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Biology Chapter Excerpt

BSCS: Biology Ecological Approach, 9th Edition

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2 3 4 5 6 7 8 9 10 10 09 08 07 06

CONTENTS

Biology Today Features

Pioneers Features

FOREWORD

Did you take a look at the frog on the cover of this book. A really close look? How is this frog like any other frog? How is *this* frog unique?

Frogs have much to tell us about the history of life on our planet. Frogs are classified as amphibians. About 400 million years ago, amphibians were the first vertebrate animals to leave the seas for life on land. Their fossil remains tell this fascinating story. Today, amphibians have another story to tell about the general condition of many environments.

The life cycle of a frog is dependent on many aspects of its environment: part of its life is spent in water, and part on land, breathing air. The frogs of today have become "sentinel animals," because changes taking place in their lives alert us to changes in our environment.

How do frogs show us these things? Some very strange-looking frogs, frogs with bizarre physical abnormalities, have started showing up in agricultural areas of the United States. These are places where pesticide use is heavier than in other parts of the country. Many other types of frogs have become extinct; vanished forever from the tropical rain forests of Central and South America. These rain forests are disappearing at the hands of humans. People are chopping down the trees, clearing the land for food crops, and using the wood for building.

So why are the frogs disappearing? Is it because of loss of their habitat? Is it due to malformations caused by pesticide use? Is it because of diseases? Is all the news bad? We frequently hear reports of global warming and the extinction of plants and animals, often blamed totally on humans. Yet ancient rocks, glacial ice, and fossil records tell us that cycles of temperature change and extinctions of life are a part of earth's history. How can we determine the role humans play in the changing environments of today's earth?

Where will we find solutions to problems so that we can make responsible personal decisions as well as contribute our voice to public policy? There are many ways to explain the world around us. Historically, people have used art, philosophy, or religion to describe the world. Today we can also use science to investigate the natural world, to make conclusions about our investigations, and to question those conclusions.

Welcome to BSCS Green Version! BSCS Green is a biology program that encourages you to investigate how organisms and their behaviors are shaped by their environments. You will ask questions about what happens as organisms and their environments interact. You will be introduced to the big picture showing how different local environments fit together to form patterns of life on Earth.

With BSCS Green Version, you will practice science as a way to study and learn about your world. In other words, Green Version is your opportunity to learn about science by actually *doing* science. You will see the ways that science can help provide solutions to the problems you have identified and studied. Finally, you will see that people who use science to study an issue are also left with the very human challenge of acting on their conclusions.

Carlo Parravano	Rodger W. Bybee	Anne L. Westbrook
Chair, Board of Directors	Executive Director	Project Director

Chapter Topics

Matter and Energy

Energy for Life

Life Is Based on Carbon

Carbon Cycling

MATTER AND ENERGY IN THE WEB OF LIFE

All living things are tied together by their need for nutrients and energy. Using matter from the surrounding soil and air and incorporating energy from the sun, producers such as green plants make their own food to sustain themselves. Consumers, on the other hand, must obtain their nutrients and energy from other organisms. Humans, for instance, eat plants and animals to get their nutrients and energy. Our food is made up of biological molecules, which we consume and digest. We then use the products from the breakdown of foods to make our own unique group of biological molecules. This chapter examines these important molecules and investigates some characteristics of matter and energy.

How does this deer interact with his environment? What role does he play in the web of life? How does the deer's browsing on plant material relate to the flow of energy and the cycling of matter?

Matter and Energy

4.1 Matter Is Made of Atoms

GUIDEPOST

How are matter and energy related in the biosphere?

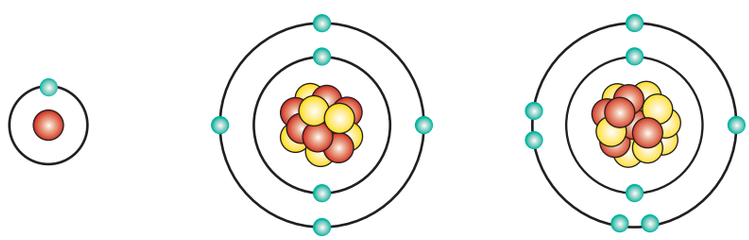
Biological molecules are **organic compounds.** Organic compounds are molecules built of carbon combined with other elements. Like all other compounds, organic compounds can be broken down to the elements from which they were formed. For example, molecules of sugar, an organic compound, can be broken down to the elements carbon, hydrogen, and oxygen. Carbon, iron, nitrogen, gold, silver, calcium, and chlorine are some elements with which you probably are familiar. Four elements—carbon, oxygen, hydrogen, and nitrogen—are common to all living systems.

Matter is made of atoms. An atom is the smallest particle of an element that retains the properties of that element. For example, the element carbon is made of only carbon atoms. Each atom has a core, or **nucleus,** that contains positively charged particles called **protons** and uncharged particles called **neutrons.** One or more **electrons,** which are negatively charged particles, rapidly orbit the nucleus. Because the number of electrons equals the number of protons, an atom is electrically neutral.

The total number of particles in an atom determines what element is formed. For example, a hydrogen atom is made of one proton and one electron (hydrogen is the only atom that does not have neutrons in its nucleus). An atom of carbon contains six protons, six neutrons, and six electrons. Oxygen atoms are composed of eight protons, eight neutrons, and eight electrons. Figure 4.1 shows models of these atoms.

4.2 Chemical Bonds Hold Atoms Together

Atoms combine to form molecules, resulting in different forms of matter. For example, hydrogen and oxygen can combine to form water. Reactions between atoms depend on the number of electrons each atom has. Sometimes a reaction involves an electron moving from one atom to another. For example, when atoms of sodium (Na) and atoms of chlorine



a hydrogen atom (1 proton) **b** carbon atom (6 protons, 6 neutrons) **c** oxygen atom (8 protons, 8 neutrons)

Figure 4.1

Simplified models of (a) hydrogen, (b) carbon, and (c) oxygen. Red circles represent protons; yellow circles represent neutrons. Electrons (in a turquoise color) are shown in shells, or levels, around the nucleus. The number of electrons in the outer level determines chemical activity.

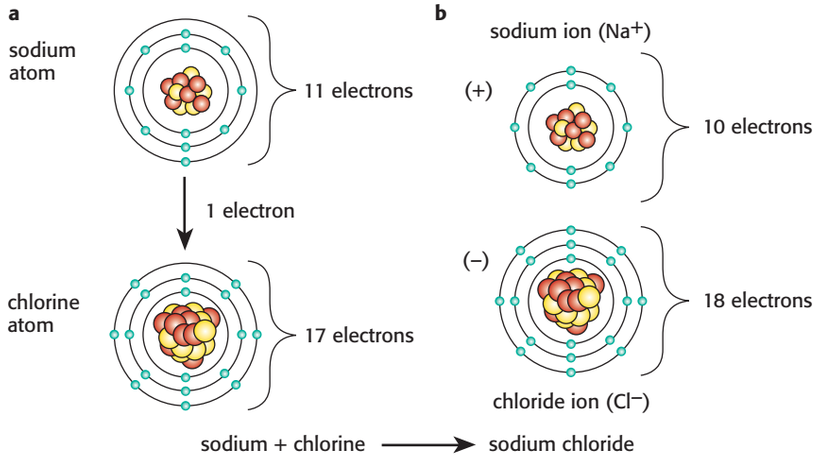


Figure 4.2

Sodium and chlorine can react to form sodium chloride (NaCl), table salt. By losing one electron, sodium becomes a positive ion, and by gaining one electron, chlorine becomes a negative ion, chloride.

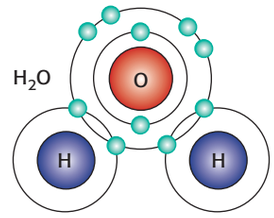


Figure 4.3

In a molecule of water, the oxygen atom forms an electron-sharing bond with each hydrogen atom.

(Cl) react to form sodium chloride (NaCl, common table salt), each sodium atom gives up an electron to a chlorine atom, as shown in Figure 4.2. As a result, the number of protons and the number of electrons in the sodium atom are no longer equal. Because the sodium atom has 11 protons (positive charge) and only 10 electrons (negative charge), it has an overall positive charge. The chlorine atom, which captured the electron from the sodium atom, now has one more electron that it had originally. Consequently, it has an overall negative charge. A charged particle that has either a negative or a positive charge is called an **ion.** In this example, the chlorine atom has become an ion with a negative charge, a chloride ion (Cl^-). The sodium atom has become an ion with a positive charge (Na^+). The positively charged sodium ions and the negatively charged chloride ions are attracted to each other and come together, forming sodium chloride (NaCl).

Often when atoms react, they do not gain or lose electrons. Instead they share electrons. For example, in a molecule of water (H_2O), one oxygen atom shares electrons with two hydrogen atoms (see Figure 4.3). Molecules of carbon dioxide (CO_2), hydrogen gas (H_2), and oxygen gas (O_2) also are formed by shared electrons. The attractions that hold atoms or ions together are called **chemical bonds.**

Topic: atoms/molecules/compounds
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4.3 Chemical Reactions Are Essential to Life

There are two general categories of chemical reactions in living cells. When sodium and chlorine ions combine to form table salt or when oxygen and hydrogen atoms combine to form water, compounds are made (synthesized). Reactions that make compounds are called **synthesis** reactions. Compounds also may be broken down. When this happens, the reaction is known as a **decomposition** reaction. The digestion of foods involves decomposition reactions.

For chemical reactions to take place, the reacting substances must come in contact with each other. This happens most easily when the substances

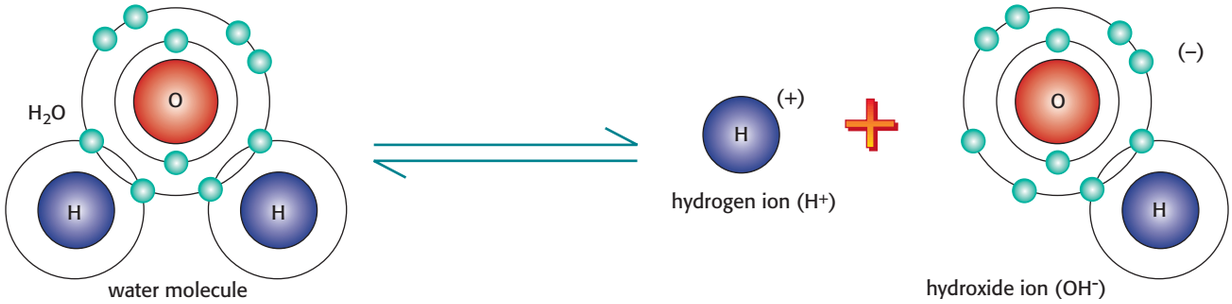

Figure 4.4

Water molecules ionize into hydrogen and hydroxide ions.

are in solution, that is, dissolved in water. When table salt dissolves in water, the sodium and chloride ions separate from each other, but they remain as ions in solution.

Compounds that are not made of ions can undergo a reaction called **ionization.** For example, water can be converted into ions through ionization (see Figure 4.4). In liquid water, there are always a very few water molecules (H_2O) that separate into hydrogen ions (H^+) and hydroxide ions (OH^-). A hydrogen ion is a single proton: a hydrogen atom that has lost its only electron. The missing electron is held by the hydroxide ion, which consists of an oxygen atom, a hydrogen atom, and the electron the hydrogen atom has lost.

Although water is a common compound, its ability to undergo ionization is one of the properties that makes it essential for life. Only about one in 10 million molecules of water forms ions, but all life processes depend on this small percentage. Hydrogen and hydroxide ions are involved in most of the reactions that occur in organisms. If more hydrogen ions than hydroxide ions exist in solution, the solution is said to be acidic. If more hydroxide ions than hydrogen ions are present, the solution is said to be basic, or alkaline. The relative levels of hydrogen and hydroxide ions are very important to organisms because of their effects on chemical reactions.

The hydrogen ion level of a solution is described by a range of numbers known as the **pH scale** (see Figure 4.5). The scale runs from 0 to 14. A solution that has equal numbers of hydrogen and hydroxide ions is neutral and has a pH of 7. Pure water has a pH of 7. As the hydrogen ion level rises, the solution becomes more acidic, and the pH drops. For example, a carbonated soft drink with a pH of 2 to 3 is highly acidic. Solutions with a

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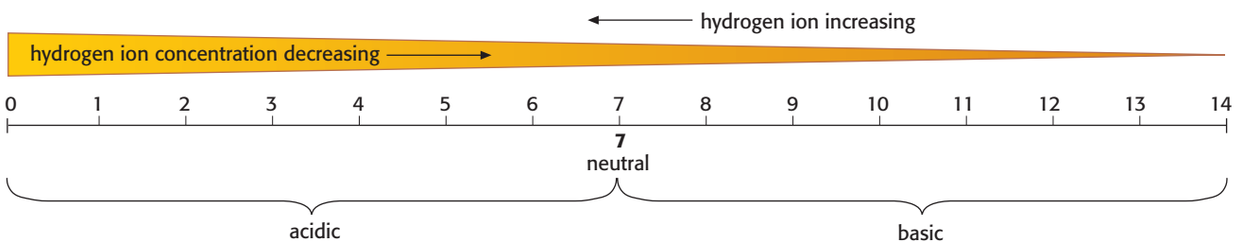


Figure 4.5

The pH scale ranges from 0 to 14. When is a substance acidic? When is it basic?

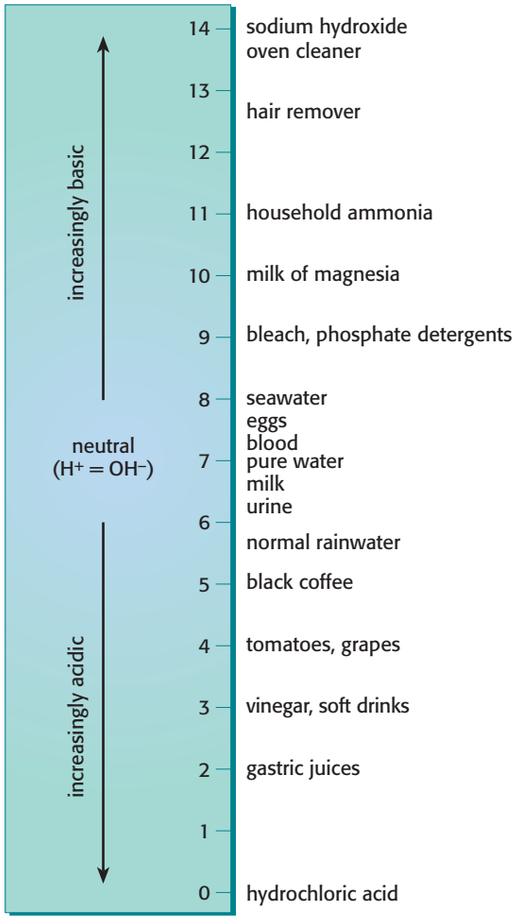


Figure 4.6
Compare the pH values of some common substances.

pH above 7 are basic. They have relatively low levels of hydrogen ions and high levels of hydroxide ions. Figure 4.6 shows the pH of several common substances.

Organisms have an internal pH that must remain fairly stable for chemical reactions to occur optimally. Environmental factors may affect that stability in a variety of ways. In Investigation 4.1, you can discover how internal pH is regulated.

Even when they are dissolved in water, molecules involved in synthesis and decomposition reactions may react extremely slowly. Certain substances, however, promote chemical reactions. These substances are called **catalysts.** Catalysts are present only in small amounts, and although they participate in the reactions, they themselves are not changed or used up. Catalysts make it possible for reactions to occur at rates high enough to sustain life. The specialized and highly specific catalysts present in organisms are proteins called **enzymes.** These are discussed in Section 4.12.

4.4 Energy Makes Work and Order Possible

Chemical reactions involve **energy** transfer. In general, synthesis reactions require an input of energy, and decomposition reactions release energy. What is energy, and how is it used in living systems?

In a general way, energy can be defined as the ability to do work or to cause change. It is work to move an arm, play tennis, jump, heat a house, or build a skyscraper. Growing a leaf or a wing also can be considered work because energy is used in these processes. In a cell, energy is used to do many things, such as move substances and build new molecules. This, too, is work.

Energy also is required to establish and maintain order. Living things are very complex. Their atoms and molecules are arranged in highly organized systems. You can imagine a highly organized system in your own body: a unique type of cell forms cardiac (heart) muscle tissue, which in turn functions as the specialized organ, the heart. High levels of organization, however, can be unstable. If left to themselves, all systems tend to become simple and disorganized. Only by a continual input of energy can organization be maintained.

A living organism is an organized system. For instance, the internal organization of a frog is maintained because the frog eats flies and other insects that contain energy. This energy keeps the frog alive and allows it to grow and reproduce. If the frog does not get enough food, it dies. As soil decomposers break down the frog's body, it loses its organization. The decomposers survive by using the matter and energy derived from the frog's body cells.

Many life processes, such as reproduction or growth and development, tend to bring about an organized state with a minimum of randomness. That requires energy. Where does the energy come from?

CONCEPT REVIEW

1. What are the parts of a typical atom?
2. Describe two ways that chemical bonds form.
3. In terms of pH value, what is the difference between neutral, acidic, and basic solutions?
4. How is matter different from energy?
5. What is a catalyst?
6. Why do all organisms need energy?

Energy for Life

GUIDEPOST

What is the source of energy for living organisms, and how is the energy used?

4.5 The Sun and Photosynthesis: How We Get Energy

Living things grow, move, and reproduce. These and other types of biological activity require energy. Consumer organisms get their energy from the food they eat, but where do the producers get their energy? Usually, their energy comes from the sun. Because no organism can use light energy directly from the sun as a source of food energy, the energy must be converted to chemical energy.

In the process of photosynthesis, plants (and some other organisms) convert light energy from the sun into chemical energy that is stored in complex sugar molecules (food). That chemical energy then can be used either by the plants themselves or by organisms that eat the plants. Because animals cannot make their own food, most animals depend on plants as their source of energy either directly or indirectly. Therefore, using energy from the sun, photosynthesis is the pathway that provides the source of energy for biological activities in most organisms on earth.

The first step in photosynthesis is the absorption of light energy by a green plant. The energy is absorbed primarily by **chlorophyll,** a green pigment that gives plants their color. A plant also absorbs carbon dioxide (CO_2) from the air and water from the soil. Light energy, carbon dioxide, and water are the raw materials used to make the biological molecules called sugars. The light energy absorbed by the plant is used to break down water molecules into hydrogen and oxygen, and then to combine the hydrogen with carbon dioxide to form sugar molecules. The oxygen is released into the air as oxygen gas (O_2). In this way, some of the light energy absorbed by the plant is stored in the sugar molecules as chemical energy. Figure 4.7 highlights these events.

When sugars are formed, several small molecules are linked together by chemical bonds. The energy used to form the sugars is stored in those chemical bonds. When sugar molecules are broken down in a cell, the energy stored in the chemical bonds is released. That energy is used by the cell to carry out the cell's activities.

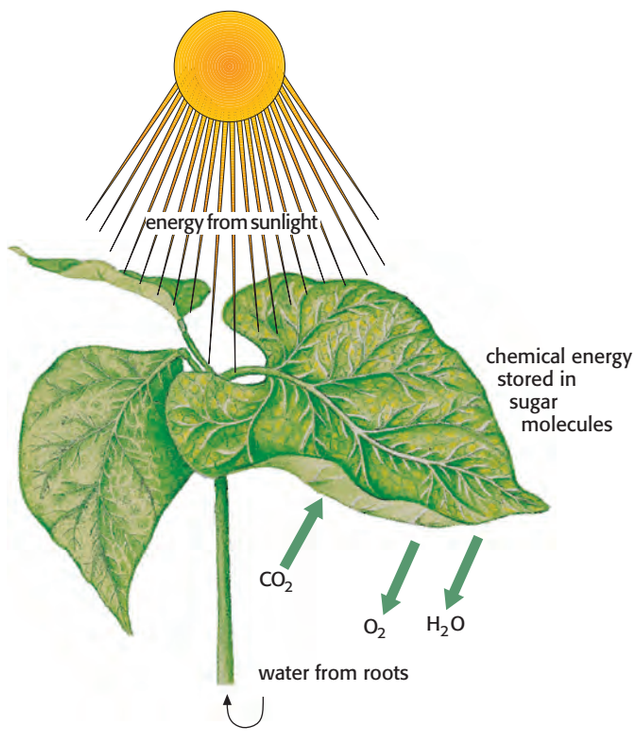


Figure 4.7 ▲
The energy in sunlight is converted to chemical energy during photosynthesis.

4.6 Energy Is Released as Food Is Broken Down

How is the energy stored in the chemical bonds of sugar molecules released so that the cell can use it? The major energy-releasing process is **cellular respiration.** Cellular respiration consists of a series of chemical reactions that occur in all living cells. During these reactions, sugars, like those made in photosynthesis, are broken down, and energy is released. The released energy is either stored in another molecule (to be used later) or is lost as heat.

The function of sugar in cells, then, is somewhat like the function of fossil fuels in machinery. Fossil fuels also contain chemical energy. During the chemical reactions that occur in burning, the fuels are reduced to simpler compounds like carbon dioxide (CO_2). The chemical energy from the fuel is released in the form of heat and light, as shown in Figure 4.8a.

The chemical energy in food is also released by chemical reactions. The chemical reactions in a cell, however, are quite different from those in a fire. When fuels burn, a large amount of energy is released in a short time. The sudden release of energy produces high temperatures—high enough to provide heat for cooking. In cells, however, energy is released gradually, in many small steps that are controlled by enzymes. Figure 4.8b suggests the step-by-step process by which foods are broken down.

