes, nuts, and vegetables.

An adult who follows a well-balanced diet should have no need for vitamin supplements; however, improper diet, disease, or other conditions might require that supplements be added. The two minerals that demand special attention are calcium and iron, especially for women. A daily intake of 1,200 milligrams of calcium should prevent calcium loss from bones (osteoporosis; figure 19.7) and a daily intake of 15 mg of iron should allow adequate amounts of hemoglobin to be manufactured to prevent anemia in women over 50

Figure 19.7

Osteoporosis
These photographs are of a healthy bone (*a*) and a section of bone from a person with osteoporosis (*b*). This nutritional deficiency disease results in a change in the density of the bones as a result of the loss of bone mass. Bones that have undergone this change look "lacy" or like Swiss cheese, with larger than normal holes. A few risk factors found to be associated with this disease are being female and fair skinned; having a sedentary lifestyle; using alcohol, caffeine, and tobacco; and having reached menopause.



(a) Healthy (b) Osteoporosis

and men over 60. In order to reduce the risk of chronic diseases such as heart attack and stroke, adults should definitely eat a balanced diet, participate in regular exercise programs, control their weight, avoid cigarettes and alcohol, and practice stress management.

Nutritional Needs Associated with Pregnancy and Lactation

Risk-management practices that help in avoiding chronic adult diseases become even more important when planning pregnancy. Studies have shown that an inadequate supply of the essential nutrients can result in infertility, spontaneous abortion, and abnormal fetal development. The period of pregnancy and milk production (lactation) requires that special attention be paid to the diet to ensure proper fetal development, a safe delivery, and a healthy milk supply.

The daily amount of essential nutrients must be increased, as should the kilocaloric intake. Kilocalories must be increased by 300 per day to meet the needs of an increased BMR; the development of the uterus, breasts, and placenta; and the work required for fetal growth. Some of these kilocalories can be obtained by drinking milk, which simultaneously supplies calcium needed for fetal bone development. In those individuals who cannot tolerate milk, supplementary sources of calcium should be used. In addition, the daily intake of protein should be at least 65 grams per day. As was mentioned earlier, most people consume much more than this amount of protein per day. Two essential nutrients, folic acid and iron, should be obtained through prenatal supplements because they are so essential to cell division and development of the fetal blood supply.

The mother's nutritional status affects the developing baby in several ways. If she is under 15 years of age or has had three or more pregnancies in a two-year period, her nutritional stores are inadequate to support a successful pregnancy. The use of drugs such as alcohol, caffeine, nicotine, and "hard" drugs (e.g., heroin) can result in decreased nutrient exchange between the mother and fetus. In particular, heavy smoking can result in low birth weights and alcohol abuse is responsible for fetal alcohol syndrome (figure 19.8).

Old Age

As people move into their sixties and seventies, digestion and absorption of all nutrients through the intestinal tract is not impaired but does slow down. The number of cells undergoing mitosis is reduced, resulting in an overall loss in the number of body cells. With age, complex organs such as the kidneys and brain function less efficiently, and protein synthesis becomes inefficient. With regard to nutrition, energy requirements for the elderly decrease as the BMR slows, physical activity decreases, and eating habits also change.

The change in eating habits is particularly significant because it can result in dietary deficiencies. For example, linoleic acid, an essential fatty acid, may fall below required levels as an older person reduces the amount of food eaten. The same is true for some vitamins and minerals. Therefore, it may be necessary to supplement the diet daily with 1 tablespoon of vegetable oil. Vitamin E, multiple vitamins, or a mineral supplement may also be necessary. The loss of body protein means that people must be certain to meet their daily RDA for protein and participate in regular exercise to prevent muscle loss. As with all stages of the life cycle, regular exercise is important in maintaining a healthy, efficiently functioning body.