The cell uses the energy in food that is released during respiration to carry out work in the cell (the stored energy in Figure 4.8b). Carbon dioxide and water molecules are the by-products that are formed as the food molecules are broken down. Notice that carbon dioxide and water are the same molecules the plant uses to make sugars in photosynthesis. Illustrating the interrelatedness of organisms, Figure 4.9 summarizes relationships between photosynthesis and cellular respiration at the level of the ecosystem.

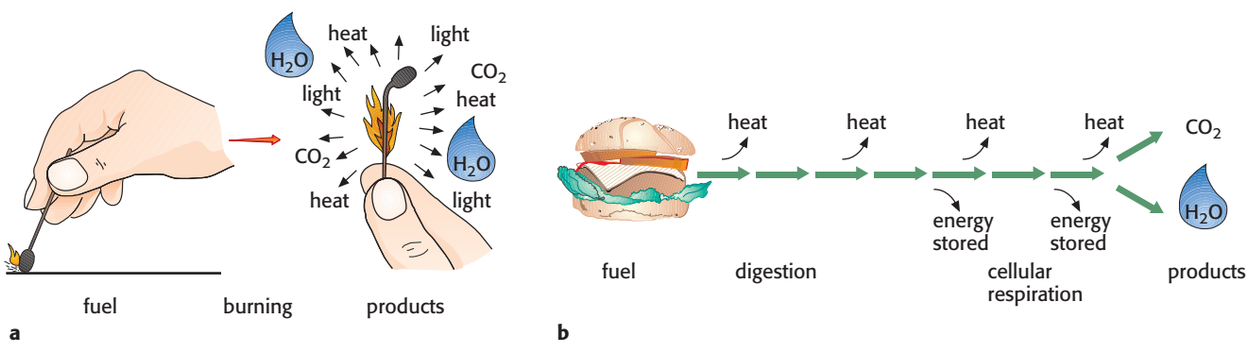


Figure 4.8 ▲

Compare the energy release that occurs (a) during burning with that which occurs (b) during cellular respiration. How are they alike? How are they different?

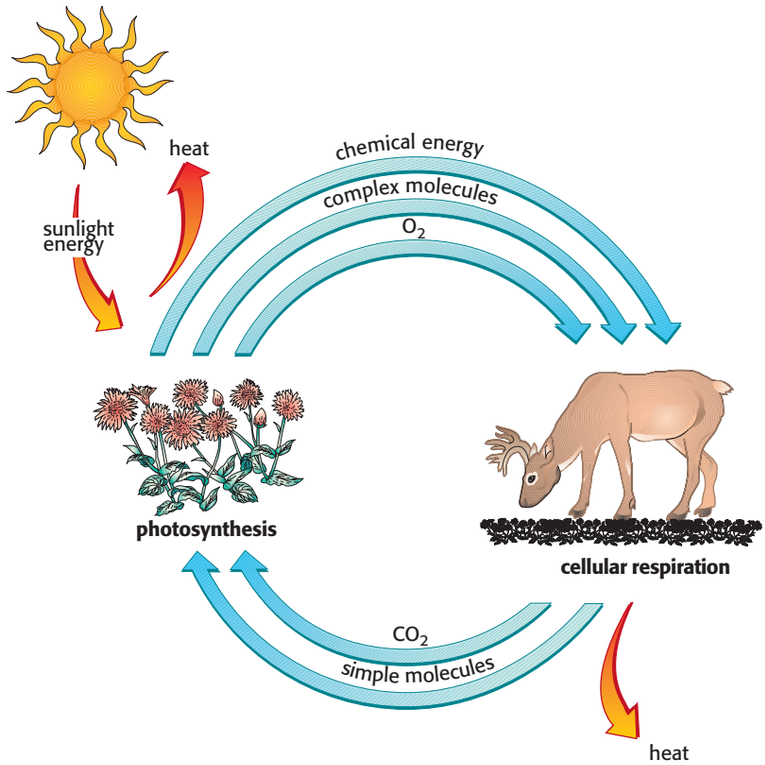


Figure 4.9 ▲

Over evolutionary time, photosynthesis (the process by which cells capture and store energy) and cellular respiration (an energy-releasing process) have been linked. Photosynthetic organisms provided the oxygen-rich atmosphere in which we now live. In the ecosystems of today, end products of photosynthesis provide the materials for cellular respiration, which in turn provides carbon dioxide for continued photosynthesis. How does water fit into this cycle?

4.7 ATP, the Cell's Currency for Energy Transfer

Cellular respiration converts the energy stored in complex molecules into chemical energy stored in smaller, more useful molecules. One of these is **ATP,** adenosine triphosphate. ATP is the most important of several energy-transfer compounds that are found in all organisms. The energy released during respiration is temporarily transferred to molecules of ATP. As you can see in Figure 4.10, each ATP molecule is made up of a main section (A) to which are attached three identical groups of atoms called phosphates (P). The three phosphates together are called the triphosphate group (TP).

As food molecules are broken down to simpler compounds, a great deal of energy is released. The energy is used to make ATP molecules. For example, in Figure 4.8b, ATP molecules are made at the steps labeled "energy stored." Chemical energy is stored in ATP until it is released by reactions that remove a phosphate from ATP. This energy is used to help the cell do its work. The work may be to move a muscle, to send a nerve impulse, to grow, or to form new compounds. Thus, ATP is a carrier of chemical energy in the cell. Because ATP connects many types of reactions in living systems, it has been referred to as the energy currency of cells.

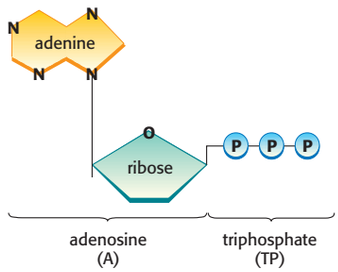


Figure 4.10 ▲

Where is the energy stored in ATP?

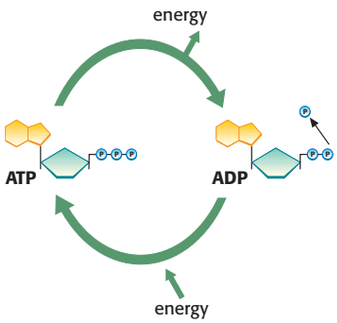


Figure 4.11

Use this diagram to explain why energy is released and when energy is required in the ATP-ADP cycle.

To see why ATP has been compared to money, imagine foreign tourists who arrive in New York City with only foreign currency. The tourists must pay a fee to change their foreign money into dollars, which they could use for their purchases. In a similar manner, a cell carries out chemical reactions that exchange the chemical energy of food molecules for the chemical energy of ATP. Then ATP pays most of the energy "debts" inside a cell. The "fee" is the energy lost as heat during the conversion.

Each ATP molecule releases energy whenever a phosphate is broken off or transferred to another molecule. The molecule that remains, which has only two phosphate groups, is called **ADP,** adenosine diphosphate. Cells must continually rebuild their ATP supply. As you can see in Figure 4.11, this is accomplished by an ADP-ATP cycle. To make ATP molecules, an ADP molecule, a phosphate group, and chemical energy are required. This energy is derived indirectly from the breakdown of food molecules.

CONCEPT REVIEW

1. In what way is photosynthesis important for all living organisms?
2. What are the two products of photosynthesis?
3. How are the reactions of photosynthesis and cellular respiration different?
4. Do you think there is more energy in one molecule of ATP or one molecule of sugar?
5. Explain the relationship between ATP and ADP.

Life Is Based on Carbon

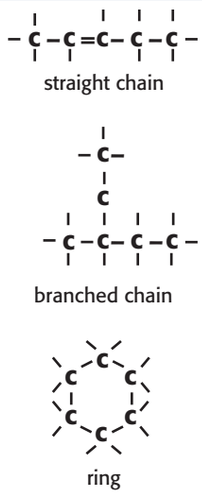


Figure 4.12

Carbon atoms can bond in several ways. The unconnected lines protruding from some of the carbon atoms show that any one of a number of elements can bond with the carbon in these positions.

4.8 Carbon Is Found in All Living Things

Although organisms are composed of many different chemical elements, carbon is the central element for all living systems. Carbon atoms can join together to form chains or rings, as shown in Figure 4.12. Furthermore, carbon atoms can combine with hydrogen, oxygen, nitrogen, sulfur, and phosphorus to form a vast number of organic compounds. In fact, the atoms of the elements present in organic compounds can be arranged in so many ways that the variety of organic compounds is almost limitless. This variety ensures the uniqueness of each organism.

Organic compounds are the essential building blocks for organisms and are also their major source of chemical energy. Four basic types of carbon-containing molecules are found in all organisms. **Carbohydrates** and **lipids** are important energy-storing compounds. They also form part of the structure of cells. The sugars produced from photosynthesis and used in cellular respiration are carbohydrates. Starch is a large carbohydrate molecule made by joining many individual sugar molecules. Oils and fats are examples of lipids. **Proteins** function as enzymes and form part of the structure of cells. **Nucleic acids** are the hereditary, or genetic, material for all organisms.

All living organisms contain carbohydrates, lipids, proteins, and nucleic acids. In order to get the building blocks needed to make these molecules,

consumers take in foods of plant and animal origin. Those foods provide the materials that organisms use to synthesize their own unique set of molecules.

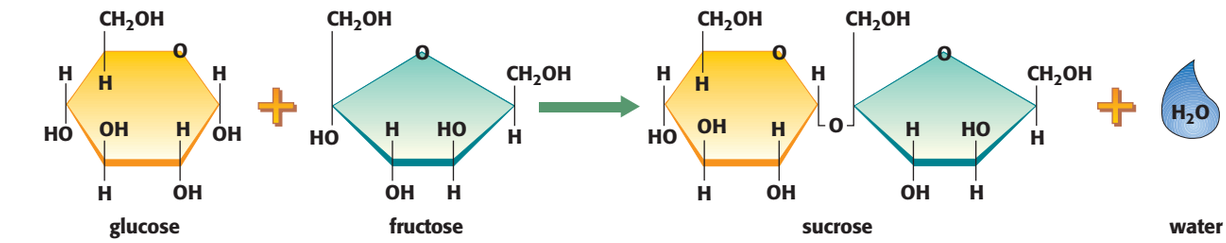
GUIDEPOST

How are carbon-containing molecules important in the structure (the matter) of living things and in the storage and flow of energy through living systems?

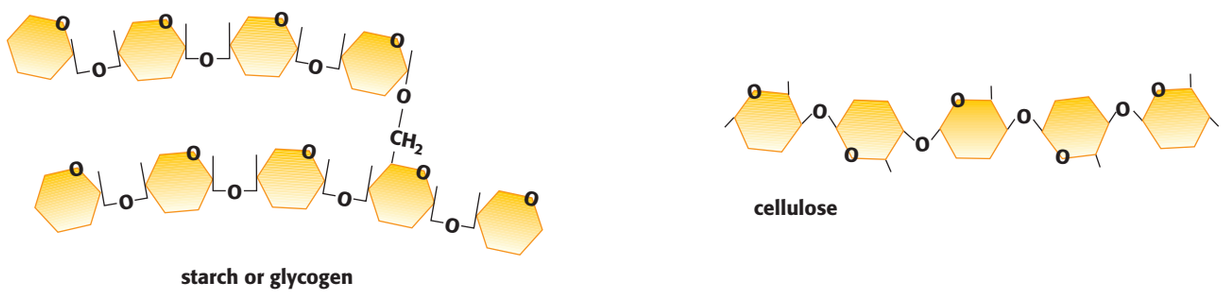
4.9 Carbohydrates Are Used for Energy Storage and Energy Production

Carbohydrates contain the elements carbon, hydrogen, and oxygen. The subunits, or building blocks, of carbohydrates are single sugars, such as glucose and fructose (see Figure 4.13a), which each contain six carbon atoms and are a major source of energy for most organisms. Single sugar molecules are also called monosaccharides. Two monosaccharides may bond together to form a double sugar, or disaccharide, as shown in Figure 4.13b. The most familiar disaccharide is sucrose, commonly called cane, beet, or table sugar. Sucrose is formed by a chemical reaction that combines a glucose molecule with a fructose molecule.

In synthesis reactions, many glucose molecules may bond together to build complex carbohydrates, called polysaccharides, such as starch and **cellulose.** Portions of these molecules are represented in Figure 4.13c. Starch is an energy-storage compound in many plants and an important food source for humans. Food and nutrition will be discussed in Chapter 15. Cellulose, a major part of wood and cotton fibers, gives the cell walls surrounding plant cells their rigidity. In human liver and muscle cells, carbohydrates are stored as glycogen, also called animal starch. Molecules of starch, cellulose, and glycogen consist of thousands of glucose units and have no fixed size.



a (single tsugars) b (double sugar)



c (polysaccharides)

Figure 4.13 △

Single sugars (a) can combine to form double sugars (b). Polysaccharides such as starch, glycogen, and cellulose (c) are formed by linking together many glucose units. Note that in these ring diagrams, each point of the ring is understood to be a carbon atom (unless an oxygen (O) is shown). Appendix Three describes the conventions used to depict carbon-based molecules.

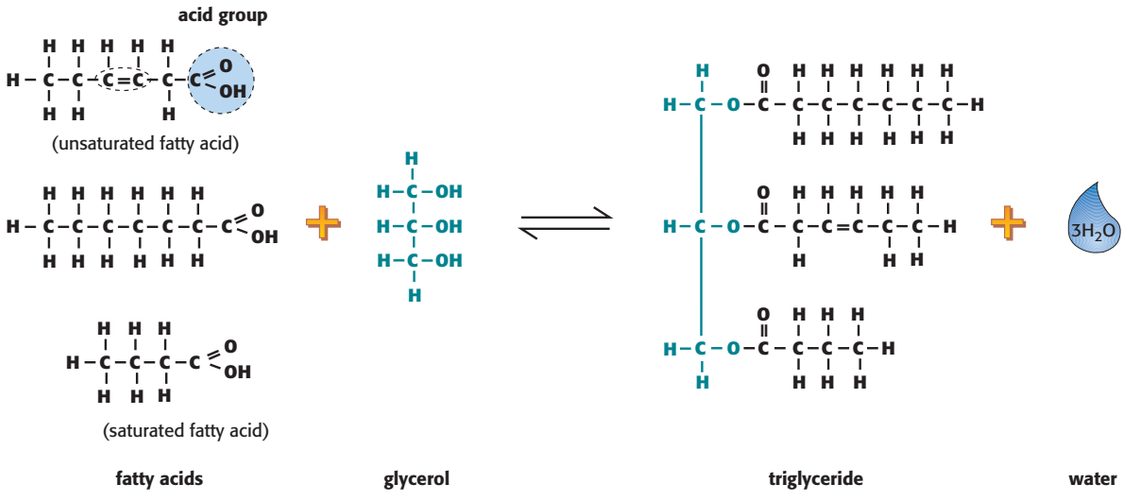


Figure 4.14 ▲

A triglyceride molecule consists of three fatty acids (look at the far left of the diagram) joined to a glycerol molecule. The fatty acids in a triglyceride may be the same or different. You can see a similarity in the structures of these fatty acids: all have a COOH group (note the blue circle in the unsaturated fatty acid). What difference can you see between unsaturated and saturated fatty acids? What molecule is formed as a by-product of the synthesis of a triglyceride?

4.10 Lipids Are Efficient Energy-Storage Compounds

Like carbohydrates, lipids are composed of carbon, hydrogen, and oxygen atoms. However, lipids contain fewer oxygen atoms than carbohydrates. Simple fats, or triglycerides, are the lipids most common in human diets and bodies. These molecules are made from two building blocks: glycerol and fatty acids. Glycerol is a three-carbon sugar. Fatty acids are chains of carbon and hydrogen with an acid grouping on one end (see Figure 4.14). Cells can form both glycerol and fatty acids from glucose.

Both carbohydrates and lipids are important energy-storage compounds in organisms. A gram of fat, however, contains more than twice as much chemical energy as a gram of carbohydrate. Therefore, fats are more efficient storage compounds. As animals prepare for winter when food is scarce, they eat large amounts of food. Much of this food energy is converted into fat, and the fat levels in their bodies increase dramatically.

Lipids are also essential structural components of all cells. Lipids include plant waxes and **cholesterol,** in addition to simple fats. The chemical structure of cholesterol is illustrated in Figure 4.15. Cholesterol is a structural component of cells and is used by the body to make hormones and other important compounds. However, excess cholesterol in the blood has been linked to heart disease.

4.11 Proteins Function as Enzymes and Structural Components of Cells

Topic: proteins/enzymes
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Proteins are a diverse group of molecules. Some proteins, called enzymes, function as catalysts to speed up chemical reactions, such as those for

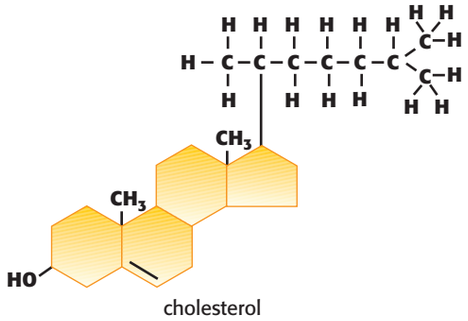

Figure 4.15
Some of the cholesterol, a type of lipid, produced in our bodies is converted into vitamin D (required for strong bones and healthy teeth).

cellular respiration and the building of other molecules. Some proteins form the structural components of cells. Specialized cells with certain kinds of proteins build body parts such as muscle, bone, and feathers.

The building block of a protein molecule is an **amino acid,** shown on the left side of Figure 4.16a. Amino acids always contain four different atoms: carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). There are two amino acids that also contain sulfur (S). Twenty different amino acids can be found in protein molecules.

Green plants can synthesize all of these amino acids from simple materials. Animals cannot. Animals must get some amino acids, called essential amino acids, from the food they eat. Unfortunately, not every type of food contains all the needed essential amino acids. Therefore, animals must have a balanced diet containing different protein sources. Without it, protein-deficiency diseases may occur.

To synthesize a protein, amino acids must be linked together. First, two amino acids are linked together to form a dipeptide, as shown in Figure 4.16a. A long chain of amino acids is a **polypeptide,** illustrated in

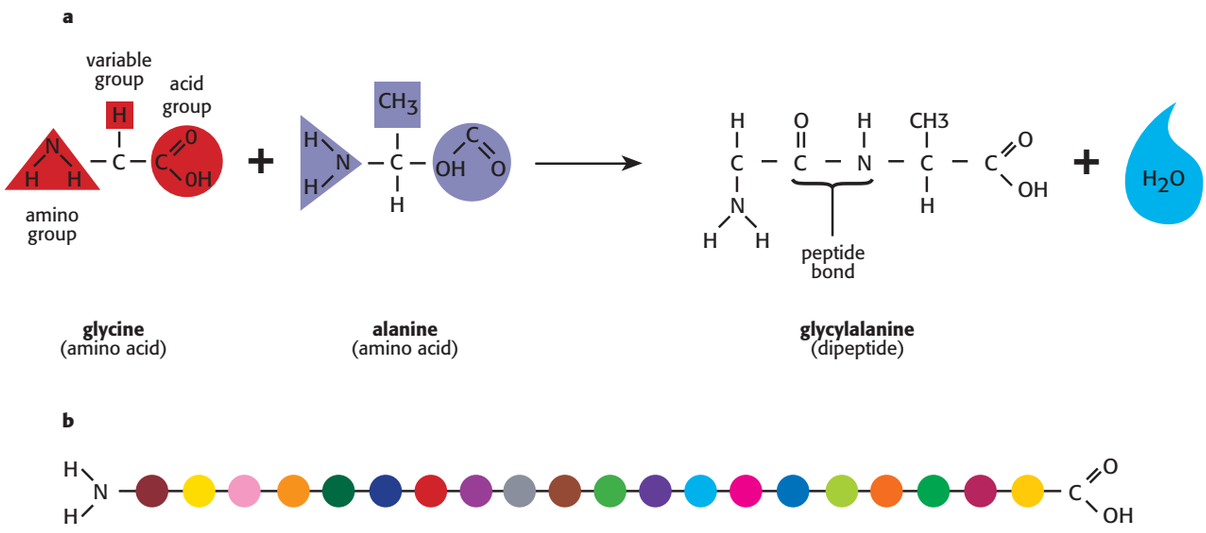

Figure 4.16
(a) The parts of an amino acid are indicated on the glycine molecule. Can you identify these parts on the alanine molecule? The formation of a peptide bond between the two amino acids creates what is called a dipeptide. Polypeptide chains (b) are composed of many amino acids, linked together by peptide bonds. In this diagram, the amino acids are shown as little balls connected by peptide bonds (shown as solid lines), just to give you the idea of what a chain of amino acids might look like.

Figure 4.17

A single polypeptide chain may coil, like a spring, giving it a three-dimensional structure (a). For simplicity, the string of amino acids may be drawn as a flat ribbon, so that the coil would look as shown in (b). Using a convention similar to a ribbon diagram, but with a tube around the coil, the shape of a folded protein, such as myoglobin, would look like (c).

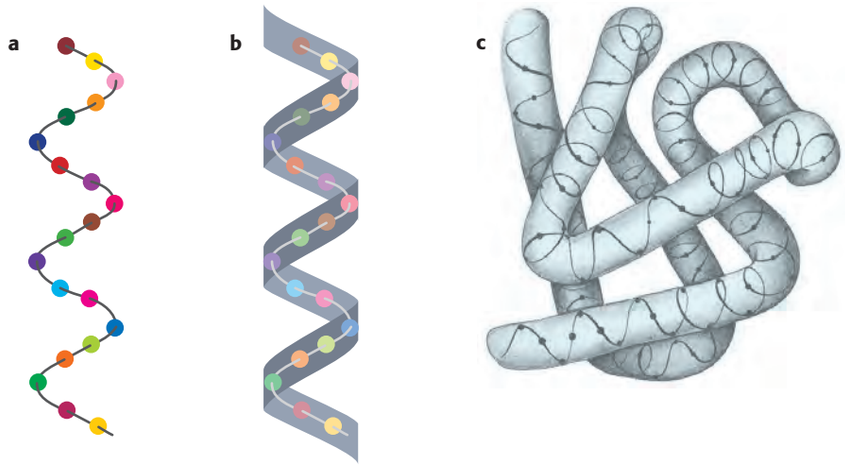

Figure 4.16b. Proteins vary considerably in the number of amino acids they contain. Additionally, many proteins are made of only one polypeptide chain, while others are made of two or more polypeptide chains joined together in some way. As shown in Figure 4.17, polypeptide chains are coiled and folded into complex three-dimensional structures. The structure and shape of a protein, such as the myoglobin in Figure 4.17c, determines how it will function.

Living organisms make thousands of different kinds of proteins from only 20 amino acids. These amino acids are joined by peptide bonds in different sequences and numbers to form polypeptide chains of sizes from small to large. A protein may be a single polypeptide chain, while another protein may be composed of more than one polypeptide chain. Given the diversity of structures that living systems exhibit and the many chemical reactions needed for life, we should not be surprised by the large number of possible proteins made by living things.

4.12 Enzymes Catalyze Chemical Reactions

Most enzymes are large, complex proteins. Enzymes participate in cellular reactions that would otherwise require added energy, such as heat, to take place. In living systems, enzymes allow chemical reactions to take place at normal cell temperatures. Enzymes function as catalysts: they promote reactions but are not used up in the reactions. Some enzymes are needed in only small amounts, because one enzyme molecule can catalyze (speed-up) its chemical reaction many times in a given time period.

As shown in Figure 4.18a, the specific reaction catalyzed by an enzyme depends on the molecule's structure and the shape of a small area of the enzyme known as the **active site.** This region, formed by the folding of the polypeptide chain or chains that make up the enzyme, can attract and hold only specific molecules. The molecules on which an enzyme acts are known as **substrates.** Some enzymes bind a very limited number of substrates and are very specific about the chemical reaction they catalyze (for instance, the enzyme that makes sucrose from glucose and fructose). Other enzymes may bind a series of substrates that share some common feature and catalyze a more general chemical reaction (for instance, the enzyme that links amino acids during protein formation).

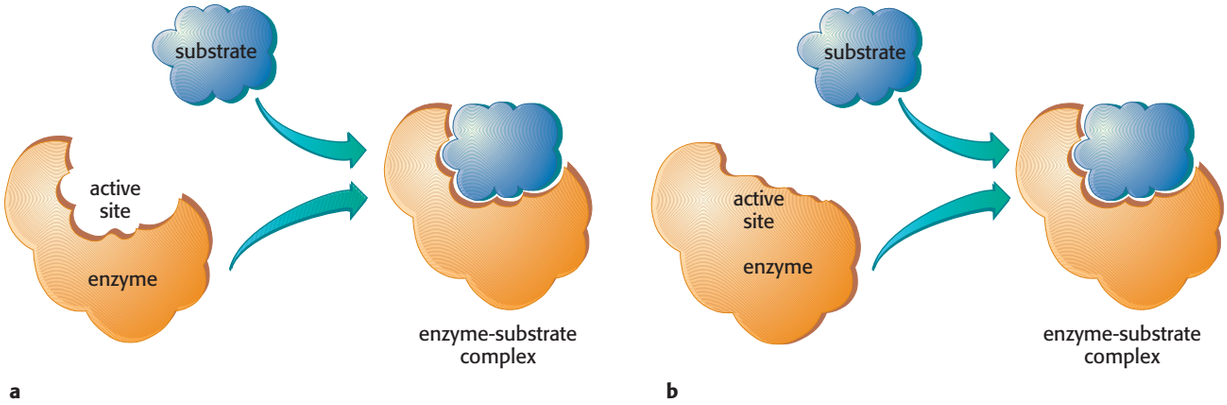

Figure 4.18

(a) A substrate binds to the enzyme at the active site. (b) Sometimes the active site changes shape after the substrate binds, bringing about the necessary fit. The binding produces an enzyme-substrate complex.

To act as a catalyst, an enzyme must participate in a chemical reaction. The reacting molecules combine with the active site of an enzyme, forming an **enzyme-substrate complex** (Figure 4.18b). The enzyme aligns the reacting molecules precisely and permits chemical changes to be completed rapidly. Once the reaction is complete, the new molecules break away, leaving the enzyme as it was before the reaction.

Different enzymes catalyze the various synthesis and decomposition reactions. In a synthesis reaction, Figure 4.19a, two or more substrates combine with the enzyme. The enzyme provides the proper alignment, which enables these small molecules to join into a new molecule. In a decomposition reaction, Figure 4.19b, the substrate combines with the enzyme and is split into two or more smaller molecules. Remember that the energy-releasing steps that occur during cellular respiration (Section 4.6) are decomposition reactions.

Two aspects of enzyme activity are very important to cells. Enzyme reactions are faster as temperatures increase, but only to a certain point. At temperatures that are too high, enzymes may begin to lose their shape. Because fit is so important for proper enzyme action, enzymes that lose their shape no longer function. Enzyme activity also varies with the pH of the solution. Thus, the temperature and the pH must be appropriate for enzymes to act effectively, as you observe in Investigation 4.3.

4.13 Nucleic Acids Contain the Blueprint for Life

Nucleic acids are carbon-containing molecules present in all cells and are vital to cell function. The two types are **RNA,** ribonucleic acid, and **DNA**, deoxyribonucleic acid. RNA is required for the synthesis of proteins. Information stored in DNA determines the genetic, or hereditary, blueprint of the organism. In this way, DNA controls the activities that occur in each cell.

Both DNA and RNA are made up of individual subunits called **nucleotides.** Each nucleotide, in turn, is made up of three smaller molecules linked together: a phosphate group, a 5-carbon sugar, and a nitrogen

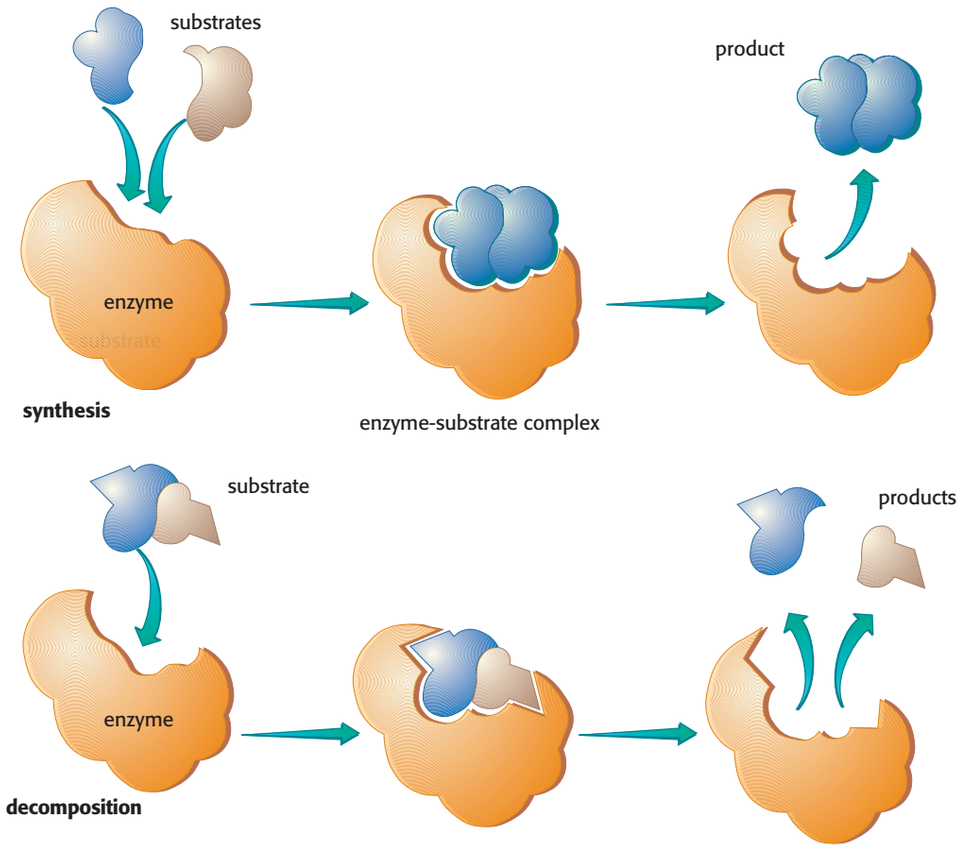

Figure 4.19 ▲

In synthesis, two or more substrate molecules join at the active site forming one larger molecule. In decomposition, the substrate combines with the enzyme and is split into two or more smaller molecules.

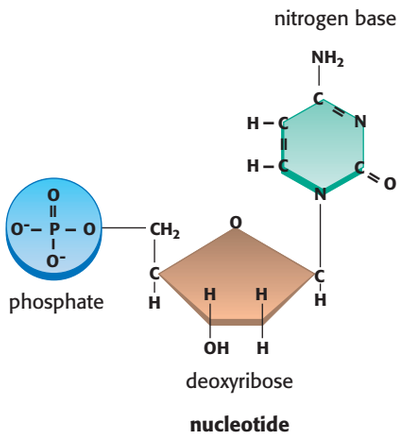

Figure 4.20 ▲

A nucleotide is made up of a 5-carbon sugar (ribose or deoxyribose), a nitrogen base, and a phosphate group.

base (see Figure 4.20). DNA and RNA each contain four nitrogen bases, three of which are common to both molecules. Each base is made up of carbon, hydrogen, oxygen, and nitrogen atoms. RNA nucleotides contain a 5-carbon sugar called ribose. DNA contains a slightly different 5-carbon sugar called deoxyribose, which has one fewer oxygen atom than ribose. Chromosomes, the genetic information found in a cell's nucleus, are each made of two large DNA strands. The two strands are joined in a specific way and coiled to form the double helix as shown in Figure 4.21. RNA molecules are single-stranded and are usually smaller.

Information is stored in DNA as the sequence of nitrogen bases that make up each DNA strand. This sequence is the information that, in turn, determines the sequence of amino acids in proteins. This sequence information also plays a major role in controlling when each protein is made. By controlling the synthesis of enzymes necessary for chemical reactions in the cell, DNA controls the activities of the cell. All the cells in a given individual (a human or other animal, for instance) have the same unique genetic information in their DNA. That individual's unique DNA resulted from the combination of genetic information provided by the individual's parents during sexual reproduction.

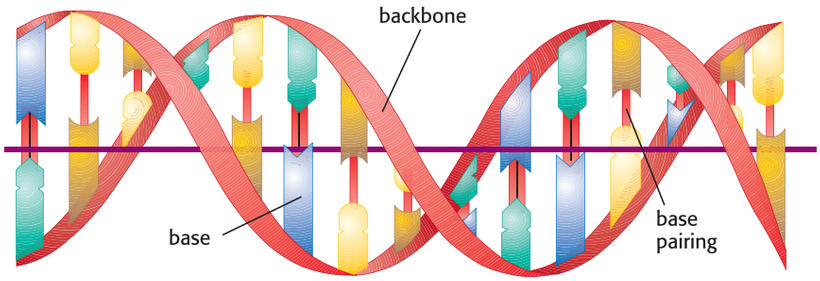

Figure 4.21 ▲

The genetic information in each cell in your body is contained in the nucleotide sequence of DNA. The backbone of the DNA molecule is made up of the deoxyribose and phosphate groups, and is shown as a red ribbon. The various nitrogen bases point to the inside. Two chains of nucleotides are held together by specific pairings of these bases. For example, we have shown the green nitrogen base from Figure 4.20 with a shape that would fit into its matching base. The two chains (the double strand) are coiled around a central axis to form what is called a double helix. We show the axis as a horizontal line to help you visualize the correct twisting.

CONCEPT REVIEW

1. Why is the element carbon so important to living things?
2. What are the building blocks of carbohydrates? Of fats? Of proteins? Of nucleic acids?
3. Name one important function of each of the biological molecules listed in question 2.
4. Why is fat a better storage compound than starch?
5. How do enzymes work to catalyze a chemical reaction?
6. How is it possible for so many different proteins to exist?
7. What role do enzymes play in the release of energy from food?

Carbon Cycling

4.14 Plants Make and Use Carbon-Containing Sugars

GUIDEPOST

What is the source of matter for living things, and what happens to the matter as it passes through living systems?

Recall from Section 4.5 that plants take up carbon atoms as carbon dioxide from the air. During photosynthesis, they use the energy in sunlight to make sugars from carbon dioxide and water. In this way, the energy from sunlight and the carbon from carbon dioxide are stored in the sugars.

The sugars created during photosynthesis can be used in four ways by the plant, as shown in Figure 4.22. First, the plant may break down the sugar molecules to release the stored energy. This energy may be used by plant cells to carry out their essential activities. Second, a plant may use the sugar molecules for growth. In this case, many sugar molecules are joined together to make the building materials necessary for more cells. Cellulose, for example, is one of these materials. Third, the plant may store sugars for future use. Starch is an important storage compound found in many parts of a plant. When the plant needs energy, starch is first broken

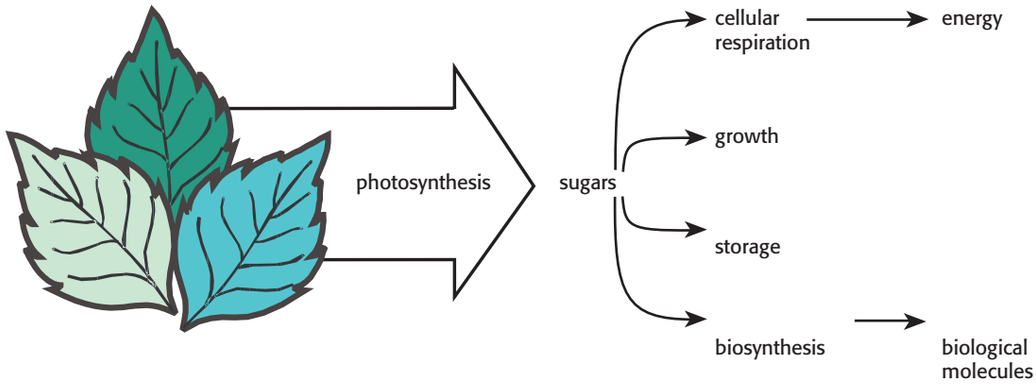

Figure 4.22 ▲

Four ways that plants use the sugars made during photosynthesis

down to individual sugar molecules. During cellular respiration, the sugars are broken down to release energy. Fourth, sugar molecules may be converted into the other biological molecules needed for life.

4.15 Carbon Cycles within an Ecosystem

Topic: carbon cycle/ global warming
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Keyword: GV10E104

When a plant is eaten, the carbon in the plant is passed to a consumer. For the consumer to use the food, it must use decomposition reactions to break the plant's molecules into their smaller building blocks. In addition to producing molecules that the consumer can use, this process also releases energy. Much of the energy released is used for the activities of the consumer. Carbon-containing molecules that are not used to make new molecules needed by the consumer are further broken down, and the carbon is exhaled into the air as carbon dioxide. For example, you take in carbon in all the foods you eat. You return carbon dioxide to the air every time you exhale. A plant also returns carbon dioxide to the air when it uses its own sugars as a source of energy. When another plant takes in this carbon dioxide during photosynthesis, the cycle of carbon through the community is complete.

Carbon dioxide also is returned to the air by decomposers, which break down both consumers and producers. Similar to what is described above, decomposers derive energy and carbon from the organisms on which they act to maintain themselves. Carbon that is not used is returned to the air as carbon dioxide. Eventually, almost all the carbon that is taken in by plants during photosynthesis is returned to the air by the activity of decomposers.

During the past tens of millions of years, many energy-rich plants were buried before decomposers could act on them. Consequently, the molecules in the plants slowly changed over long periods of time. They were converted to fuels, like coal, oil, and natural gas. When these fossil fuels are burned, energy is released, and the carbon in the fuels is returned to the air as carbon dioxide. So even the energy obtained from fuels is a result of photosynthesis. The process in which carbon is passed from one organism to another, then to the abiotic community, and finally back to the plants is called the **carbon cycle** (see Figure 4.23). Some of the other cycles found within ecosystems—the water cycle, the sulfur cycle, and the nitrogen cycle—are described in later chapters.

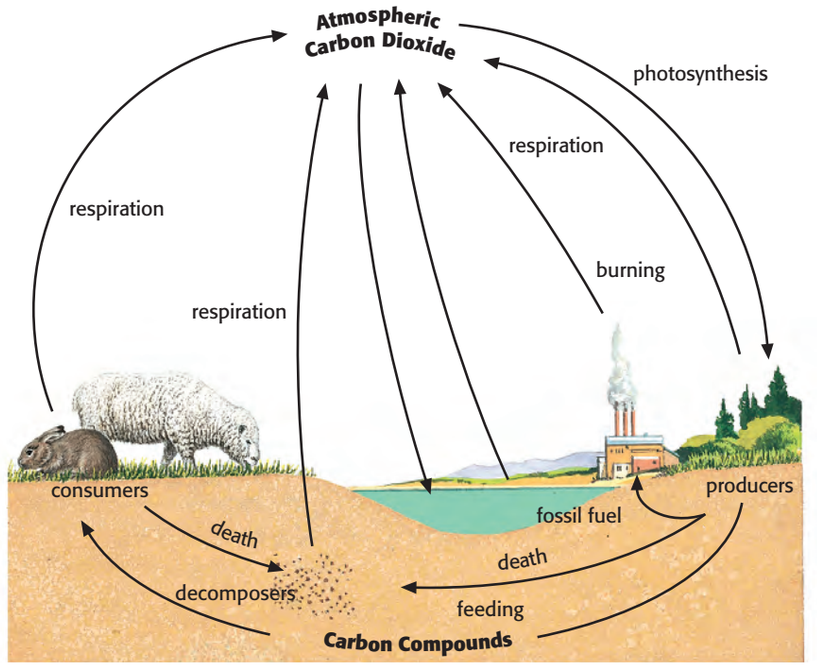

Figure 4.23 ▲

Where would you place humans in the carbon cycle?

CONCEPT REVIEW

1. Of the four ways a plant uses the sugars it makes, which is the only way that does not add material to the plant?
2. How are producers, consumers, and decomposers involved in the carbon cycle?
3. What is the greenhouse effect and how does it work?
4. Explain why the ultimate fate of a piece of bread you eat is that you will exhale it.

Summary

Energy is needed to do work and to create and maintain order. Without energy, highly organized systems such as living things could not exist. The need for energy is continuous; therefore, organisms must obtain and use energy throughout their lives. ATP is the major energy-transfer molecule in cells. Organisms also must obtain matter to maintain their structure and to grow and reproduce. Plants make sugars from carbon dioxide, water, and light energy in the process of photosynthesis. This process converts light energy into chemical energy, which is stored in the form of carbohydrates. Plants can use this energy to make their own biological molecules, including proteins, lipids, and nucleic acids, all of which contain carbon. Other organisms, like humans, use the energy obtained from eating plant and animal tissues for energy production and to make their own biological molecules. There are two main types of chemical reactions in cells, synthesis and decomposition. All chemical reactions are catalyzed by a class of proteins called enzymes.

BIOLOGY TODAY

The Carbon Cycle and Global Warming

Over the past 100 years, the surface of the earth has warmed by approximately 0.5 C. This effect is called global warming. Scientists believe global warming is mostly due to human technology adding to gases in the atmosphere. Carbon dioxide is one of the gases that compose the earth's atmosphere, and has a great effect on climate. Although some carbon dioxide is released by the cellular respiration of organisms, larger amounts are released when humans burn fossil fuels. Since the industrial Revolution, the amount of carbon dioxide in the atmosphere has increased by about 25 percent.

As early as the 19th century, experts recognized that carbon dioxide in the atmosphere gives rise to a greenhouse effect. Think how the closed windows of a car or the glass in a greenhouse will allow sunlight to stream in but will prevent heat from escaping. Similarly, carbon dioxide and other greenhouse gases, such as methane, ozone, and nitrous oxide, allow sunlight to reach the earth but trap the reflected heat. If there were no greenhouse gases, the earth would be cold and devoid of life. Too great a concentration of such gases, on the other hand, would cause the temperature to rise.

Human activity also interrupts the carbon cycle in two ways. First, the burning of carbon-containing fossil fuels adds carbon dioxide to the atmosphere. Second, the destruction of rain forests and other vegetation leaves less plant life to absorb carbon dioxide. When unharvested plant matter decays and when roots in the exposed soil react with oxygen, still more carbon dioxide enters the atmosphere. Many scientists expect the increased levels of carbon dioxide, other gases, and water vapor to raise the earth's temperature by 1 C to 6 C in the next 100 years. Such an increase could affect global climate (changing rainfall patterns), cause a rise in sea levels (flooding low-lying areas), and change food-producing patterns (bringing famine to some regions). Famine and floods may cause a population to migrate into a new area, adding to existing problems of the population there and creating new ones. The opposing point of view states that the computer models used to predict the greenhouse effect are so weak they do not account for the warming that has occurred in the last 100 years. Many experts feel that not enough research has been done to tell us what we need to know about interactions between the oceans and the atmosphere. This ignorance limits our ability to predict effects. For example, in February 1990, a federal government study indicated that the temperature in the southeastern United States actually had fallen 1 C during the past 30 years. The report did not disprove that global warming is happening, but it did stimulate debate. You may want to research current studies and bring these into class to discuss with your classmates and teacher.