19.9 Nutrition for Fitness and Sports

In the past few years there has been a heightened interest in fitness and sports. Along with this, an interest has developed in the role nutrition plays in providing fuel for activities, controlling weight, and building muscle. The cellular respiration process described in chapter 6 is the source of the energy needed to take a leisurely walk or run a marathon. However, the specific molecules used to get energy depends

Figure 19.8

Fetal Alcohol Syndrome (FAS)
The 1-day-old infant on the left displays fetal alcohol syndrome; the child on the right with the syndrome is 8 years old. The 8-year-old was diagnosed at birth and has spent his entire life in a foster home where the quality of care has been excellent. His IQ has remained stable at 40 to 45.

on the length of the period of exercise, whether or not you warm up before you exercise, and how much effort you exert during exercise. The molecules respired by muscle cells to produce ATP may be glucose, fatty acids, or amino acids. Glucose is stored as glycogen in the muscles, liver, and some other organs. Fatty acids are stored as triglycerides in fat cells. Amino acids are found as protein in muscles and other organs. Which molecules are respired depends on the duration and intensity of exercise. Glucose from glycogen and fatty acids from triglycerides are the typically primary fuels. Amino acids provide 10% or less of a person's energy needs even in highly trained athletes.

Aerobic exercise occurs when the level of exertion allows the heart and lungs to keep up with the oxygen needs of the muscles. **Anaerobic exercise** involves bouts of exercise that are so intense that the muscles cannot get oxygen as fast as they need it. Therefore, they must rely on anaerobic respiration of glucose to provide the energy needed. During a long, brisk walk, the heart and lungs of most people should be able to keep up with the muscle cells' requirement for oxygen. The oxygen is used by mitochondria to run the aerobic Krebs cycle and electron-transport system. (They are exercising aerobically.) Studies have shown that during the first 20 minutes of moderate exercise glucose from the blood and glycogen from the muscles are used as the fuel for aerobic respiration. When the period of exercise is greater than 20 minutes, triglycerides stored in cells and fatty acids from the circulatory system are used as the prime sources of energy. Many exercise programs encourage a warm-up period before the exercise begins. During the warm-up period the body is using glucose and glycogen but will switch to the burning of triglycerides and fatty acids later in the exercise period. This is why moderate, longer periods of exercise are most beneficial in weight loss.

But what about extreme exertion or vigorous exercise for longer periods? Extreme bouts of activity that last only several seconds, such as a 100-meter dash or lifting weights, rely on the ATP already present in the muscle cells. Because the activity period is so short and the ATP is already in the muscles, oxygen is not needed. Intense exercise that lasts for a few minutes, such as a 400-meter run or gymnastic events, requires additional ATP—more than can be stored in the muscles. This is supplied primarily by anaerobic respiration of glycogen and glucose. As the period of exercise increases it is impossible to continue to rely on anaerobic respiration. Aerobic respiration of triglycerides and fatty acids becomes more important. Without a warm-up period, your muscle cells will begin to respire mostly muscle-stored glycogen. At first the heart and lungs are not able to supply all the oxygen needed by the mitochondria. Glycolysis will provide ATP for muscle contraction, but there will be an increase in the amount of pyruvic and lactic acids. About 20 minutes into vigorous exercise, 20% of muscle glycogen is gone and little triglyceride has been respired. By this time, the heart and lungs are "warmed up" and are able to provide the oxygen necessary to respire larger amounts of triglycerides and fatty acids along with the glycogen and glucose. Fatty acid levels in the blood increase greatly and ATP output increases dramatically. A person who has not warmed up experiences this metabolic shift as a "second wind."

From this point on, all sources of energy—glucose from glycogen, fatty acids from triglycerides, and even small amounts of amino acids from proteins—are utilized, but the balance shifts during the period of exercise. The glycogen

OUTLOOKS 19.2

Myths or Misunderstandings About Diet and Nutrition

Myth or Misunderstanding	Reality
1. Exercise burns calories.	You don't burn calories, but you do oxidize (burn) the fuels to provide yourself with the energy needed to perform various actitivies.
2. Active people who are increasing their fitness need more protein.	The amount of protein needed is very small. Most people get many times the amount of protein required.
3. Vitamins give you energy.	Vitamins are involved with enzymes in the release of energy from food items, but are not sources of energy.
4. Large amounts of protein are needed to build muscle.	A person can only build a few grams of new muscle per day. Therefore, consuming large amounts of protein will not increase the rate of muscle growth.
5. Large quantities (megadoses) of vitamins will fight disease, build strength, and increase length of life.	Quantities of vitamins that greatly exceed the recommended dietary allowance (RDA) have not been shown to be beneficial. Large doses of some vitamins are toxic (vitamins A, D, B_3).
6. Special protein supplements are more quickly absorbed and can build muscle faster.	There is adequate protein in nearly all diets. The supplements may be absorbed faster but that does not mean that they will be incorporated into muscle mass faster.

continues to be used but, at approximately one hour into exercise, glycogen stores have largely been depleted lowering blood glucose and the athlete experiences debilitating fatigue known as "hitting the wall."

There are also metabolic shifts that occur as one stops exercising. If exercise is suddenly stopped while there are high concentrations of fatty acids in the blood they will be converted to keto acids which could negatively affect kidney function; a loss of sodium, calcium, and other minerals; and change the pH of the blood. For this reason, many exercise physiologists suggest a cool-down period of light exercises that allow the body to slowly shift back to a more normal fuel balance of glucose and fatty acids.

Diet is an important aspect of an athlete's training program. The kind of diet needs to be tailored to the kind of performance expected from the athlete. To avoid or postpone hitting the wall, many marathon athletes practice **carbohydrate loading.** This should be done only by those engaged in periods of hard exercise or competition lasting 90 minutes or more. It requires a week-long diet and exercise program. On the first day, the muscles needed for the event are exercised for 90 minutes and carbohydrates, such as fruits, vegetables, or pasta provide a source of dietary kilocalories. On the second and third days of carbohydrate loading, the person continues the 50% carbohydrate diet, but the period of exercise is reduced to 40 minutes. On the fourth and fifth days, the workout period is reduced to 20 minutes and the carbohydrates are increased to 70% of total kilocalorie intake. On the sixth day, the day before competition, the person rests and continues the 70% carbohydrate diet. Following this program increases muscle glycogen levels and makes it possible to postpone "hitting the wall."

Conditioning includes many interrelated body adjustments in addition to energy considerations. Training increases the strength of muscles, including the heart, and increases the efficiency of operation. Practicing a movement allows for the development of a smooth action that is more energy efficient than a poorly trained motion. As the body is conditioned, there is an increase in the number of mitochondria per cell, the Krebs cycle and the ETS run more efficiently, the number of capillaries increases, fats are respired more efficiently and for longer periods, and weight control becomes easier.

The amount of protein in an athlete's diet has also been investigated. Understand that an increase in dietary protein does not automatically increase strength, endurance, or speed. In fact, most Americans eat the 10% additional protein that athletes require as a part of their normal diets. The additional percentage is used by the body for many things, including muscle growth. But increasing protein intake will not automatically increase muscle size. Only when there is a need will the protein be used to increase muscle mass. That means exercise. Your body will build the muscle it needs in order to meet the demands you place on it. Vitamins and minerals operate in much the same way. No supplements should be required as long as your diet is balanced and complex. Your meals should provide the vitamins and minerals needed to sustain your effort (Outlooks 19.2).

Athletes must monitor their water intake because dehydration can cripple an athlete very quickly. A water loss of only 5% of the body weight can decrease muscular activity by as much as 30%. One way to replace water is to drink 1 to 1½ cups of water 15 minutes before exercising and ½ cup during exercise. In addition, drinking 16 ounces of cool tap water for

each pound (16 ounces) of body weight lost during exercise will prevent dehydration. Another method is to use diluted orange juice (1 part juice to 5 parts water). This is an excellent way to replace water and resupply a small amount of lost glucose and salt. Salt pills (so-called electrolyte pills) are not recommended because salt added to the digestive tract tends to reduce the rate at which water is absorbed from the gut. When the salt is absorbed into the bloodstream, additional water is needed to dilute the blood to the proper level.