Applications

1. How would a biologist studying food chains or food webs benefit from understanding the carbon cycle?
2. The proteins in the cells of a wheat plant are different from the proteins in your cells. How can the differences be explained? What must happen when you use wheat as a nutrient for the formation of your proteins?
3. Many botanists will tell you that the concentration of carbon dioxide in the air was much greater during the Carboniferous period (about 295 million years ago), when most of the large coal deposits were being formed, than it is today. What might be the basis for their information?
4. Are animals absolutely necessary for carbon to cycle within a community? Explain. In what ways do you contribute to the carbon cycle?
5. In terms of calories, why do you think seeds (small structures containing young plants) are high in fat content? Examples are the peanut, corn, and sunflower seeds from which we get cooking oils. Why are such seeds good sources of food for humans?

Problems

1. Make two lists: (a) all the ways you use energy in a day, and (b) all the different types of energy you use in a day (for example, light, heat, mechanical, chemical).
2. One hundred years ago, the carbon dioxide in the atmosphere was measured at 0.0283 percent. Today the level is 0.0330 percent. What factors during the last 100 years may have contributed to this increase? What are some possible future consequences if this trend continues?
3. Many fats and cooking oils are called polyunsaturated. Find out what this means in chemical terms.
4. Each day, you come in contact with many basic, acidic, and neutral solutions. You may have seen products that are labeled "pH-balanced" or "buffered." What does this mean? Make a list of such products or foods and explain how they affect you. Do you use these products or eat these foods because of their acidity or alkalinity, or does it make any difference what their pH is?

Investigation 4.1

Organisms and pH

Chapter 2 discussed the tendency for populations to maintain a relative stability, or homeostasis. Furthermore, the ability of individual organisms and cells to maintain an internal homeostasis is a fundamental characteristic of life. Many factors can affect that stability, for example, the relative concentrations of hydrogen ions (H^+) and hydroxide ions (OH^-). The biochemical activities of living tissues frequently affect pH, yet life depends on maintaining a pH range that is normal for each tissue or system. Using a pH meter or wide-range pH paper, you can compare the responses of several materials to the addition of an acid and a base.

▶ Before you begin, study the investigation and develop a hypothesis that answers the question, How do organisms survive and function despite metabolic activities that tend to shift pH toward either the acidic or basic end of the scale?

Materials *(per team of 4)*

4 lab aprons
4 pairs of safety goggles
50-mL beaker or small jar
50-mL graduated cylinder
forceps (optional)
pH meter or wide-range pH paper
tap water
3 colored pencils
0.1 *M* HCl in dropping bottle
0.1 *M* NaOH in dropping bottle
sodium phosphate pH 7 buffer solution
liver homogenate
potato homogenate
egg white (diluted 1 : 5 with water)
warm gelatin suspension, 2% solution
data books
pens

Put on your safety goggles and lab apron.

Procedure

1. In your data book, prepare a table similar to Table 4.1.
2. Pour 25 mL of tap water into a 50-mL beaker.
3. Record the initial pH by using a pH meter or by dipping small strips of pH paper into the water and comparing the color change to a standard color chart.
4. Add 0.1M HCl 1 drop at a time. Gently swirl the mixture after each drop. Determine the pH after 5 drops have been added. Repeat this procedure until 30 drops have been used. Record the pH measurements in your table.

0.1M HCl is an irritant and may destroy clothing. Avoid skin/eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.

Table 4.1 Testing pH

	Tests with 0.1*M* HCl							Tests with 0.1*M* NaOH						
Solution Tested	pH after addition of							pH after addition of						
	0	5	10	15	20	25	30 drops	0	5	10	15	20	25	30 drops
tap water														
liver														
potato														
egg white														
gelatin														
buffer														

5. Rinse the beaker thoroughly and pour into it another 25 mL of tap water. Record the initial pH of the water and add 0.1M NaOH drop by drop, recording the pH probe changes in exactly the same way as for the 0.1M HCl.

0.1M NaOH is an irritant and may destroy clothing. Avoid skin/eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.

6. Using the biological material assigned by your teacher, repeat Steps 2–5. Record the data in your table.
7. Test the buffer solution (a nonliving chemical solution) using the same method outlined in Steps 2–5. Record the data in your table.
8. Wash your hands thoroughly before leaving the laboratory.

Discussion

1. Summarize the effects of HCl and NaOH on tap water.
2. What was the total pH change for the 30 drops of HCl added to the biological material? What was the total pH change for the 30 drops of NaOH added? How do these data compare with the changes in tap water?
3. In your data book, prepare a simple graph of pH versus the number of drops of acid and base solutions added to tap water. Plot two lines: a solid line for changes with acid and a dashed line for changes with base. Using different colored solid and dashed lines, add the results for your biological material. Compare your graph with the graphs of teams that used a different biological material. What patterns do the graphs indicate for biological materials?

4. How do biological materials respond to changes in pH?
5. Use different colored solid and dashed lines to plot the reaction of the buffer solution on the same graph. How does the buffer system respond to the HCl and NaOH?
6. Is the pH response of the buffer system more like that of water or of the biological material?
7. How does the reaction of the buffer solution serve as a model for the response of biological materials to pH changes?
8. Would buffers aid or hinder the maintenance of homeostasis within a living cell in a changing environment?
9. What does the model suggest about a mechanism for regulating pH in an organism? Your answer should allow you to evaluate your original hypothesis.

Investigation 4.2

Compounds in Living Organisms

The compounds that your body needs for energy and building materials are carbohydrates, proteins, fats, vitamins, and other nutrients. These compounds are present in the plants and animals you use as food. In this investigation, you will observe tests for specific compounds and then use those tests to determine which compounds are found in ordinary foods.

Materials *(per team of 4)*

4 pairs of safety goggles
4 lab aprons
4 pairs of plastic gloves
250-mL beaker
10-mL graduated cylinder
6 18-mm ≥ 150-mm test tubes
test tube clamp
Biuret solution in dropping bottle
indophenol solution in dropping bottle
Lugol's iodine solution in dropping bottle
1% silver nitrate solution in dropping bottle
isopropyl alcohol (99%) in screw-top jar
Benedict's solution in dropping bottle
apple, egg white, liver, onion, orange, potato, or other foods of your choice
brown wrapping paper
hot plate
data books
pens

Safety

Put on your safety goggles, lab apron, and gloves. Tie back long hair.

Safety Goggles Lab Gloves Lab Apron

Procedure

Part A: Test Demonstration

1. In your data book, prepare a table similar to Table 4.2.

Table 4.2 Reagent Tests of Known Food Substances

Food Substance	Reagent Test	Results
gelatin	Biuret solution	
glucose	Benedict's solution	
starch	Lugol's iodine solution	
vitamin C	indophenol solution (0.1%)	
sodium chloride	silver nitrate solution (1%)	
butter or vegetable oil	brown paper	

2. Scientists use special chemical solutions, or reagents, to detect the presence of certain compounds. Observe the six reagent tests your teacher performs. In your table, describe the results of each test.

Part B: Compounds in Foods

3. In your data book, prepare a table similar to Table 4.3. Then, record the presence (+) or absence (–) of each substance in the foods you test.

The reagents you will use in this procedure may be corrosive, poisonous, and/or irritants, and they may destroy clothing. Avoid skin and eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.

4. Predict what substances you will find in each sample your teacher assigns to you. Then, test the samples as your teacher demonstrated or as described in Steps 5–10. Record the result of each test in your data book, using a + or –.

Table 4.3 Analysis of Compounds in Common Foods

Substance		Protein	Glucose	Starch	Vitamin C	Chloride	Lipid
egg	prediction						
	test results						
potato	prediction						
	test results						
etc.	prediction						
	test results						

5. Protein test: Place 5 mL of the assigned food in a test tube. Add 10 drops of Biuret solution.
6. Glucose test: Add 3 mL of Benedict's solution to 5 mL of the assigned food. Place the test tube in a beaker of boiling water and heat for 5 minutes.

Use test tube clamps to hold hot test tubes. Boiling water will scald, causing second-degree burns. Do not touch the beaker or allow boiling water to contact your skin. Avoid vigorous boiling. Should a burn occur, call your teacher immediately; place burned area under cold, running water.

7. Starch test: Add 5 drops of Lugol's iodine solution to 5 mL of the assigned food.
8. Vitamin C test: Add 8 drops of indophenol to 5 mL of the assigned food.
9. Chloride test: Add 5 drops of silver nitrate solution to 5 mL of the assigned food.
10. Fat test: Rub the assigned food on a piece of brown wrapping paper. Hold the paper up to the light. Food that contains fat makes a translucent, greasy spot on the paper. When food contains only a small amount of fat, it may not be detected by this method. If no fat has been detected, place the assigned food in 10 mL of a fat solvent such as isopropyl alcohol (99%). Allow the food to dissolve in the solvent for about 5 minutes. Then, pour the solvent on brown paper. The spot should dry in about 10 minutes. Check the paper.

Isopropyl alcohol is flammable; its vapors may explode. Keep away from heat and sparks. Extinguish any open flames in the area.

11. Wash your hands thoroughly before leaving the laboratory.

Discussion

1. How did your predictions compare with the test results?
2. Which of your predictions was correct?
3. Which foods contained all the compounds for which you tested?
4. On the basis of your tests, which food could be used as a source of protein? Glucose? Starch? Vitamin C? Fat?
5. How might the original colors of the test materials affect the results?

Investigation 4.3

Enzyme Activity

In this investigation, you will study several factors that affect the activity of enzymes. The enzyme you will use is catalase, which is present in most cells and found in high concentrations in liver and blood cells. You will use liver homogenate as the source of catalase. Catalase promotes the decomposition of hydrogen peroxide (H_2O_2) in the following reaction:

$$2H_2O_2 \xrightarrow{\text{catalase}} 2H_2O + O_2$$

Hydrogen peroxide is formed as a by-product of chemical reactions in cells. It is toxic and would kill cells if not immediately removed or broken down.

Materials *(per team of 3)*

- 3 pairs of safety goggles
- 3 lab aprons
- 50-mL beaker
- 2 250-mL beakers
- 10-mL and 50-mL graduated cylinders
- 6 18-mm × 150-mm test tubes
- test tube rack
- nonmercury thermometer
- filter-paper disks
- reaction chamber
- forceps
- square or rectangular pan
- buffer solutions: pH 5, pH 6, pH 7, pH 8
- stock catalase solution
- fresh 3% H_2O_2
- ice
- water bath at 37° C
- data books
- pens

Put on your safety goggles and lab apron. Tie back long hair.

Procedure

As shown in Figure 4.24, the reaction chamber is a 25-mL square glass bottle equipped with a 1-hole rubber stopper into which a dropping pipet has been inserted. In all experiments, make certain that your reaction chamber is scrupulously clean. Catalase is a potent enzyme, and if the chamber is not washed thoroughly, enough will adhere to the sides to make later tests inaccurate. Measure all substances carefully. Results depend on comparisons between experiments, so the amounts measured must be equal or your comparisons will be valueless. Before you do the experiment, read the instructions completely. Make sure that you have all the required materials on hand, that you understand the sequence of steps, and that each member of your team knows his or her assigned function.

Figure 4.24 ▲

This apparatus will allow you to measure O_2 production in a reaction between catalase and hydrogen peroxide.

Part A: The Time Course of Enzyme Activity

1. Prepare a table in your data book similar to Table 4.4.
2. Obtain a small amount of stock catalase solution in a 50-mL beaker.
3. Obtain a reaction chamber and a number of filter-paper disks.
4. Prepare a disk for use in the reaction chamber by holding it by its edge with a pair of forceps and dipping it into the stock catalase solution for a few seconds. Drain excess solution from the disk by holding it against the side of the beaker before you transfer it to the reaction chamber. Prepare 4 catalase-soaked filter-paper disks and place each one high on one interior side wall of the reaction chamber. (They will stick to the side wall.)

Table 4.4 Catalase Activity under Various Conditions

Experiment	mL O_2 Produced/30 sec																			
reading	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(Part A) full concentration																				
(Part B) ¾ concentration																				
etc.																				

5. Stand the reaction chamber upright and carefully add 10 mL of 3% hydrogen peroxide (H_2O_2) solution. *Do not allow the peroxide to touch the filter-paper disks.*

Hydrogen peroxide (H_2O_2) is a reactive material. Avoid skin/eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.

6. Put the stopper on the chamber and seal it tightly.
7. Fill a pan almost full with water.
8. Lay the 50-mL graduated cylinder on its side in the pan so that it fills with water completely. If any air bubbles are present, carefully work these out by tilting the cylinder slightly. Turn the cylinder upside down into a vertical position, keeping its mouth underwater at all times.
9. Making certain the side with the disks is at the top, carefully place the reaction chamber on its side in the pan of water.
10. Move the graduated cylinder so that its mouth lies directly over the tip of the dropping pipet extending from the reaction chamber, as shown in Figure 4.24. One member of the team should hold it in this position for the duration of the experiment.
11. Rotate the reaction chamber 180° on its side so that the H_2O_2 solution comes into contact with the soaked disks.
12. Measure the gas levels in the graduated cylinder at 30-second intervals for 10 minutes. Record the levels in your data table.

Part B: The Effect of Enzyme Concentration on Enzyme Activity

13. Test ¾, ½, and ¼ concentrations of enzyme solution, using the procedure for Part A with the following changes:
    a. ¾ concentration: Use 3 catalase-soaked disks instead of 4.
    b. ½ concentration: Use 2 catalase-soaked disks and a 10-mL graduated cylinder instead of a 50-mL graduated cylinder.
    c. ¼ concentration: Use 1 catalase-soaked disk and a 10-mL graduated cylinder.
14. Record all data in your data table.

Part C: The Effect of Temperature on Enzyme Activity

15. Add 10 mL of 3% H_2O_2 to each of two test tubes. Place one test tube in a beaker of ice water and the other in a beaker with water maintained at 37° C.
16. When the temperature of the chilled H_2O_2 reaches approximately 10° C, repeat Part A with the following changes:
    a. In Step 5, use 10 mL of chilled 3% H_2O_2.
    b. In Step 7, add ice to the pan to chill the water to approximately 10° C.
17. When the temperature of the warmed H_2O_2 reaches approximately 37° C, repeat Part A with the following changes:
    a. In Step 5, use 10 mL of warmed 3% H_2O_2.
    b. In Step 7, fill the pan with water warmed to approximately 37° C.
18. Record the data in your data table.

Part D: The Effect of pH on Enzyme Activity

19. Label 4 test tubes *pH 5*, *pH 6*, *pH 7*, and *pH 8*, respectively. Add to each of these 8 mL of 3% H_2O_2.
20. Add 4 mL of pH 5 buffer solution to the pH 5 test tube, shaking well to ensure mixing. Do the same for the other buffer solutions.
21. Repeat Part A for each pH value, substituting the buffered 3% H_2O_2 solutions.
22. Record the results in your data table.
23. Wash your hands thoroughly before leaving the laboratory.

Discussion

1. In your data book, plot the data of Part A on a graph. Label the horizontal axis *Time (sec)*, and label the vertical axis *mL O_2 Produced*. Does the action of catalase change through time?
2. Plot the data of Part B on the graph used for Part A, and label the concentrations on the graph. Based on these data, how does enzyme activity vary with concentration?
3. Copy the graph for Part A, and plot the data from Part C on it. Based on these data, how does temperature affect enzyme action?

4. Plot the results of all four runs of Part D on a third graph. How does pH affect enzyme action?
5. What is a buffer? Would Parts A, B, and C have been different if buffers had been used in them too? If so, how?
6. Summarize the general conditions necessary for effective enzyme action. Are these conditions the same for each enzyme? Why?
7. How would you design an experiment to show how much faster H_2O_2 decomposes in the presence of catalase than it does without the enzyme?
8. Since the liver from which you obtained catalase was dead, why is the enzyme still active?

GLOSSARY

A

abiotic (AY by OT ik) **factor:** a physical or nonliving component of an ecosystem. p. 32

abscisic (ab SIS ik) **acid:** a plant hormone that protects a plant in an unfavorable environment by promoting dormancy in buds and seeds and closing of stomates. p. 554

absorption: the movement of water and of substances dissolved in water into a cell, tissue, or organism. p. 420

absorption spectrum: the characteristic array of wavelengths (colors) of light that a particular substance absorbs. p. 545

acid deposition: The falling of acids and acid-forming compounds from the atmosphere on the earth's surface; commonly known as acid rain. p. 648

acidic: having a pH of less than 7, reflecting more dissolved hydrogen ions than hydroxide ions. p. 90

acquired characteristics: characteristics acquired during the life of an organism; once thought to be heritable. p. 241

actin: a protein in a muscle fiber that, together with myosin, is responsible for muscle contraction and relaxation. p. 484

action spectrum: a representation of the rate of an activity, especially photosynthesis, under different wavelengths of light at a given light intensity. p. 543

active site: the specific portion of an enzyme that attaches to the substrate through weak chemical bonds. p. 100

active transport: the movement of a substance across a biological membrane against its concentration gradient with the help of energy input and specific transport proteins. p. 133

adaptation: in natural selection, a hereditary characteristic of some organisms in a population that improves their chances for survival and reproduction in their environment compared with the chances of other organisms in the population. p. 240

adaptive radiation: the emergence of numerous species from a common ancestor introduced to an environment presenting a diversity of conditions. p. 248

adenosine diphosphate: see *ADP.*

adenosine triphosphate: see *ATP.*

addiction: the continued, compulsive abuse of drugs in spite of negative health or social consequences. p. 504.

ADP: adenosine diphosphate (uh DEN oh seen dy FOS fayt); the compound that remains when a phosphate group is transferred from ATP to a cell reaction site requiring energy input. p. 96

adrenal cortex: the outer portion of the adrenal gland. p. 499

adrenal medulla: the central portion of the adrenal gland that secretes epinephrine. p. 499

aerobic (eh ROH bik): occurring or living in the presence of free or dissolved oxygen. p. 271

agglutinate (uh GLOO tin ayt): to unite in a mass; clump. p. 464

aggression: forceful or hostile behavior. p. 577

algae: unicellular or multicellular photosynthetic organisms lacking multicellular sex organs. p. 326

alkaline: basic; having a pH greater than 7, reflecting more dissolved hydroxide ions than hydrogen ions. p. 90

allele (al LEEL): one of two or more possible forms of a gene, each affecting the hereditary trait somewhat differently. p. 196

alpine tundra: a biome roughly similar to arctic tundra that occurs above the timberline on mountains. p. 629

alternation of generations: a reproductive cycle in which a haploid *(n)* phase, the gametophyte, gives rise to gametes that, after fusion to form a zygote, produce a diploid (2*n*) phase, the sporophyte; spores from the sporophyte give rise to new gametophytes. p. 356

alveoli (al VEE oh ly): air sacs in a lung. p. 465

amino (uh MEEN oh) **acid:** an organic compound composed of a central carbon atom to which are bonded a hydrogen atom, an amino group (—NH_2), an acid group (—COOH), and one of a variety of other atoms or groups of atoms; amino acids are the building blocks of polypeptides and proteins. p. 99

ammonia: (1) a toxic nitrogenous waste excreted primarily by aquatic organisms, p. 304; (2) a gas in the earth's early atmosphere. p. 297

amniocentesis (AM nee oh sen TEE sus): a technique used to detect genetic abnormalities in a fetus through the presence of certain chemicals or defects in fetal cells in the amniotic fluid; the fluid is obtained through a needle inserted into the amniotic sac. p. 179

amnion: a sac or membrane, filled with fluid, that encloses the embryo of a reptile, bird, or mammal. p. 177

amniotic fluid: the liquid that bathes an embryo or fetus. p. 179

amphibian: any of the various ectothermic, smooth-skinned vertebrate organisms, belonging to the class Amphibia, that characteristically hatch as aquatic larvae with gills and that develop into adult forms that use lungs for gas exchange. p. 398

anaerobic (an eh ROH bik): occurring or living in conditions without free oxygen. p. 285

anaphase: the stage in mitosis in which chromosomes on the spindle separate and are pulled toward opposite ends of the cell. p. 138

Animalia (an ih MAYL yuh): the animal kingdom. p. 277

Annelida (an NEL ih duh): the phylum that includes segmented worms, such as earthworms and leeches. p. 394

annelids (AN ih lidz): worms belonging to the phylum Annelida. p. 394

anorexia nervosa (an oh REX ee uh ner VOH suh): a condition characterized by abnormal loss of appetite and induced self-starvation to reduce body weight. p. 437

anterior: situated toward the front; toward a head end. p. 388

anther: the enlarged end of a stamen, inside which pollen grains with male gametes form in a flower. p. 358

Anthophyta (an THOF ih tuh): the phylum containing the flowering plants. p. 370

anthropologist (an thruh PAH loh jist): a scientist who studies humans—human evolution, variability, and both past and present cultures and behavior. p. 613

antibody: a blood protein produced in response to an antigen, with which it combines specifically; antibodies block the ability of pathogens or foreign material to injure the body. p. 306

antigen: any material, usually a protein, that is recognized as foreign and elicits an immune response. p. 458

anus (AY nus): the outlet of the digestive tube. p. 421

aorta: the main artery of the circulatory system; blood that has been oxygenated in the lungs and has been returned to the heart enters the aorta to be carried to all other parts of the body. p. 452

Apicomplexa (ap ih kum PLEX suh): the phylum containing the sporozoans. p. 331

appendage (uh PEN dij): a structure attached to the main part of a body; in animals, a tentacle, a leg, a flipper, a wing, etc. p. 389

aquatic (uh KWAH tik): describing a water environment or organisms that live in water. p. 388

arboreal: adapted for living in or around trees, as are monkeys and some apes. p. 609

archaebacteria (AR kee bak TIR ee uh): the more ancient of the two major lineages of prokaryotes, represented today by a few groups of bacteria inhabiting extreme environments; commonly referred to as Archaea. p. 297

archaeology: the systematic study of the human past; locating and interpreting the cultural products of prehistoric humans. p. 620

arctic tundra: biome at the northernmost limits of plant growth, where plant forms are limited to low, shrubby, or matlike vegetation. p. 629

artery: a vessel that transports blood away from the heart. p. 452

arthropod: any of the numerous invertebrate organisms of the phylum Arthropoda. p. 395

Arthropoda (ar THRAP uh duh): the phylum that includes insects, crustaceans, arachnids, and others; an alternate classification scheme, as shown in Appendix Four, "The Catalog of Living Things," divides this phylum into three phyla, the crustaceans, the chelicerates (horseshoe crabs, mites, spiders, etc.), and the mandibulates (insects). p. 395

artificial selection: the selective breeding of domesticated plants and animals to encourage the occurrence of desirable traits. p. 240

Ascomycota (AS koh my KOH tuh): the phylum containing the sac fungi. p. 335

ascus (AS kus): a reproductive structure formed by sac fungi when two hyphae conjugate. pp. 186, 336

asexual reproduction: any method of reproduction that requires only one parent or one parent cell. p. 153

atherosclerosis (ATH uh roh skleh roh sis): a chronic cardiovascular disease in which plaques develop on inner walls of arteries, restricting the flow of blood. p. 433

atom: the smallest particle of an element; in turn, an atom is made of smaller particles that do not separately have the properties of the element. p. 13

ATP: adenosine triphosphate (uh DEN oh seen try FOS fayt); a compound that has three phosphate groups and is used by cells to store energy. p. 95

atrium (AY tree um; plural atria): a chamber of the heart that receives blood from the veins. p. 453

australopithecine (AH strahl oh PITH uh seen): any of the earliest known species of hominids that walked erect and had humanlike teeth but whose skull, jaw, and brain capacity were more apelike; may include several species. p. 610

autoimmune: a response in which antibodies are produced against some of the body's own cells. p. 461

autonomic nervous system: a division of the nervous system that controls involuntary activities of the body such as blood pressure, body temperature, and other functions necessary to the maintenance of homeostasis. p. 492

autosome: a chromosome that is not directly involved in determining sex. p. 202

autotroph (AWT oh trohf): an organism able to make and store food, using sunlight or another nonliving energy source. p. 275

auxin (AWK sin): a plant hormone produced in an actively growing region of a plant and transported to another part of the plant, where it produces a growth effect. p. 553

axon: a structure that extends out from a neuron and conducts impulses away from the cell body. p. 488

B

Bacillariophyta (buh SIL er ee OFF ih tuh): the phylum containing the diatoms. p. 327

basic: alkaline; having a pH greater than 7, reflecting more dissolved hydroxide ions than hydrogen ions. p. 90

basidia (buh SID ee uh): specialized reproductive cells of basidiomycetes, often club-shaped, in which nuclear fusion and meiosis occur. p. 337

Basidiomycota (buh SID ee oh my KOH tuh): the phylum containing the club fungi. p. 337

B cell: a type of lymphocyte that develops in the bone marrow and later produces antibodies. p. 458

bilateral symmetry (by LAT er ul SIM eh tree): a body having two corresponding or complementary halves. p. 388

bile: a secretion of the liver stored in the gall bladder and released through a duct to the small intestine; breaks large fat droplets into smaller ones that enzymes can act upon more efficiently. p. 419

binomial nomenclature (by NOH mee ul NOH men klay chur): the two-word naming system used in systematics or taxonomy. p. 271

biocide: a poisonous substance produced and used to kill forms of life considered to be pests to humans or that spread diseases. p. 70

biodiversity: the diversity of different species and the genetic variability among individuals within each species. p. 71

biology: the study of living organisms and life processes. p. 7

biomass: the dry weight of organic matter composing a group of organisms in a particular habitat. p. 669

biome: the distinctive plant cover and the rest of the community of organisms associated with a particular physical environment; often the biome is named for its plant cover. p. 626

biosphere (BY oh sfir): the outer portion of the earth (air, water, and soil) where life is found. p. 16

biosynthesis (by oh SIN thuh sis): the process of putting together or building up the large molecules characteristic of a particular type of cell or tissue. p. 427

biotic (by OT ik): living or recently living; a biotic factor is an organism or its remains in an ecosystem. p. 32

bipedal: capable of walking erect on the hind limbs, freeing the hands for other uses. p. 610

birthrate: the rate at which reproduction increases the population; often expressed as new individuals per 1,000 or 10,000 in the population. p. 31

blade: the broad, expanded part of a leaf. p. 514

blastocyst: the mammalian embryonic stage that corresponds to the blastula of other animals. p. 177

blastula (BLAS choo luh): an animal embryo after the cleavage stage, when a pattern of cell movements toward the outside of the ball of cells results in a fluid-filled cavity inside. p. 172

blood pressure: the fluid pressure created by heart contractions; allows blood to circulate. p. 454

brachiopods (BRAY kee oh podz): marine invertebrates with dorsal and ventral shells and a pair of tentacled structures on either side of the mouth. p. 598

Brain stem: the major route by which the forebrain sends information to, and receives information from, the spinal cord and peripheral nerves. p. 491

Bryophyta (bry OFF ih tuh): the phylum containing the bryophytes. p. 361

bryophytes (BRY oh fyts): the mosses, liverworts, and hornworts; a group of nonvascular plants that inhabit land but lack many of the terrestrial adaptations of vascular plants. p. 355

bulimia (buh LEE mee uh): an abnormal craving for food beyond the body's needs; frequently expressed as gorging followed by forced vomiting. p. 437

bundle-sheath cells: tightly packed cells surrounding veins in the leaves of C-4 plants that receive a rearranged 4-carbon acid in the first stage of C-4 photosynthesis; within the bundle sheath cells, carbon dioxide is released and reincorporated by an enzyme into PGA. p. 551

C

C-4 plants: plants with a photosynthetic pathway that incorporates carbon dioxide into 4-carbon compounds before beginning the Calvin cycle. p. 551

callus: a mass of dividing, undifferentiated cells at the cut end of a shoot or in a tissue culture, from which adventitious roots develop. p. 558

calorie: the amount of heat required to raise the temperature of one gram of water 1° C. p. 41

Calvin cycle: the cycle (named for its discoverer) by which carbon dioxide is incorporated in sugars during photosynthesis; uses chemical energy previously converted from light energy. p. 544

CAM: crassulacean (kras yoo LAY see un) acid metabolism; an adaptation for photosynthesis in arid conditions, in which carbon dioxide entering open stomates at night is converted into organic acids, which release carbon dioxide during the day when the stomates are less open. p. 552

cambium (KAM bee um): a layer of meristem tissue in the stems and roots of plants that produces all growth in diameter, including new xylem and phloem cells. p. 519

cancer: malignancy arising from cells that are characterized by profound abnormalities in the plasma membrane and in the cytosol, and by abnormal growth and division. p. 182

capillary (KAP ih layr ee): a microscopic blood vessel that penetrates the tissues and that has walls consisting of a single layer of cells that allows exchange between the blood and tissue fluids. p. 452

carbohydrate (kar boh HY drayt): an organic compound made of carbon, hydrogen, and oxygen, with the hydrogen and oxygen atoms in a 2:1 ratio; examples are sugars, starches, glycogen, and cellulose. p. 96

carbon cycle: the biogeochemical cycle in which carbon compounds made by some organisms are digested and decomposed by others, releasing the carbon in small inorganic molecules that can be used again by more organisms to synthesize carbon compounds. p. 104

carbon-14 dating: a technique to date fossils that uses the known disintegration rate of radioactive carbon; the amount of carbon-14 remaining in fossils indicates their age. p. 595

cardiac (KARD ee ak) **muscle:** a specialized type of muscle tissue found only in the heart. p. 484

cardiovascular disease: disease of the heart and/or blood vessels, such as atherosclerosis. p. 433

cardiovascular fitness: the relative state of health or fitness of the lungs, heart, and blood vessels. p. 487

carnivore (KAR nih vor): any organism that eats animals; a meat-eater, as opposed to a plant-eater, or herbivore. p. 62

carpel (KAR puhl): the female reproductive organ of a flower, consisting of the stigma, style, and ovary. p. 358

carrying capacity: the maximum population size that can be supported by the available resources of a given area. p. 34

cartilage: a tough, elastic connective tissue that makes up the skeleton of cartilaginous fishes, but that in other vertebrates is replaced mostly by bone as the animal matures. p. 397

catalyst (KAT uh list): a chemical that promotes a reaction between other chemicals and may take part in the reaction but emerges in its original form. p. 91

cell cycle: an ordered sequence of events in the life of a dividing cell, composed of the M, G_1, S, and G_2 phases. p. 135

cell membrane: the membrane at the boundary of every cell that serves as a selective barrier to the passage of ions and molecules. pp. 128

cell theory: the theory that organisms are composed of cells and their products and that these cells all are derived from preexisting cells. pp. 122, 124

cellular respiration (SEL yoo ler res pih RAY shun): the series of chemical reactions by which a living cell breaks down food molecules and obtains energy from them. p. 94

cellulose (SEL yoo lohs): a carbohydrate found in cell walls. p. 97

cell wall: a nonliving covering around the plasma membrane of certain cells, as in plants, many algae, and some prokaryotes; in plants the cell wall is constructed of cellulose and other materials. p. 130

central nervous system: the brain and spinal cord in vertebrates. p. 490

centriole (SEN tree ohl): one of two structures in animal cells, composed of cylinders of nine triplet microtubules in a ring; centrioles help organize microtubule assembly during cell division. p. 130

centromere (SEN troh meer): the specialized region of a chromosome that holds two replicated chromosomal strands together and that attaches to the spindle in mitosis. p. 157

cerebellum (ser eh BEL um): the part of the brain in vertebrates that is associated with regulating muscular coordination, balance, and similar functions. p. 491

cerebrum (seh REE brum): the largest portion of the brain in humans and many other animals; controls the higher mental functions such as learning. p. 490

chancre (SHAN ker): an ulcer located at the initial point of entry of a pathogen; a dull red, hard lesion that is the first manifestation of syphilis. p. 312

chaparral (shap uh RAL): a scrubland biome of dense, spiny evergreen shrubs found at midlatitudes along the coast where cold ocean currents circulate offshore; characterized by mild, rainy winters and long, hot, dry summers. p. 642

chelicerates (chih LIS er ayts): arthropods possessing paired appendages near the mouth that are modified for grasping. p. 395

chemical bond: the attraction between two atoms resulting from the sharing or transfer of outer electrons from one atom to another. p. 89

chemical energy: energy stored in the structure of molecules, particularly organic molecules. p. 12

chemoautotroph: the eubacteria that use inorganic molecules (sulfur, iron, or other minerals) in the environment to synthesize organic molecules and to create their own stores of chemical energy; compare to photoautotrophic organisms, which use the energy from sunlight. p. 303

chemosynthesis (KEE moh SIN thih sis): a pathway that uses energy from the oxidation of inorganic substances to drive the formation of organic molecules. p. 303

chemosynthetic: eubacteria that use chemosynthesis to obtain energy from inorganic molecules in the environment (as opposed to photosynthetic organisms that use light energy in the process of photosynthesis to synthesize organic compounds and to create stores of their own chemical energy). p. 303

chitin (KYT in): a hard organic substance secreted by insects and certain other invertebrates as the supporting material in their exoskeletons. pp. 274, 334

chlorophyll (KLOR uh fil): the green pigments of plants and many microorganisms; converts light energy (via changes involving electrons) to chemical energy that is used in biological reactions. p. 93

Chlorophyta (kloh ROF it uh): the phylum containing the green algae. p. 326

chloroplast (KLOR oh plast): an organelle found only in plants and photosynthetic protists; contains chlorophyll that absorbs light energy used to drive photosynthesis. pp. 130

cholesterol (koh LES ter ol): a lipid that is associated particularly with animal plasma membranes and is linked to deposits in blood vessels and to corresponding disorders of the heart. p. 98

Chordata (kohr DAH tuh): the phylum containing the chordates. p. 397

chordates: a diverse phylum of animals that possess a notocord, a dorsal hollow nerve cord, a tail, and pharyngeal gill slits at some stage of the life cycle. p. 397

chorion (KOR ee on): an embryonic membrane that surrounds all the other embryonic membranes in reptiles, birds, and mammals. p. 177

chorionic villi sampling (CVS): a procedure by which a small piece of membrane surrounding a fetus is removed and analyzed to detect genetic defects. p. 178

chromatid (KROH muh tid): one of two strands of a replicated chromosome before their separation during mitosis or meiosis. p. 157

chromatography: various techniques that scientists can use to separate mixtures of molecules based on their mass, charge, or ability to bind to other molecules. p. 219

chromosome (KROH moh sohm): a long, threadlike group of genes found in the nucleus of all eukaryotic cells and most visible during mitosis and meiosis, chromosomes consist of DNA and protein. p. 129

chromosome theory of heredity: the ideas that both eggs and sperm make equal genetic contributions to a new organism, that genes are located in the nucleus of both gametes, and that chromosomes contain the genes. p. 207

cilia (SIL ee uh): short, hairlike cell appendages specialized for locomotion and formed from a core of nine outer doublet microtubules and two inner single microtubules. p. 331

ciliates: unicellular, heterotrophic organisms that move by means of cilia. p. 331

Ciliophora (sil ee OFF er uh): the phylum containing the ciliates. p. 331

class: the third largest grouping, after kingdom and phylum or division, in the biological classification system. p. 269

cleavage (KLEE vaj): the process of cell division in animal cells, characterized by rapid cell divisions without growth that occur during early embryonic development and that convert the zygote into a ball of cells. p. 172

climatogram: a graph of monthly measurements of temperature and precipitation for a given area during a year. p. 628

clone: a lineage of genetically identical individuals. p. 555

closed circulatory system: a type of internal transport in which blood is confined to vessels. p. 404

closed population: a population in which there is no immigration or emigration; a completely isolated population. p. 47

clotting factors: the proteins involved in the sequence of events that results in the clotting of blood (usually, the sealing of a wound). p. 455

club fungi: fungi belonging to the phylum Basidiomycota and possessing basidia, on which spores are produced. p. 337

Cnidaria: the phylum containing cnidarians. p. 391

cnidarians (nih DAR ee unz): radially symmetrical, stinging-tentacled animals that possess nerve networks and digestive sacs. p. 391

CoA: an enzyme present in all cells and necessary for cellular respiration and fatty acid metabolism. p. 424

coacervate (koh AS er vayt): a cluster of proteinlike substances held together in a small droplet within a surrounding liquid; used as a model for a precell to investigate the formation of the first life on the earth. p. 283

codominance: a condition in which both alleles in a heterozygous organism are expressed. p. 200

codon: the basic unit of the genetic code; a sequence of three adjacent nucleotides in DNA or mRNA. p. 212

coevolution: the evolution of two different species interacting with each other and reciprocally influencing each other's adaptations. p. 251

cohesion-tension: the process by which water is raised upward in a column in the xylem of plants due to the force holding the water molecules together and by the continuing evaporation of water from the top of the column, in leaves. p. 520

collecting duct: the part of the kidney where filtrate from the nephrons is collected and where the filtrate is concentrated and can be called urine. p. 468

communication: the exchange of thoughts, messages, or information by vocalizations, signals, or writing. p. 573

community: all the organisms that inhabit a particular area. p. 8

companion cell: a specialized elongated cell in the phloem of flowering plants that is associated with a sieve cell. p. 519

competition: interaction between members of the same population or of two or more populations to obtain a mutually required resource in limited supply. p. 64

complement system: a complex group of serum proteins that can destroy antigens. p. 460

compound: a substance formed by chemical bonds between atoms of two or more different elements. p. 13

concentration: the amount (often with reference to the number of molecules or ions) of a substance in a specified volume of liquid or air; the process of increasing the amount of a substance in a volume of liquid, as in the kidneys during formation of urine. pp. 132, 468

concentration gradient: a difference in the concentration of certain molecules over a distance. p. 132

conditioning: training that modifies a response so that it becomes associated with a stimulus different from the stimulus that originally caused it. p. 587

Coniferophyta: the phylum containing conifers. p. 367

conjugation: the process by which sexual exchange and reproduction take place in many microscopic organisms, principally protists and fungi. p. 297

consumer: a heterotroph; an organism that feeds on other organisms or on their organic wastes. pp. 8, 275

continental drift: a hypothesis proposed by Wegener in 1912 suggesting that the earth's landmasses had at one time been joined in a supercontinent, Pangaea, that has broken up to form the present continents. Continental drift is now considered to be part of a broader theory of plate tectonics. p. 599

control: in an experiment, the control is the individual, thing, or group designated to receive no treatment (the unchanged group); all other groups are compared against this one. p. 24

convergent evolution: the independent development of similarity between species as a result of their having similar ecological roles and selection pressures. p. 250

cooperative behavior: behavior that increases the reproductive fitness of the performing individual and of the recipient. p. 580

cornea (KOR nee uh): the transparent outer layer of the vertebrate eye. p. 175

corpus luteum (KOR pus LOOT ee um): the structure that forms from the tissues of a ruptured ovarian follicle and secretes female hormones. p. 163

cortex: (1) the outer layers of the adrenal gland, p. 499; (2) a layer of cells under the epidermis or bark of some plant stems and roots. p. 518

cotyledons (kot ih LEE dunz): the single (monocot) or double (dicot) seed leaves of a flowering plant embryo. p. 371

cravings: an intense desire for drugs of abuse that occurs after a user takes drugs for a period of time. p. 504

creatine phosphate (KREE uh tin FOS fayt): an energy storage compound used by muscle cells of vertebrates to replenish ATP supplies; replenished by the breakdown of glycogen. p. 485

crossing-over: during prophase I of meiosis, the breakage and exchange of corresponding segments of chromosome pairs at one or more sites along their length, resulting in genetic recombination. p. 157

crustaceans: includes aquatic organisms such as lobsters, shrimp, and crabs, as well as terrestrial sow bugs and pill bugs; phylum Crustacea formerly of the phylum Arthropoda. p. 395

cultural adaptation: an adaptation to new pressures or situations resulting from cultural innovation. p. 700

culture: a system of learned behaviors, symbols, customs, beliefs, institutions, artifacts, and technology characteristic of a group and transmitted by its members to their offspring. p. 696

cuticle: in plants, a noncellular, waxy outer layer covering certain leaves and fruits. p. 355

cyanobacteria (SY an oh bak TIR ee uh): the blue-green bacteria, which carry on oxygen-producing photosynthesis much like plants, but without membrane-enclosed chloroplasts isolating their chlorophyll. p. 302

cytokinesis (syt oh kih NEE sus): the division of the cytoplasm of a cell after nuclear division. pp. 136

cytokinin (syt oh KY nin): a plant hormone that promotes cell division, stem and root growth, chlorophyll synthesis, and chloroplast development. p. 554

cytoplasm (SYT oh plaz um): the entire contents of the cell, except the nucleus, bounded by the plasma membrane. p. 128

cytoskeleton: a network of microtubules, microfilaments, and intermediate filaments that run throughout the cytoplasm and serve a variety of mechanical and transport functions. pp. 130

D

data (singular, datum): observations and experimental evidence bearing on a biological question or problem. p. 17

decomposer: an organism that lives on decaying organic material, from which it obtains energy and its own raw materials for life. p. 8

decomposition (de kom poh ZISH un): the process of taking molecules apart; heat and chemicals are the chief agents. p. 89

deforestation: the removal of trees from a forested area without adequate replanting. p. 647

dendrite: a structure that extends out from a neuron and transmits impulses toward the cell body. p. 488

denitrifying (dee NY trih fy ing) **eubacteria:** bacteria that break down nitrogen compounds in the soil and release nitrogen gas to the air. p. 305

density: the number of individuals in a population in proportion to the size of their environment or living space. p. 33

dental caries: cavities; tooth decay caused, in part, by lactic acid bacteria. p. 308

dental plaque: a film composed of eubacteria in a sugar matrix on the surface of teeth. p. 308

deoxyribose (dee OK sih RY bohs): a sugar used in the structure of DNA; it contains one fewer oxygen atom than does ribose. p. 102

depressant: a drug that slows the functioning of the central nervous system. p. 501

desert: a biome characterized by lack of precipitation and by extreme temperature variation; there are both hot and cold deserts. p. 637

desertification: the conversion of rangeland or cropland to desertlike land with a drop in agricultural productivity; usually caused by a combination of overgrazing, soil erosion, prolonged drought, and climate change. p. 647

development: (1) cell division, growth, and differentiation of cells from embryonic layers into all the tissues and organs of the body; (2) later changes with age, including reproductive maturity with its effects on appearance and body function. p. 172

diabetes mellitus (MEL luh tus): a disease resulting from insufficient insulin secretion by the pancreas or impairment of insulin receptors on body cells; characterized by abnormal absorption and use of glucose. p. 496

diaphragm (DY uh fram): (1) the sheet of muscle that separates the chest and abdominal cavity in mammals and, along with rib muscles, is important in breathing, p. 465; (2) a caplike rubber device inserted in the vagina and used as a contraceptive. p. 165

diatom (DY uh tom): any of a large group of algae with intricate, patterned, silica-containing shells made in two halves; unusually shaped pores create the patterns. p. 327

dicot (DY kot): flowering plant that has two embryonic seed leaves, or cotyledons. p. 373

differentiation: specialization, as when developing cells become ordered into certain tissues and organs. p. 172

diffusion (dih FYOO zhun): the movement of a substance down its concentration gradient from a more-concentrated area to a less-concentrated area. pp. 132, 144

digestion: the process by which larger food molecules are broken down into smaller molecules that can be absorbed. p. 392

dinoflagellate: any of the numerous, chiefly marine, protozoans characteristically possessing two flagella; one of the major types of plankton. p. 329

dipeptide (dy PEP tyd): two amino acid molecules bonded to one another; the dipeptide may be the start of a chain for a protein or a product of digestion of a protein and a polypeptide. p. 99

diploid (DIP loyd): a cell containing both members of every chromosome pair characteristic of a species ($2n$). p. 156

dispersal: (1) the spreading of organisms from a place of concentration, p. 35; (2) the scattering of spores and seeds that promotes spreading of nonmotile organisms. p. 36

divergent evolution: evolutionary change away from the ancestral type, with selection favoring newly arising adaptations. p. 250