SUMMARY

To maintain good health, people must receive nutrient molecules that can enter the cells and function in the metabolic processes. The proper quantity and quality of nutrients are essential to good health. Nutritionists have classified nutrients into six groups: carbohydrates, proteins, lipids, minerals, vitamins, and water. Energy for metabolic processes may be obtained from carbohydrates, lipids, and proteins, and is measured in kilocalories. An important measure of the amount of energy required to sustain a human at rest is the basal metabolic rate. To meet this and all additional requirements, the United States has established the RDAs, recommended dietary allowances, for each nutrient. Should there be metabolic or psychological problems associated with a person's normal metabolism, a variety of disorders may occur, including obesity, anorexia nervosa, bulimia, kwashiorkor, and vitamin-deficiency diseases. As people move through the life cycle, their nutritional needs change, requiring a reexamination of their eating habits in order to maintain good health.

THINKING CRITICALLY

You're 21 years old, female, have never been involved in any kind of sports, and have suddenly become interested in rugby! This is a very demanding contact sport and many people are injured while playing. If you are to succeed and experience only minor injuries, you must get in condition. Describe changes you should make in your daily diet and exercise program that would prepare you for this new experience. Well, get busy, or you'll never make the team!

CONCEPT MAP TERMINOLOGY

Construct a concept map to show relationships among the following concepts.

anorexia
basal metabolic rate
bulimia
calorie
carbohydrate
diet
essential amino acids
fat
nutrition
obesity
protein

KEY TERMS

absorption
aerobic exercise
anaerobic exercise
anorexia nervosa
assimilation
basal metabolic rate (BMR)
bulimia
calorie
carbohydrate loading
complete protein
diet
digestion
electrolytes
essential amino acids
essential fatty acid
fiber
Food Guide Pyramid
incomplete protein
ingestion
kilocalorie (kcal)
kwashiorkor
minerals
nutrients
nutrition
obese
osteoporosis
protein-sparing
recommended dietary allowances (RDAs)
specific dynamic action (SDA)
vitamin-deficiency disease
vitamins

e—LEARNING CONNECTIONS *www.mhhe.com/enger10*

Topics	Questions	Media Resources
19.1 Living Things as Chemical Factories: Matter and Energy Manipulators		**Quick Overview** • Manipulating matter and energy **Key Points** • Living things as chemical factories
19.2 Kilocalories, Basal Metabolism, and Weight Control	1. What are basal metabolism, specific dynamic action, and voluntary muscular activity?	**Quick Overview** • Supply and demand **Key Points** • Kilocalories, basal metabolism, and weight control

(*continued*)

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Topics	Questions	Media Resources
19.3 The Chemical Composition of Your Diet	2. Why are some nutrients referred to as essential? Name them.	**Quick Overview** • Nutrients **Key Points** • The chemical composition of your diet **Interactive Concept Maps** • Nutrients
19.4 Amounts and Sources of Nutrients	3. List the six classes of nutrients and give an example of each. 4. What do the initials RDA stand for? 5. List four of the dietary guidelines. 6. Americans are currently consuming 37% of their kilocalories in fat. According to the dietary goals, what should that percentage be?	**Quick Overview** • Recommended daily allowances **Key Points** • Amounts and sources of nutrients **Animations and Review** • Nutrition • Vitamins & minerals
19.5 The Food Guide Pyramid with Five Food Groups	7. Name the five basic food groups and give two examples of each.	**Quick Overview** • The Food Guide Pyramid **Key Points** • The Food Guide Pyramid with five food groups **Interactive Concept Maps** • The Food Guide Pyramid
19.6 Eating Disorders		**Quick Overview** • Eating habits and society • Eating disorders **Key Points** • Eating disorders **Food for Thought** • Bulimia
19.7 Deficiency Diseases		**Quick Overview** • Something is missing **Key Points** • Deficiency diseases **Interactive Concept Maps** • Text concept map
19.8 Nutrition Through the Life Cycle	8. During which phase of the life cycle is a person's demand for kilocalories per unit of body weight the highest?	**Quick Overview** • Needs change **Key Points** • Nutrition through the life cycle **Interactive Concept Maps** • Nutrition throughout life
19.9 Nutrition for Fitness and Sports		**Quick Overview** • Exercise and special needs **Key Points** • Nutrition for fitness and sports