DNA: deoxyribonucleic (dee OK sih ry boh noo KLEE ik) acid; the hereditary material of most organisms; DNA makes up the genes; these nucleic acids contain deoxyribose, a phosphate group, and one of four bases. p. 101

dominance hierarchy: a linear pecking order of animals in which position dictates characteristic social behaviors. p. 577

dominant: a trait that is visible in a heterozygous organism. p. 195

dormant: inactive but alive or viable. p. 341

dorsal: in animals, situated toward the top or back side. p. 388

drugs: a chemical compound or substance that can alter the structure and function of the body. Psychoactive drugs affect the function of the brain, and some of these may be illegal to use and possess. Some drugs are medications that are used to treat specific health problems. p. 501

E

ecology: the study of living and nonliving components of the environment and of the interactions that affect biological species. p. 7

ecosystem (EE koh sis tum): a biological community in its abiotic environment. p. 62

ectoderm (EK toh derm): the outer layer of cells in the gastrula stage of an animal embryo. p. 173

effector: a muscle or gland activated by nerve impulses or hormones. p. 490

electron (ee LEK trahn): a negatively charged particle that occurs in varying numbers in clouds surrounding the nuclei of atoms. p. 88

electron transport system: the process in which electrons are transferred from one carrier molecule to another in photosynthesis and in cellular respira-

tion; results in storage of some of the energy in ATP molecules. p. 423

electrophoresis: any of several techniques for separating large molecules, such as proteins or DNA fragments based on their ability to move through a gel medium subjected to an electric field. p. 219

element: a substance composed of atoms that are chemically identical—alike in their proton and electron numbers. p. 13

embryo: an organism in its earliest stages of development. p. 172

emigration (em uh GRAY shun): departure of individuals from a population; decreases the size of the population. p. 32

emphysema (em fuh SEE muh): a lung condition in which the air sacs dilate and the walls atrophy, resulting in labored breathing and susceptibility to infection. p. 466

endocrine (EN doh krin) **gland:** a ductless gland that secretes one or more hormones into the bloodstream. p. 494

endocrine system: the system of glands that secrete their products from their cells directly into the blood. p. 494

endoderm (EN doh derm): an inner layer of cells, as in an embryo. p. 173

endoplasmic reticulum (en doh PLAZ mik reh TIK yoo lum): an extensive membranous network in eukaryotic cells composed of ribosome-studded (rough) and ribosome-free (smooth) regions. p. 129

endoskeleton (EN doh SKEL eh tun): a hard skeleton buried in the soft tissues of an animal, such as the spicules of sponges and bony skeletons of vertebrates. p. 409

endosperm (EN doh sperm): a nutrient-rich structure, formed by the union of a sperm cell with two polar nuclei during double fertilization, that provides nourishment to the developing embryo in seeds of flowering plants. p. 359

endospore (EN doh spor): a thick-walled spore of a particular type, like that produced by the anaerobic bacterium that causes botulism. p. 297

energy: the ability to do work or to cause change; see *chemical energy*. p. 91

energy pyramid: a graphic representation of the energy available for use by producers and consumers as levels of a pyramid: at the bottom, with the greatest amount of available energy, are the producers, followed by primary consumers, secondary consumers, and top-level consumers; only about 10 percent of the energy available at the preceding level is available for use at the next higher level. p. 68

environment (en VY run ment): everything living and nonliving in an organism's surroundings, including light, temperature, air, soil, water, and other organisms. p. 32

enzyme (EN zym): a protein or part-protein molecule made by an organism and used as a catalyst in a specific biochemical reaction. p. 91

enzyme-substrate complex: an enzyme molecule together with the molecules on which it acts, correctly arranged at the active site of the enzyme. p. 101

epinephrine (ep ih NEF rin): an adrenal hormone, also called adrenaline, that speeds up heart rate and raises blood sugar level and blood pressure, the fight-or flight hormone that is secreted during a sudden fright or emergency. p. 499

epiphyte (EP ih fyt): a plant that takes its moisture and nutrients from the air and from rainfall and that usually grows on a branch of another plant; not a parasite. p. 634

esophagus: the tubular portion of the digestive tract that leads from the pharynx to the stomach. p. 418

essential nutrient: a nutrient that an organism cannot synthesize, or cannot synthesize in the quantities it requires; plants obtain these nutrients from the soil, animals from food they ingest. p. 431

estivation (es tih VAY shun): a physiological state, characterized by decreased metabolism and inactivity, that permits survival during long periods of elevated temperature and diminished water supplies. p. 639

estrogen (ES troh jen): a hormone that stimulates the development of female secondary sexual characteristics. p. 163

ethylene (ETH ih leen): a gaseous plant hormone that promotes fruit ripening while inhibiting further plant growth in roots and stems. p. 554

eubacteria (YOO bak TIR ee uh): the bacterial group including the cyanobacteria but not the archaebacteria; sometimes called the "true bacteria"; they differ from archaebacteria in their ribosomal RNA and tRNA, and in other ways. p. 297

euglenoids: a small group of freshwater flagellates similar to the organisms of the genus Euglena; many contain chloroplasts, others absorb organic substances or ingest prey; all lack rigid cell walls. p. 329

eukaryote (yoo KAIR ee oht): an organism whose cells have a membrane-enclosed nucleus and organelles; a protist, fungus, plant, or animal. p. 125

eutrophic (yoo TROH fik): characterizing a body of water that is nutrient-rich, leading to population explosions of photosynthetic organisms and then of decomposers, which deplete the dissolved oxygen and cause fishes and other aquatic organisms to die. p. 681

excretion (ek SKREE shun): the elimination of wastes, especially by-products of body metabolism, by organisms. p. 405

exon (EKS on): a segment of DNA that is transcribed into RNA and translated into protein, specifying the amino acid sequence of a polypeptide; characteristic of eukaryotes and some prokaryotes. p. 215

exoskeleton (EK soh SKEL eh tun): a hard encasement deposited on the surface of an animal, such as the shell of a mollusk, that provides protection and points of attachment for muscles. p. 408

extensor: a muscle that extends a limb or skeletal part. p. 487

extinct: no longer surviving as a species. p. 73

F

F_1: the first filial, or hybrid, offspring in a genetic cross-fertilization. p. 195

F_2: offspring resulting from interbreeding of the hybrid F_1 generation. p. 195

family: the fifth largest grouping after kingdom, phylum or division, class, and order, in the biological classification system; a group of related genera. p. 268

famine (FAM in): severe shortage of food, causing widespread hunger and starvation within a population. p. 40

feces (FEE seez): the waste material expelled from the digestive tract. p. 421

feedback system: a relationship in which one activity of a body system affects another, which in turn affects the first, yielding a regulatory balance. p. 495

fermentation (fer men TAY shun): the incomplete breakdown of food molecules, especially sugars, in the absence of oxygen. p. 427

fertilization: the union of an egg nucleus and a sperm nucleus. p. 156

fetus: a vertebrate embryo in later stages of development when it has attained the recognizable structural plan and features of its type. p. 179

fibrin (FY brin): an insoluble, fibrous protein that forms a network of fibers around which a blood clot develops. p. 456

fibrinogen (fy BRIN oh jen): a soluble blood protein that is changed into its insoluble form as fibrin during the blood-clotting process. p. 456

fight-or-flight response: a response of the neuroendocrine system to stressors in which the body prepares to fight or flee; includes the secretion of epinephrine that speeds up heart rate and elevates blood pressure. p. 500

filtration: in vertebrate kidneys, filtration occurs when blood pressure forces the blood into the glomerulus of the nephron where blood cells and plasma proteins are separated from the blood's water, nitrogenous wastes, and ions; most of the liquid filtrate is reabsorbed, but some wastes are secreted from the body in the urine. p. 468

flagella (fluh JEL uh): singular, flagellum; the long cellular appendages specialized for locomotion and formed from a core of nine outer doublet microtubules and two single inner microtubules; many protists and certain animal cells have flagella. p. 274

flame cell: in planarians, a cell with cilia in a network connected by tubules; absorbs fluid and wastes and moves fluid through the tubules to eliminate excess water. p. 406

flatworm: any member of the phylum Platyhelminthes. p. 392

flexor: a muscle that bends a joint; its action is opposite to that of an extensor. p. 487

follicle: in mammals, an ovarian sac from which an egg is released. p. 163

follicle-stimulating hormone (FSH): a substance secreted by the anterior lobe of the pituitary that stimulates the development of an ovarian follicle in a female or the production of sperm cells in a male. p. 163

food: a substance containing energy-rich organic compounds made by organisms and used as a source of energy and matter for life. p. 7

food chain: the transfer of food from one feeding level to another, beginning with producers. p. 8

food web: food chains in an ecosystem taken collectively, showing partial overlapping and competition for many food organisms. p. 9

foraminiferan (FOR am ih NIF er un): any of the unicellular microorganisms of the order Foraminifera, characteristically possessing a calcareous shell with perforations through which numerous pseudopodia protrude. p. 330

fossil: a cast of an organism preserved in rock that formed where it died; the organism itself in ice, vol-

canic glass, or amber; or the skeleton preserved in deposits. p. 267

Fungi (FUN jy): a kingdom of heterotrophic organisms that develop from spores; many are decomposers; some are parasites of other organisms. p. 277

G

G_1 (Gap 1, or in this text, Growth 1): the first growth phase of the cell cycle, starting just after offspring cells form. p. 135

G_2 (Gap 2 or in this text, Growth 2): the second growth phase of the cell cycle, beginning after DNA synthesis. p. 136

Gaia hypothesis: the hypothesis which proposes that the connections between living organisms and nonliving environment qualify our planet as a single, complex living organism. p. 285

Galápagos Islands: a group of volcanic islands west of Ecuador; formed only 5 million years ago; life could not have arisen there, so the organisms that inhabit these equatorial islands must have come from mainland South America and achieved their present diversity through adaptation and evolution. p. 238

gamete (GAM eet): a sex cell, either an egg cell or a sperm formed by meiosis, having half the number of chromosomes as body cells. p. 154

gametophyte (guh MEET oh fyt): the gamete-producing generation in a plant species that undergoes alternation of generations. p. 356

ganglion: a grouping of nerve cells where nerve impulses are exchanged; in more complex organisms, these are in areas of the body other than the brain or spinal cord. p. 407

gastric juice: mixed secretions of the glands in the stomach wall; in humans, principally mucus, hydrochloric acid, and protein-fragmenting enzymes. p. 419

gastrula (GAS truh luh): an early embryo at the stage when infolding of cells from the outside occurs. p. 172

gastrulation: the formation of the gastrula stage of an embryo; the stage at which the embryo acquires three layers. p. 172

gene: the fundamental physical unit of heredity, which transmits a set of specifications from one generation to the next; a segment of DNA that codes for a specific product. p. 129

gene flow: the loss or gain of alleles in a population due to the emigration or immigration of fertile individuals. p. 246

gene pool: the total aggregate of genes in a population at any one time. p. 244

genetic drift: changes in the gene pool of a small population due to chance. p. 246

genome: the total genetic content or complement of a haploid cell from any given species. p. 216

genotype (JEE noh typ): the genetic makeup of an organism. p. 196

genus (JEE nus): the next largest grouping after kingdom, phylum or division, class, order, and family in the biological classification system; a group of related species. p. 268

gibberellin (jib uh REL en): a plant hormone that stimulates elongation of the stems, triggers the germination of seeds, and with auxin, stimulates fruit development. p. 553

gills: the respiratory organs chiefly of aquatic organisms such as fish; the chief excretory organs in many ocean fish. p. 404

gizzard: a muscular sac in the digestive system of birds, earthworms, and other animals that mechanically changes food by grinding it against sand particles. p. 403

glomerular capsule: the cup-shaped portion of the nephron enclosing a mass of capillaries (the glomerulus); the site of filtration in the kidneys. p. 468

glomerulus (glah MER yoo lus): a ball of capillaries surrounded by a capsule in the nephron and serving as the site of filtration in the kidneys. p. 468

glucagon (GLOO kuh gahn): a pancreatic hormone that acts to raise the blood glucose level. p. 495

glycerol: a 3-carbon alcohol molecule that combines with fatty acids to form fats and oils. p. 98

glycogen: the chief carbohydrate used by animals for energy storage. p. 97

glycolysis (gly KAWL uh sis): the initial breakdown of a carbohydrate, usually glucose, into smaller molecules at the beginning of cellular respiration. p. 423

Golgi (GOHL jee) **apparatus:** an organelle in eukaryotic cells consisting of stacked membranes that modifies and packages materials for export from the cell. pp. 127, 129

grana (GRAY nuh): singular, granum; stacks of thylakoids within a chloroplast. p. 542

gravitropism (grav ih TROH piz um): a positive or negative response of a plant or animal to the acceleration force of gravity. p. 557

guard cells: a pair of cells that surround a stomate in a leaf's epidermis; turgor pressure in the guard cells

regulates the opening and closing of the stomate. p. 515

gut: the alimentary canal, or portions thereof, especially the stomach and intestines. p. 418

H

habitat (HAB ih tat): place where an organism lives; even in the same ecosystem, different organisms differ in their habitats. p. 64

half-life: in radioisotopes, the time required for half of a specified quantity to decay. p. 594

halophile (HAL uh fyl): an organism that requires a salty environment; usually refers to a type of archaebacteria. p. 300

haploid (HAP loyd): a cell containing only one member *(n)* of each chromosome pair characteristic of a species. p. 156

hemoglobin (HEE moh gloh bin): the pigment in red blood cells responsible for the transport of oxygen. p. 455

hemophilia: an X-linked recessive human trait; a disorder in which blood does not clot properly. p. 456

herbaceous (her BAY shus): herblike; without woody tissues. p. 373

herbivore (HER bih vor): a plant-eating consumer; one of the class of consumers most closely associated with producers. p. 62

heterotroph (HET eh roh trohf): an organism that obtains carbon and all metabolic energy from organic molecules previously assembled by autotrophs; a consumer. p. 275

heterotroph hypothesis: the hypothesis that the first life-forms used the supply of naturally occurring organic compounds for food. p. 284

heterozygous (HET er oh ZY gus): having two different alleles for a given trait. p. 197

hibernation: a physiological state that permits survival during long periods of cold and diminished food, in which metabolism decreases, the heart and respiratory system slow down, and body temperature is maintained at a lower level than normal. p. 581

histamine: a substance released by injured cells that causes blood vessels to dilate during an inflammatory response. p. 462

homeostasis (hoh mee oh STAY sis): a fundamental characteristic of living systems; maintenance of stability of numbers of individuals within a population (social); the tendency of an organism to maintain a stable, constant internal environment (physiological). pp. 35, 479

hominid (HOM ih nid): a primate of the family Hominidae, which includes modern humans, earlier subspecies, and *australopithecines*. p. 610

***Homo erectus*:** an extinct tool-using human species that lived from 1.6 million to 300,000 years ago; the first undisputed human species. p. 610

***Homo habilis*:** a fossil hominid, larger than an australopithecine, thought to be between 1.6 and 2 million years old. p. 610

homologies (hoh MOL uh jeez): likeness in form, as a result of evolution from the same ancestors. p. 267

Homo sapiens neanderthalensis (nee an der tal EN sis): a subspecies of modern humans that lived in Europe Africa and Asia from about 100,000 to 35,000 years ago; their relationship to modern humans is debated. p. 611

***Homo sapiens sapiens*:** a subspecies of anatomically modern humans composed of present-day human groups. p. 611

homozygous (HOH moh ZY gus): having two identical alleles for a given trait. p. 197

hormone: a substance, secreted by cells or glands, that has a regulatory effect on cells and organs elsewhere in the body; a chemical messenger. p. 162

host: an organism that serves as a habitat or living food source, or both, for another organism. p. 305

hybrid: having different alleles for a given trait, one inherited from each parent; heterozygous. p. 197

hyphae (HY fee): threadlike growth of a fungus; in an irregular mass they compose the mycelium of many fungi; in an orderly and tightly packed arrangement they compose the body of a mushroom or bracket fungus. p. 334

hypoglycemia (hy poh gly SEE mee uh): low blood sugar level. p. 496

hypothalamus: a specialized part at the base of the brain; in humans it links the nervous system to what is called the endocrine system (the endocrine system controls the hormones that regulate many body functions). p. 162

hypothesis (hy POTH uh sis): a statement suggesting an explanation for an observation or an answer to a scientific problem. p. 17

I

immigration (im uh GRAY shun): arrival of new individuals into a population; increases the size of a population. p. 32

immune response: the body's response against specific pathogens or foreign materials; results in the production of proteins, called *antibodies*. p. 458

immune system: the body's specific defense system; a response to foreign material occurs in the lymphatic system, the bone marrow, the thymus, tonsils, spleen, and appendix; these tissues produce cells which then produce antibodies or a cellular defense against an antigen. p. 458

immunity: disease resistance, usually specific for one disease or pathogen. p. 306

imperfect fungi: any of the fungi not belonging to other phyla, in which the method of reproduction, if known, is asexual; a taxonomic grouping of convenience. p. 337

incomplete dominance: a situation in which the phenotype of a heterozygous offspring is intermediate to the phenotype of the parents. p. 200

incubation period: the time from the entry of an infectious agent into an organism up to the time of the first appearance of disease signs or symptoms. p. 312

industrialized agriculture: using large inputs of energy primarily derived from fossil fuels to produce large quantities of crops and livestock. p. 698

infectious disease: a disease caused by viruses or microorganisms that can be transmitted directly from an affected individual to a healthy individual. p. 305

inflammatory response: occurs when injured tissue releases chemical signals that cause capillaries to become leaky, allowing white blood cells into the area of injury (causing swelling and reddening of the injured area); the white blood cells engulf pathogens. p. 458

ingestion: the process of taking a substance from the environment, usually food, into the body. p. 402

innate behavior: behavior that is genetically determined, as in the organization of an ant society; also called *instinctive behavior*. p. 572

instinct: the capacity of an animal to complete a fairly complex, stereotyped response to a key stimulus without having prior experience. p. 572

insulin (IN suh lin): a pancreatic hormone that promotes cell absorption and use of glucose; impairment of its secretion or its action results in diabetes. p. 495

interneuron: associative neuron; a neuron located between a sensory neuron and a motor neuron. p. 489

interphase (IN ter fayz): a normal interval between successive cell divisions when the only evidence of future divisions is that chromosomes begin to be replicated; a cell at work, rather than a cell dividing. pp. 135, 139

intertidal zone: the shallow zone of the ocean where land meets water; also called the *littoral zone*. p. 676

intestinal juice: secretions of the glands in the small intestinal wall containing enzymes that act on dipeptides and double sugars. p. 420

intron (IN tron): a segment of DNA that is transcribed into precursor mRNA but then removed before the mRNA leaves the nucleus. p. 215

ion (EYE on): an atom or molecule that has either gained or lost one or more electrons, giving it a positive or negative charge. p. 89

ionization: the conversion of a nonionic substance, such as water, into ions. p. 90

J

joint: a point of movement, or of fixed calcium deposits preventing movement, marking where two bones meet in the skeleton. p. 486

K

karyotype: a method of organizing the chromosomes of a cell in relation to number, size, and type. p. 202

kcal: kilocalorie; a measure of food energy equal to 1,000 calories. p. 41

kidney: an organ that regulates water and salt levels, filters water and wastes from the blood, and gets rid of the end products as urine. p. 467

killer *T* cell: lymphocytes that are produced in the bone marrow but mature in the thymus; these cells recognize and destroy infected cells, limiting the spread of the infection. p. 458

kingdom: the largest grouping in the biological classification system. p. 269

Krebs cycle: the cycle in cellular respiration that completes the breakdown of intermediate products of glycolysis, releasing energy; also a source of carbon skeletons for use in biosynthesis reactions. p. 423

L

larval (LAR val): an immature stage of development in offspring of many types of animals. p. 397

latent: present but not evident or active. p. 312

learned behavior: behavior developed as a result of experience. p. 572

lens: in the eye, a transparent tissue layer behind the iris that focuses light rays entering through the pupil to form an image on the retina. p. 175

lenticel (LENT ih sel): an opening in the surface of a plant stem through which air can diffuse. p. 517

lichen (LY kin): an alga and a fungus that live in symbiosis, forming a distinctive structure, or thallus, that may be low and crusty, leafy, or bushy; lichens are pioneers on rock or other surfaces. p. 64

life cycle: all the events that occur between the beginning of one generation and the beginning of the next generation. p. 152

ligaments: a cord or sheet of connective tissue by which two or more bones are bound together at a joint. p. 486

light reactions: the energy-capturing reactions in photosynthesis. p. 544

limiting factor: an environmental condition such as food, temperature, water, or sunlight that restricts the types of organisms and population numbers that an environment can support. p. 32

lipid (LIP id): a fat, oil, or fatlike compound that usually has fatty acids in its molecular structure; an important component of the plasma membrane. p. 96

luteinizing hormone (LH): a hormone secreted by the anterior lobe of the pituitary gland that controls the formation of the corpus luteum in females and the secretion of testosterone in males. p. 163

Lycophyta (ly KOF ih tuh): the phylum containing the club mosses. p. 362

lymph (LIMF): the fluid transported by the lymphatic vessels. p. 421

lymphatic (lim FAT ik) **system:** a system of vessels through which body lymph flows, eventually entering the bloodstream where the largest lymph duct joins a vein. p. 421

lymph node: a tiny, twisted portion of a lymph vessel in which white blood cells attack any pathogenic organisms in the lymph and engulf any foreign particles. p. 456

lymphocyte (LIM foh syt): a type of small white blood cell important in the immune response. p. 458

lymphokine (LIM foh kyn): any of a class of proteins by which the cells of the vertebrate immune system communicate with one another. p. 459

lymph vessel: a vessel in which lymph from the body tissues, or from villi in the intestine, flows until it enters the largest lymph duct, which empties into a vein. p. 456

lysosome (LY soh zohm): a cell vesicle that contains digestive enzymes. pp. 126, 130

M

macronucleus: the larger of two types of nuclei in ciliates; one or more of the macronuclei may be present in each organism. p. 332

macronutrient: a nutrient required in large amounts by a plant or other organism. p. 524

macrophage (MAK roh fayj): a large white blood cell that ingests pathogens and dead cells. p. 458

mammary glands: the organs in female mammals, consisting of clusters of milk-producing cells with small ducts terminating in a nipple or teat. p. 400

marsupials: a group of mammals, such as koalas, kangaroos, and opossums, whose young complete their embryonic development inside a maternal pouch called a marsupium. p. 400

mating behavior: the behaviors, including courtship rituals and displays, that lead to mating; such behavior usually is specific for each species. p. 577

medulla (meh DUL lah): a part of the brain stem in vertebrates. p. 491

meiosis (my OH sis): two successive nuclear divisions (with corresponding cell divisions) that produce gametes (in animals) or sexual spores (in plants) having one-half of the genetic material of the original cell. p. 156

memory cell: B- or T-lymphocyte, produced in response to a primary immune response, that remains in the circulation and can respond rapidly if the same antigen is encountered in the future. p. 458

menopause (MEN oh pahz): in human females, the period of cessation of menstruation, usually occurring between the ages of 45 and 50. p. 164

menstrual cycle: the female reproductive cycle that is characterized by regularly recurring changes in the uterine lining. p. 162

menstruation: periodic sloughing of the blood-enriched lining of the uterus when pregnancy does not occur. p. 164

meristem (MER ih stem): plant cells at the growing tips of roots and stems and in buds and cambium that divide and produce new cells that can differentiate into various plant tissues. p. 527

mesoderm (MEZ oh derm): in most animal embryos, a tissue layer between the ectoderm and

endoderm that gives rise to muscle, to organs of circulation, reproduction, and excretion, to most of the internal skeleton (if present), and to connective tissue layers of gut and body covering. p. 173

mesophyll (MEZ oh fil): the green leaf cells between the upper and lower epidermis of a leaf; the primary site of photosynthesis in leaves. p. 514

mesosome (MEZ oh sohm): an infolding of the plasma membrane of a prokaryotic cell. p. 296

metabolism (meh TAB oh liz um): the sum of all the chemical changes taking place in an organism. p. 131

metamorphosis (met uh MOR phuh sis): in the life cycles of many animals, marked changes in body form and functions that transform young or immature stages to adults. p. 396

metaphase: the stage in mitosis in which replicated chromosomes move to the center of the spindle and become attached to it. p. 136

metastasize: to spread, as in the spread of cancer cells. p. 183

methanogen (meh THAN uh jen): a methane-producing archaebacterium. p. 300

micronucleus: the smaller of two types of nuclei in ciliates; one or more micronuclei may be present in each organism. p. 332

micronutrient: a nutrient required in only small amounts by a plant or other organism. p. 524

microorganism: an organism too small to be seen with the unaided human eye. p. 8

microsphere: a cooling droplet from a hot-water solution of polypeptides; the droplet forms its own double-layered boundary as it cools; used as a model for precells to study the formation of the first life on the earth. p. 283

microtubule: a hollow rod of protein found in the cytoplasm of all eukaryotic cells, making up part of the cytoskeleton and involved in cell contraction. p. 130

midlatitude forest: a biome located throughout midlatitude regions where there is sufficient moisture to support the growth of large trees, mostly of the broad-leaved deciduous type; also called *temperate forest*. p. 632

mitochondria (my toh KON dree uh): the cell organelles in eukaryotic cells that carry on cellular respiration, releasing energy from food molecules and storing it in ATP. pp. 129, 130

mitosis (my TOH sis): the replication of the chromosomes and the production of two nuclei in one cell; usually followed by cytokinesis. pp. 136, 148

mixed-grass prairie: the biome composing the central Great Plains that contains both short and tall grasses and is characterized by low precipitation, low winter temperatures, and relatively high elevation. p. 636

molecule (MOL uh kyool): a particle consisting of two or more atoms of the same or different elements chemically bonded together. p. 13

mollusc: any invertebrate of the phylum Mollusca, typically having a hard shell that wholly or partly encloses a soft, unsegmented body; includes chitons, snails, bivalves, squid, octopuses, and similar animals. p. 394

Mollusca (muh LUS kuh): the phylum containing molluscs. p. 394

monocot (MON oh kot): a subdivision of flowering plants whose members have one embryonic seed leaf, or cotyledon. p. 373

monotremes: a group of egg-laying mammals, represented by the platypus and echidnas. p. 400

morphology: the shape, form, and structure of an organism or its parts. p. 172

mortality (mor TAL ih tee): death rate, measured as the proportion of deaths to total population over a given period; often expressed as number of deaths per 1,000 or 10,000 individuals. p. 31

motile (MOH tuhl): capable of movement from place to place, characteristic of most animals. p. 388

motor neuron: a specialized neuron that receives impulses from the central nervous system and transmits them to a muscle or gland. p. 490

multicellular: composed of many cells, as contrasted with a single-celled organism. p. 122

multifactorial inheritance: a pattern of inheritance in which characteristics are determined by at least several genes with a large number of environmental variables. p. 201

multiple alleles: the existence of several known alleles for a gene. p. 200

mutation (myoo TAY shun): a chemical change in a gene, resulting in a new allele; or, a change in the portion of a chromosome that regulates the gene; in either case the change is hereditary. p. 203

mycelium (my SEE lee um): the densely branched network of hyphae in a fungus. p. 334

mycoplasma (my koh PLAZ muh): eubacteria that lack cell walls; probably the smallest organisms capable of independent growth. p. 301

mycorrhizae (my koh RY zee): symbiotic associations of plant roots and fungi. p. 339

myosin: a protein that, together with actin, is responsible for muscular contraction and relaxation. p. 484

Myxomycota (mik soh my KOH tuh): the phylum containing the slime molds. p. 332

N

NAD^+: nicotinamide adenine dinucleotide (nik uh TEE nuh myd AD uh neen DY NOO klee oh tyd); an electron and hydrogen carrier in cellular respiration. p. 424

$NADP^+$: nicotinamide adenine dinucleotide phosphate; a hydrogen-carrier molecule that forms NADPH in the light reactions of photosynthesis. p. 546

natural selection: a mechanism of evolution whereby members of a population with the most successful adaptations to their environment are more likely to survive and reproduce than members with less successful adaptations. p. 240

nectar: a secretion, mainly a sugar solution, produced by small glands in the petals of many flowers. p. 370

Nematoda (nee muh TOH duh): the phylum containing the unsegmented worms. p. 393

nephron (NEF rahn): the functional unit of a kidney, consisting of a long, coiled tubule, one end of which forms a cup that encloses a mass of capillaries and the other end of which opens into a duct that collects urine; the entire nephron is surrounded by a network of capillaries. p. 468

nerve: a bundle of nerve fibers; the cell bodies from which the fibers extend usually are located together at one end of the fiber. p. 488

nerve impulse: a wave of chemical and electrical changes that passes along a nerve fiber in response to a stimulus. p. 488

nervous system: a coordinating mechanism in all multicellular animals, except sponges, that regulates internal body functions and responses to external stimuli; in vertebrates, it consists of the brain, spinal cord, nerves, ganglia, and parts of receptor and effector organs. p. 407

neural tube: the structure formed in the embryo that eventually gives rise to the brain and spinal cord. p. 173

neuron (NOO rahn): a nerve cell; a name usually reserved for nerve cells in animals that have a complex brain and specialized associative, motor, and sensory nerves. p. 488

neurotransmitter (NOOR oh trans MIT er): a chemical messenger, often similar to or identical with a hormone, that diffuses across the synapse and transmits a nerve impulse from one neuron to another. p. 488

neutral: a solution in which the concentrations of hydrogen and hydroxide ions are equal. p. 91

neutron (NOO trahn): a particle carrying no electrical charge; found in the nuclei of all atoms except those of hydrogen. p. 88

niche (NITCH): the sum total of all the adaptations an organism uses to survive in its environment; this includes its role in the community, what it eats, and what interactions it has with other organisms and with its environment. p. 64

nitrifying (NY trih fy ing) **eubacteria:** bacteria that use ammonium ions to produce nitrite and nitrate ions. p. 304

nitrogen-fixing eubacteria: bacteria that take in free nitrogen from the atmosphere and use it to produce ammonia; subsequent reactions by other bacteria produce ammonium ions and nitrates, from which plants obtain their nitrogen. p. 304

nodule (NOD yool): a rounded growth of tissue that usually contains microorganisms or some other agent associated with the growth; in certain plants, nitrogen-fixing bacteria live in nodules on the plant roots. p. 304

norepinephrine: a hormone secreted by the adrenal medulla in response to nerve signals from the sympathetic division of the autonomic nervous system. p. 499

notochord (NOH toh kord): in chordates, a flexible, dorsal, rodlike structure that extends the length of the body; in vertebrates it is replaced in later stages of development by the vertebrae. p. 397

nuclear membrane: the membrane in eukaryotes that encloses the genetic material, separating it from the cytoplasm. p. 129

nucleic (noo KLEE ik) **acid:** DNA or RNA; an organic compound composed of nucleotides and important in coding instructions for cell processes. p. 96

nucleoid (NOO klee oyd): a region in a prokaryotic cell consisting of a concentrated mass of DNA. p. 296

nucleotide (NOO klee oh tyd): a subunit or building block of DNA or RNA, chemically constructed

of a 5-carbon sugar, a nitrogen base, and a phosphate group. p. 101

nucleus (NOO klee us): in atoms, the central core, containing positively charged protons and (in all but hydrogen) electrically neutral neutrons, p. 71; in eukaryotic cells, the membranous organelle that houses the chromosomal DNA. pp. 88, 125

nutrient: (1) a food substance usually digested or not requiring digestion in a form, that is interchangeable among organisms, p. 87; (2) certain chemicals used by plants. p. 524

O

omnivore (OM nih vor): a consumer organism that feeds partly as a herbivore and partly as a carnivore, eating plants, animals, and fungi. p. 62

oncogene: a gene found in viruses or as part of the normal genome that is crucial for triggering cancerous characteristics. p. 183

open circulatory system: a system in which the blood does not travel through the body completely enclosed in vessels; the return to the heart is usually through open spaces, or sinuses, as in the grasshopper. p. 405

open population: a population that gains members by immigration or loses them by emigration, or both. p. 35

opportunistic infections: infections that occur in organisms with weakened immune responses; normally these infections would be repelled by healthy immune systems. p. 313

order: the fourth largest grouping, after kingdom, phylum or division, and class, in the biological classification system; a group of related families. p. 269

organelle (or guh NEL): an organized structure within a cell, with a specific function; a chloroplast and a mitochondrion are examples. p. 125

organic compounds: compounds built of carbon combined with other elements. p. 88

osmosis (os MOH sis): the movement of water across a selectively permeable membrane. p. 132

ova (singular, *ovum*): the mature female gamete. p. 154

ovaries (singular, *ovary*): the primary reproductive organs of a female; egg-cell-producing organs. p. 160

oviduct: a tube leading from an ovary to the uterus. p. 163

ovulation: in vertebrates, the release of one or more eggs from an ovary. p. 161

ovule (OHV vool): a structure that develops in the plant ovary and contains the female egg. p. 358

ovum: a female gamete, or egg. p. 154

P

P: the parental organisms in a genetic cross. p. 195

paleontologist (pay lee un TOL uh jist): a specialist who studies extinct organisms through fossils. p. 594

palisade layer: the layer of tightly packed and column-shaped mesophyll cells containing many chloroplasts. p. 514

pancreatic (pan kree AT ik) **juice:** fluid secreted by the pancreas; converts the acidic food mixture to a basic pH and contains enzymes that break down proteins, fats, and carbohydrates. p. 420

Pangaea (pan GEE uh): in the Triassic period, the supercontinent formed by the four major continents; the breakup of Pangaea affected the distribution and evolution of organisms. p. 600

parallel evolution: the type of evolution that occurs when organisms from a single species become so different that they no longer can interbreed, yet both groups continue to evolve in a similar direction; the ostrich and the rhea are the result of parallel evolution. p. 250

parasitism (PAIR uh sih tiz um): an ecological niche in which one organism is the habitat and the food for another, which lives and feeds on the host organism, usually without killing it. p. 65

parasympathetic division: in vertebrates, one of the two divisions of the autonomic nervous system; stimulates resting activities, such as digestion, and restores the body to normal after emergencies. p. 492

passive transport: the diffusion of a substance across a biological membrane through a transport protein in the membrane. p. 133

pathogen: a disease-causing organism. p. 305

penicillin: any of several antibiotic compounds obtained from penicillium mold and used to prevent or treat a wide variety of diseases and infections. p. 242

penis: in vertebrates, the male organ through which sperm are passed to the female and through which nitrogenous wastes from the kidneys—in the form of urine—are discharged outside the body. p. 160

peptidoglycan (PEP tid oh GLY kan): a substance found only in eubacteria cell walls that consists of modified sugars cross-linked by short polypeptides. p. 298

peripheral nervous system: the sensory and motor neurons that connect the central nervous system to the rest of the body. p. 490

peristalsis (per ih STAWL sis): rhythmic waves of contraction of smooth muscle that push food along the digestive tract. p. 418

permafrost: the sublayers of soil that remain frozen through the summer thaw in the tundra of northern latitudes. p. 629

petal: one of the leaflike, often brightly colored structures within the ring of green sepals in a developing flower; in the mature flower the petals may form their own ring or fuse to form a cuplike or tubular structure. p. 358

petiole (PET ee ohl): the slender structure at the base of a leaf that attaches it to a plant stem. p. 514

pH scale: a scale from 0 to 14 reflecting the concentration of hydrogen ions; the lower numbers denote acidic conditions, 7 is neutral, and the upper numbers denote basic or alkaline conditions. p. 90

Phaeophyta (fay OFF it uh): the phylum containing the brown algae. p. 328

phenotype (FEE noh typ): the expression of a genotype in the appearance or function of an organism; the observed trait. p. 197

pheromone (FAYR uh mohn): a chemical signal functioning in communication between animals and acting much like hormones to influence physiology and behavior. p. 186

phloem (FLOH em): a portion of the vascular system in plants, consisting of living cells arranged into elongated tubes that transport sugar and other organic nutrients throughout the plant. p. 518

photoperiodism (foh toh PIH ree ud iz um): a physiological response to day length, such as in flowering plants. p. 558

photorespiration: a metabolic pathway that uses oxygen, produces carbon dioxide, generates no ATP, and slows photosynthetic output; generally occurs on hot, dry, bright days, when stomates are nearly closed and the oxygen concentration in the leaf exceeds that of carbon dioxide. p. 550

photosynthesis: the process by which living cells that contain chlorophyll use light energy to make organic compounds from inorganic materials. p. 12

photosystems (PS) I and II: the light-harvesting units in photosynthesis, located in the thylakoid membranes of the chloroplast. p. 545

phototropism (foh toh TROH piz um): movement or growth curvature toward light. p. 556

phylum (FY lum): the second largest grouping, after kingdom, in the biological classification system, for all organisms except plants, which are classified in divisions. p. 269

phytoplankton (FYT oh PLANK ton): very small aquatic organisms, many microscopic, that carry on photosynthesis. p. 663

pigment: any coloring matter or substance. p. 545

pith: cells at the center of the young stems of many plants; in some plants the pith disappears as the stems age. p. 519

pituitary (pih TOO ih ter ee) **gland:** a part of the brain that produces and secretes hormones that regulate a variety of body functions. The pituitary also stores and then releases two hormones produced by cells in the hypothalamus. p. 163

placenta (pluh SEN tuh): a structure in the pregnant uterus for nourishing a fetus with the mother's blood supply, formed from the uterine lining and embryonic membranes. p. 177

plankton (PLANK ton): very small aquatic organisms, many microscopic, that usually float or feebly swim near the surface. p. 662

Plantae (PLAN tee): the plant kingdom, containing multicellular, autotrophic eukaryotes; all members have cellulose-containing cell walls and chloroplasts; reproduction may be sexual or asexual. p. 275

plaque: an abnormal change that occurs on inner arterial walls when lipids, such as cholesterol, infiltrate a matrix of smooth muscle; plaques are a product of atherosclerosis. p. 433

plasma (PLAZ muh): the liquid portion of the blood in which the cells are suspended. p. 454

plasma cell: an antibody-producing cell that is formed as a result of the proliferation of sensitized B-lymphocytes. p. 459

plasma membrane: see *cell membrane*.

plasma proteins: proteins dissolved in the liquid portion of the blood; there are several different kinds of proteins in the plasma, performing functions such as blood clotting, defense against pathogens (this is the immune system), and maintenance of blood osmotic pressure and pH balance. p. 454

plasmid: in prokaryotes, a small ring of DNA that carries accessory genes separate from those of the bacterial chromosome. p. 216

plasmodium (plaz MOHD ee um): the motile sheetlike stage of life formed by the fusion of many amoebalike slime molds. p. 332

platelet (PLAYT let): a small plate-shaped blood factor that contributes to blood clotting at the site of a wound; platelets release substances that begin formation of a network in which the platelets are caught, forming a clot. p. 455

plate tectonics: the theory and study of the great plates in the earth's crust and their movements, which produce earthquakes, seafloor spreading, continental drift, and mountain building. p. 601

Platyhelminthes (plah tih hel MIN theez): the phylum containing bilaterally symmetrical, somewhat flattened worms. p. 392

pollen grain: a haploid spore produced by a flowering plant; it gives rise to sperm nuclei. p. 358

pollen tube: a tube that develops from a germinating pollen grain and penetrates the carpel until it reaches the ovary; sperm nuclei pass through the tube. p. 359

pollination: the placement of pollen onto the stigma of a carpel by wind or animal vectors, a prerequisite to fertilization. p. 359

polypeptide (POL ee PEP tyd): a long chain of chemically bonded amino acids. p. 99

population: a group of organisms of one species that live in the same place at the same time. p. 30

Porifera (poh RIH fer uh): the phylum containing sponges and their relatives. p. 390

posterior: situated toward the rear, or coming last; the tail end in most animals. p. 388

potassium-40 dating: a radiometric dating technique that involves measuring the relative amounts of potassium-40 to argon-40 in a volcanic rock sample; the ratio is compared to the known half-life of potassium-40, thus yielding an estimate of the age of the rocks. p. 594

predator-prey relationship: the relationship between organisms in which one, the predator, feeds on the other, the prey. p. 64

pressure-flow: the hypothesis that food is transported through the phloem as a result of differences in pressure. p. 520

primary growth: growth in the length of plant roots and stems. p. 526

principle of independent assortment: the inheritance of alleles for one trait does not affect the inheritance of alleles for another trait. p. 199

principle of segregation: during meiosis, chromosome pairs separate into different gametes such that each of the two alleles for a given trait appears in a different gamete. p. 196

probability: the chance that any given event will occur. p. 194

producer: an autotroph; any organism that produces its own food using matter and energy from the nonliving world. p. 8

productivity: the amount of available solar energy converted to chemical energy by producers during any given period. p. 669

progesterone (proh JES tuh rohn): a female hormone secreted by the corpus luteum of the ovary and by the placenta that acts to prepare and maintain the uterus for pregnancy and to prepare the breasts for lactation. p. 163

Prokaryotae (proh kayr ee OH tee): the kingdom of bacteria; their cells are prokaryotic and lack membrane-enclosed organelles such as nuclei and mitochondria. This kingdom is often called kingdom Bacteria and was called kingdom Monera. p. 275

prokaryote (pro KAIR ee oht): an organism whose cells do not have membrane-enclosed organelles, such as nuclei, mitochondria, and chloroplasts; a bacterium. pp. 125

prophase: the stage in mitosis during which replicated strands of chromosomes condense to become thicker and shorter, the nuclear envelope begins to disappear, and a spindle forms. p. 139

protein (PROH teen): an organic compound composed of one or more polypeptide chains of amino acids; most structural materials and enzymes in a cell are proteins. p. 96

prothrombin (proh THROM bin): a plasma protein that functions in the formation of blood clots. p. 455

prothrombin activator: in the clotting process, a substance that catalyzes the conversion of prothrombin to thrombin. p. 455

Protoctista (proh toc TIST uh): a kingdom of mostly aquatic organisms whose cells are eukaryotic, but that are mostly microscopic; exceptions in size include the larger seaweeds such as kelp. This kingdom was formerly named Protista. p. 278

proton (PRO tahn): a particle bearing a positive electrical charge, found in the nuclei of all atoms. p. 88

proto-oncogene: the normal cellular version of a gene, which, if the DNA is altered, can become an oncogene capable of causing cancer. p. 183

pseudopod (SOO doh pod): literally, a false foot; a term used to describe an amoebalike extension of a cell or unicellular organism; pseudopods are used in locomotion and obtaining food, or, as in white

blood cells, in engulfing bacteria and foreign particles. p. 330

psychoactive (sy koh AK tiv) **drug:** a drug that affects the mind or mental processes. p. 501

Pterophyta (ter OFF ih tuh): the phylum containing the ferns. p. 364

puberty: the stage of development in which the reproductive organs become functional. p. 161

pulmonary artery: one of two major arteries leaving the heart (the aorta is the other); the pulmonary artery carries the blood from the right side of the heart to the lungs, where the blood picks up oxygen. p. 452

punctuated equilibria: a theory of evolution positing spurts of relatively rapid change followed by long periods of stasis. p. 248

pyloric valve: the valve located between the stomach and the small intestine that regulates the passage of food from the stomach. p. 419

R

radial (RAYD ee ul) **symmetry:** correspondence in size, shape, and position of parts as though they all radiated equally from a center point, or from a center line or axis. p. 388

rate: change per unit of time; the amount of change measured over a period of time, divided by the length of time. p. 31

ray cell: any of the cells in the stems of woody plants that form a channel allowing the passage of material laterally back and forth between the xylem and the phloem. p. 528

reabsorption: in the kidney; occurs in capillaries outside the glomerulus (in the renal tubule); water and some dissolved substances that had been filtered from the blood are returned (reabsorbed) back into the filtered blood. p. 468

receptor: a specialized sensory cell, as in the eye or the skin, that is sensitive to a particular type of stimulus. p. 489

recessive: a term used to describe an allele or trait that is masked by a dominant allele or trait. p. 195

recombinant DNA: DNA that incorporates parts of different parent DNA molecules, as formed by natural recombination mechanisms or by recombinant DNA technology. p. 216

reduction division: the first meiotic division, in which the chromosome number is reduced from diploid ($2n$) to haploid (n). p. 157

reflex: an involuntary reaction or response to a stimulus. p. 490

renal tubule: leading away from the glomerulus; the place where reabsorption takes place. p. 468

replication: the process of making a copy of the chromosome in a cell nucleus, and other genes in certain organelles outside the nucleus—particularly chloroplasts and mitochondria; the process is unlike duplication in that each gene and each chromosome in the double set is partly new but also includes part of the old gene or chromosome. p. 136

reproductive isolation: the state of a population or species in which successful mating outside the group is impossible because of anatomical, geographical, or behavioral differences. p. 235

reptile: any of the ectothermic, usually egg-laying vertebrates that belong to the class Reptilia; includes snakes, lizards, crocodiles, turtles. p. 397

resistance: relative immunity; the ability of a host organism to destroy a pathogen or prevent the disease symptoms it causes. p. 305

resource: in ecology, an environmental supply of one or more of an organism's requirements (light energy, food energy, water, oxygen or carbon dioxide, living space, protective cover, and so on); in a human society, a resource may be anything useful. p. 34

retina (REH tin uh): the photosensitive layer of the vertebrate eye that contains several layers of neurons and light receptors (rods and cones); the retina receives the image formed by the lens and transmits it to the brain via the optic nerve. p. 175

retrovirus: certain RNA viruses that must make copies of DNA from their RNA before they can reproduce. p. 311

reverse transcriptase: an enzyme that transcribes RNA into DNA, found only in association with retroviruses. p. 311

Rh factor: marker on red blood cells; a woman with no Rh markers (Rh–) will develop antibodies to Rh factors during a pregnancy in which the fetus is Rh+; these antibodies may harm the blood supply of a following pregnancy. p. 464

rhizoid (RY zoid): the threadlike structure that in nonvascular plants absorbs water and nutrients from the soil and helps hold the plants in place. p. 362

Rhodophyta (roh DOF it uh): the phylum containing the red algae. p. 328

rhodopsin: a light-absorbing purplish protein pigment; in the retina of the eye, it transforms light into a signal that is transmitted to the brain; in extreme halophiles, bacterial rhodopsin is adapted to carry out photosynthesis (in place of chlorophyll). p. 300

ribose (RY bohs): a 5-carbon sugar found in RNA molecules. p. 102

ribosome (RY boh sohm): a cell organelle constructed in the nucleus, consisting of two subunits and functioning as the site of protein synthesis in the cytoplasm. p. 130

ritual: a detailed method of procedure that is faithfully or regularly followed. p. 576

RNA: ribonucleic (ry boh noo KLEE ik) acid; the hereditary material of certain viruses, and the material coded by the DNA of other cells to carry out specific genetic functions, for example, messenger RNA and transfer RNA. p. 101

root cap: a layer of protective cells that covers the growing tip of a plant root. p. 527

root hair: a hairlike extension of an epidermal cell of a plant root that absorbs water and nutrients. p. 523

roundworm: an unsegmented, cylindrical worm having a digestive tube with two openings; a nematode. p. 393

rubisco (roo BIS koh): ribulose bisphosphate carboxylase (RY byoo lose BIS fos fayt kar BOX uh lays); an enzyme that catalyzes the initial incorporation of carbon dioxide in the Calvin cycle. p. 550

rumen (ROO men): an enlargement of the digestive tract of many herbivorous mammals, in which microorganisms that can digest cellulose live. p. 300

S

S phase (synthesis): the synthesis phase of the cell cycle during which DNA is replicated. p. 136

sac fungi: fungi belonging to the phylum Ascomycota, in which sexual spores are formed in a saclike structure, the ascus. p. 335

sarcodines: microscopic, or almost microscopic, protists that move by using pseudopods; many produce intricate shells or skeletal structures; includes amoebas, foraminiferans, and radiolarians. p. 330

saturated fat: a fat containing fatty acids with no double carbon bonds; usually solid at room temperature. p. 431

savanna (suh VAN uh): a tropical grassland biome with scattered individual trees and large herbivores; water is the major limiting factor. p. 639

scavenger (SKAV en jer): a consumer organism that feeds on the dead carcasses of other consumer organisms it did not kill. p. 66

scrotum: a pouch of skin that encloses the testes. p. 160

scurvy: a disease caused by a deficiency of vitamin C, characterized by spongy, bleeding gums, bleeding under the skin, and extreme weakness. p. 306

secondary growth: growth in girth or diameter of plant and root. p. 528

secondary sexual characteristics: differences in appearance or behavior brought about by male or female hormones; in many animal species, males are larger or more colorful. p. 579

secretion: in the kidney, takes place near the end of the renal tubule, unfiltered wastes are passed from the blood (secreted) into the filtrate, a process that adjusts the blood pH. p. 468

seed: an embryonic plant, along with food storage tissue (endosperm), both enclosed within protective coatings formed of tissues from an ovule in the parent plant. p. 360

seed coat: the tough, protective outer covering of a seed. p. 526

semen (SEE men): in mammalian males, the thick fluid in which sperm are transported. p. 166

sensory neuron: a neuron that receives impulses from a sensory organ or receptor and transmits them toward the central nervous system. p. 489

sepal (SEE pul): one of the leaflike structures that encloses and protects a flower bud; in the mature flower sepals are on the underside, next to the stem; they often are green. p. 358

sessile (SES il): not free to move about in the environment; sessile animals usually are attached by the base to an object in the environment. p. 388

sex chromosome: one of a pair of chromosomes that differentiates between and is partially responsible for determining the sexes. p. 202

sexual reproduction: reproduction involving the contribution of genetic material from two parents. p. 153

sexual selection: selection based on variation in secondary sexual characteristics, leading to the enhancement of individual reproductive fitness. pp. 246, 579

short-grass prairie: a grassland biome that stretches from the central Great Plains to the Rocky Mountains; grasses usually are less than 0.5 m tall. p. 636

sieve cell: a type of phloem cell in plants that forms a column. p. 519

skeletal muscle: a type of muscle tissue found in muscles attached to skeletal parts and responsible for voluntary muscle movement. p. 484

slash-and-burn cultivation: cutting down trees and other vegetation in a patch of forest, leaving the cut material to dry, and then burning it; the ashes add plant nutrients to the nutrient-poor soils of most tropical forest areas. p. 697

slime molds: members of the phylum Myxomycota; slime molds form amoebalike colonies, are heterotrophic, and reproduce by spores. p. 332

small intestine: a digestive organ of vertebrates and some invertebrates; in vertebrates it is located between the stomach and the large intestine and is the organ in which the digestive processes are completed. p. 419

smooth muscle: the type of muscle tissue found in the walls of hollow internal organs. p. 484

social behavior: animal behavior that shows evidence of differing individual roles in the organization of a group and of cooperation or division of labor in tasks. p. 576

somatic nervous system: those nerves leading from the central nervous system to skeletal muscles. p. 492

speciation: an evolutionary process involving reproductive isolation of a population from others of its species; a new species has been formed when interbreeding is no longer possible between individuals of the isolated population and those of the parent species. p. 246

species (SPEE sheez): a group of organisms that can interbreed with others of the same type; individuals within a species possess similar anatomical characteristics. p. 73

sperm cell: a male gamete, usually motile in swimming movements; its motility increases its chance of encountering and fertilizing an egg. p. 154

Sphenophyta (sfen OFF ih tuh): the phylum containing horsetails. p. 363

sphincter (SFINK ter): a circular muscle that functions to close an opening of a tubular structure. p. 419

spina bifida (SPY nuh BIH fih duh): a birth defect resulting from the failure of the neural tube to close properly during formation of the spinal cord and brain. p. 176

spinal cord: a complex band of neurons that runs through the spinal column of vertebrates to the brain. p. 490

spongy layer: a layer of round, chloroplast-containing mesophyll cells surrounded by air spaces. p. 514

sporangia (spoh RAN jee uh): spore-producing structures formed in one stage of the life cycle of many organisms, but not animals. p. 332

spores: one-celled reproductive bodies that are usually resistant to harsh environmental conditions and may remain dormant, in a dry covering, for long periods; in some organisms, spores are asexual and may initiate the growth of a new organism under favorable conditions; in other organisms, spores are sexual and must unite with those of the other sex before producing a new organism. p. 190

sporophyte (SPOR oh fyt): the spore-producing generation in a plant species that undergoes alternation of generations; in some species, the sporophyte is reduced to a dependent structure that grows from the gametophyte plant. p. 357

sporozoans: usually nonmotile, heterotrophic, parasitic protists of the phylum Apicomplexa, with complex life cycles. p. 331

stamen (STAY men): the pollen-producing male reproductive organ of a flower, consisting of an anther and filament. p. 358

sterile: not capable of reproducing. p. 236

stigma: the tip of the carpel in a flower; it secretes a sticky substance that traps pollen. p. 358

stimulant: a drug that increases the activity of the central nervous system. p. 504

stimuli: the plural of stimulus. p. 407

stimulus (STIM yoo lus): a change or signal in the internal or external environment that causes an adjustment or reaction by an organism. p. 488

stomach: the digestive organ located between the esophagus and the small intestine. p. 419

stomate (STOH mayt): the opening between two guard cells in the epidermis of a plant leaf; gases are exchanged with the air through stomates. p. 355

strata (STRAYT uh; singular, *stratum*): layers, usually of deposited earth sediments carried by erosion; many strata become mineralized into rock layers. p. 594

stress: a physiological response to factors causing disruptive changes in the body's internal environment. p. 501

stressor: a factor capable of stimulating a stress response. p. 501

stroma (STROH muh): the colorless substance in a chloroplast surrounding the thylakoids; the enzymes of the Calvin cycle also are in the stroma. p. 542

stromatolite (stroh MAT uh lyt): a rock made of banded domes of sediment in which are found the most ancient forms of life, fossil prokaryotes dating back as far as 3.5 billion years. p. 281

subsistence agriculture: producing only enough food to feed oneself and family members; in good years, enough may be left over to sell or store. p. 697

substrate (SUB strayt): a molecule on which enzymes act. p. 100

succession: the replacement of one community by another in a progression to a climax community. p. 642

succulent: in botany, a type of plant with thick, fleshy, water-storing leaves or stems. p. 516

surface receptor: a protein-containing molecule on the outside membrane of a cell that binds to a specific molecule; for example, in a cell such as a lymphocyte, the receptor binds to a specific antigen, a step in the immune response. p. 458

sustainable agriculture: a method of growing crops and raising livestock based on organic fertilizers, soil conservation, water conservation, biological pest control, and minimal use of nonrenewable energy sources. p. 706

symbiosis (sim by OH sis): an ecological relationship between organisms of two different species that live together in direct contact. p. 64

symmetry: correspondence in form and arrangement of parts on opposite sides of a boundary. p. 388

sympathetic division: a division of the autonomic nervous system of vertebrates that functions in an alarm response; increases heart rate and dilates blood vessels while placing the body's everyday functions on hold; mobilizes the body for response to stressors, danger, or excitement. p. 492

synapse (SIN aps): an open junction between neurons, across which an impulse is transmitted by a chemical messenger, a neurotransmitter. p. 488

synthesis (SIN thih sis): the process of putting together or building up; applicable to ideas, chemical compounds, and so on. p. 89

T

taiga: (TY guh): the coniferous or boreal forest biome, characterized by much snow, harsh winters, short summers, and evergreen trees. p. 631

tall-grass prairie: a grassland biome found at the western edge of the deciduous forest in the United States; grasses may grow 1.5 to 2 m tall. p. 636

target organ: a specific organ on which a hormone acts. p. 495

taxonomy (tak SAHN uh mee): the study of species and their classification by genus, family, order, class, phylum (or division), and kingdom. p. 266

T cell: a lymphocyte that matures in the thymus, stimulated by the presence of a particular antigen; it differentiates and divides, producing offspring cells (killer cells) that attack and kill the cells bearing the antigen. p. 458

telophase: the final stage in mitosis; two new cell nuclei are completed as nuclear envelopes form around the two clusters of chromosomes at opposite ends of the cell, and the cell itself divides. p. 137

tendon: a cordlike mass of white fibrous connective tissue that connects muscle to bone. p. 487

terrestrial (ter ES tree uhl): living on land. p. 389

territoriality: the behavior pattern in animals consisting of the occupation and defense of a territory. p. 578

testes: the primary reproductive organs of a male; sperm cell-producing organs. p. 160

thermoacidophiles (THER moh a SID uh fylz): archaebacteria requiring high temperatures and/or acidic conditions for life. p. 299

thermocline (THER moh klyn): a layer in a thermally stratified body of water that separates upper, oxygen-rich and nutrient-poor warm water from lower, oxygen-poor and nutrient-rich cold water. p. 665

threat display: a behavior in which an animal attempts to make itself appear larger or fiercer than it actually is in an attempt to discourage intruders. p. 578

thrombin: a blood protein that is important in the clotting process. p. 456

thylakoid (THY luh koyd): a flattened sac in a chloroplast; many of the thylakoids are arranged in stacks known as grana; the pigments and enzymes for the light reactions of photosynthesis are embedded in the sac membrane. p. 542

thyroid gland: an endocrine gland in the neck region of most vertebrates that controls the rate of cell metabolism in the body through one of its hormones, thyroxine. p. 499

thyroxine (thy ROK sin): a principal hormone of the thyroid gland; regulates the rate of cell metabolism. p. 499

tolerance: the ability to withstand or survive a particular environmental condition. pp. 504, 582

toxin: a naturally occurring chemical or substance that is poisonous to an organism. p. 727

trachea (TRAY kee uh): the windpipe of an air-breathing vertebrate, connecting the air passage in the throat with the lungs. p. 465

tracheid (TRAY kee id): a water-conducting and supportive element of xylem composed of long, thin cells with tapered ends and hardened walls. p. 519

transpiration (trans pih RAY shun): the loss of water to the atmosphere by a plant through the stomates in its leaves. p. 515

trimester: a period or term of three months; the gestation period of humans usually is divided into trimesters. p. 180

tropical deciduous forest: a tropical forest biome with wet and dry seasons and constant temperatures. p. 635

tropical rain forest: the most complex of all communities, located near the equator where rainfall is abundant and harboring more species of plants and animals than any other biome in the world; light is the major limiting factor. p. 634

tropism (TROH piz um): a change in the orientation of a plant, or part of a plant, in response to light, gravity, or other environmental factors. p. 556

true breeding: organisms that are genetically identical; homozygous. p. 195

tumor: a mass that forms within otherwise normal tissue, caused by the uncontrolled growth of a transformed cell. p. 183

turgor (TER ger) **pressure:** pressure exerted by plant cells against their cell walls whenever the plant is adequately supplied with water. p. 515

U

ultrasound: high frequency sound waves; a method used to determine some fetal abnormalities. p. 178

ultraviolet light: the range of radiation wavelengths just beyond violet in the visible spectrum, on the border of the X-ray region. p. 543

umbilical (um BIL ih kul) **cord:** in placental mammals, a tube connecting the embryo with the placenta. p. 177

unicellular: one-celled. p. 122

Uniramia (yoo nih RAY mee uh): the subphylum containing animals with three distinct body parts and one pair of antennae; includes millipedes, centipedes, and insects. p. 395

unsaturated fat: a fat containing fatty acids with one or more double-bonded carbon atoms; each double bond in the carbon chains reduces by one the number of hydrogen atoms that can be bonded to the carbons; unsaturated fats usually are liquid at room temperature. p. 431

uranium-235 dating: a radiometric dating technique in which the decay of uranium into lead isotopes is measured; used to date rocks 2 billion years old. p. 594

urban wildlife: wildlife living in urban and suburban areas, including raccoons, skunks, pigeons, songbirds, raptors, mice, rats, and similar animals. p. 585

urea (yoo REE uh): a nonprotein nitrogenous substance produced as a result of protein metabolism. p. 407

ureter (YOOR ee ter): a muscular tube that carries urine from the kidney to the urinary bladder. p. 467

urethra (yoo REE thruh): the tube through which urine is carried from the bladder to the outside of the body in vertebrates. pp. 467–468

uric (YOOR ik) **acid:** the insoluble precipitate of nitrogenous waste excreted by land snails, insects, birds, and some reptiles. p. 407

urinary bladder: an organ that stores urine before it is discharged from the body through the urethra. p. 467

urine: in vertebrates, a liquid waste material, carrying nitrogenous compounds and other salts, secreted by the kidneys. p. 468

uterus: a hollow muscular organ, located in the female pelvis, in which a fetus develops. p. 162

V

vaccine: a substance that contains antigens and is used to stimulate the production of antibodies. p. 306

vacuole (VAK yoo ohl): a membrane-enclosed structure in the cytoplasm of a cell or a unicellular organism; different types of vacuoles serve different functions. pp. 127, 130, 402

vagina: a tubular organ that leads from the uterus to opening of the female reproductive tract. p. 162

valve: a membrane or similar structure in an organ or passage, such as an artery or vein, that retards or prevents the return flow of a bodily fluid. p. 453

variable: a factor that can change during an experiment; a scientist conducting an experiment will

allow only one factor (variable) to change while holding all other factors constant. p. 24

variation: small differences among individuals within a population or species that provide the raw material for evolution. p. 237

vascular tissue: plant tissues specialized for the transport of water and nutrients; also for support. p. 355

vegetative reproduction: asexual reproduction by plants that also may reproduce sexually; examples include potato plants from eyes and grass plants from runners. p. 153

vein: (1) a vessel that carries blood toward the heart. p. 452; (2) a continuation of the vascular tissues of the stem and root in a plant leaf. p. 514

ventral: in animals, situated toward the lower or belly side. p. 388

ventricle (VEN trih kul): one of two lower chambers of the heart that pump blood out of the heart. p. 453

vertebrae (VER teh bray): an articulated bone; the vertebrae make up the backbone, or spinal column, of vertebrates. p. 397

vertebrate: a chordate animal with a backbone; mammals, birds, reptiles, amphibians, and various classes of fishes are examples. p. 397

vesicle: a small, intracelluar membrane-enclosed sac in which various substances are transported or stored. p. 129

vessel: in plants, a type of water-conducting xylem cell. p. 519

villi (VIL eye): (1) fingerlike projections of the small intestine that increase surface area. p. 420; (2) fingerlike projections of the chorion that together with the uterine lining form the placenta. p. 177

virulence (VIR yuh lents): the relative ability of a pathogen to overcome body defenses and cause disease. p. 305

virus: a submicroscopic pathogen composed of a core of nucleic acid surrounded by a protein coat that can reproduce only inside a living cell. p. 322

W

wetland: land that stays flooded all or part of the year with freshwater or salt water; includes coastal and inland wetlands. p. 677

X

X-linked trait: a trait determined by a gene carried on the X chromosome. p. 204

xylem (ZY lem): conducting tissue that transports water and dissolved nutrients in vascular plants. p. 518

Z

zooplankton (ZOH oh PLANK ton): very small, feebly swimming aquatic organisms that are herbivorous or carnivorous or both. p. 663

Zygomycota (ZY goh my KOH tuh): the phylum containing conjugation fungi. p. 335

zygospore (ZY goh spor): a zygote that forms a spore; produced in some fungi and many plants following the union of sexual cells or nuclei. p. 335

zygote (ZY goht): the diploid product of the union of haploid gametes in conception; a fertilized egg. p. 156

INDEX

Note: Illustrations and tables are referenced in italics.

A

B

C

D

E

F

G

H

I

J

K

L

M

N

P

Q

R

S

T

U

V

W

X

Y

Z