History & Biology

1600 — **1700**

1620
Pilgrims aboard the *Mayflower* land at Plymouth, Massachusetts.

1665
Robert Hooke first describes and names cells when he observes a slice of cork using a hand-crafted microscope that magnifies 30 times.

1674
The first living cells—single-celled organisms—are observed. They are called *animalcules* meaning "little animals."

Unit 3

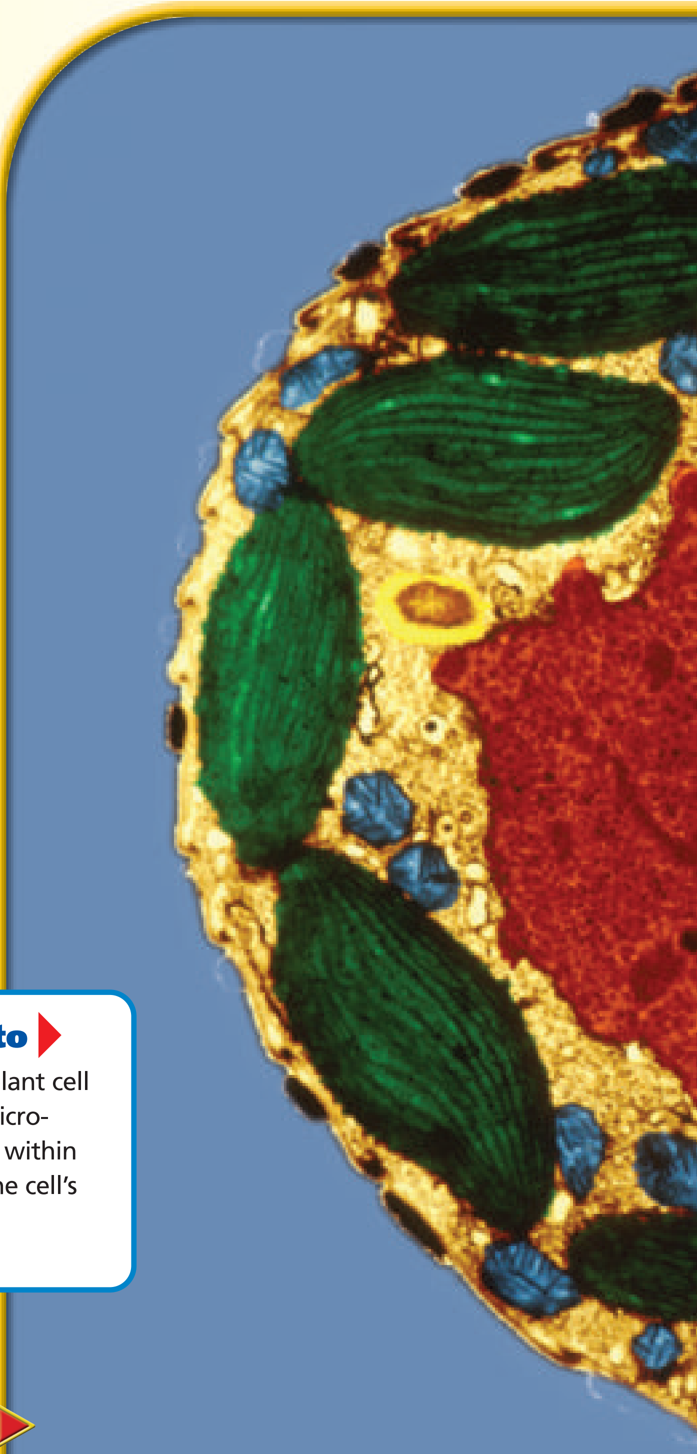
The Life of a Cell

What You'll Learn

Why It's Important

A cell is the most basic unit of living organisms. No matter how complex an organism is, at its core it is a collection of cells. In many organisms, cells work together, forming more complex structures.

California Standards
The following standards are covered in Unit 3:
Investigation and Experimentation: 1a, 1d, 1h, 1j, 1k
Biology/Life Sciences: 1a, 1b, 1c, 1d, 1h, 4e, 4f, 5a



Understanding the Photo

This is a color-enhanced image of a plant cell taken with a transmission electron microscope. Note the many compartments within the cell. These compartments keep the cell's functions separated.

Color-enhanced TEM Magnification: 4200×

1776 The Declaration of Independence is signed by the Second Continental Congress.

1945 First atomic bomb explodes over Hiroshima, Japan, during World War II.

1800 | 1900 | 2000

1831 The cell nucleus is discovered and named.

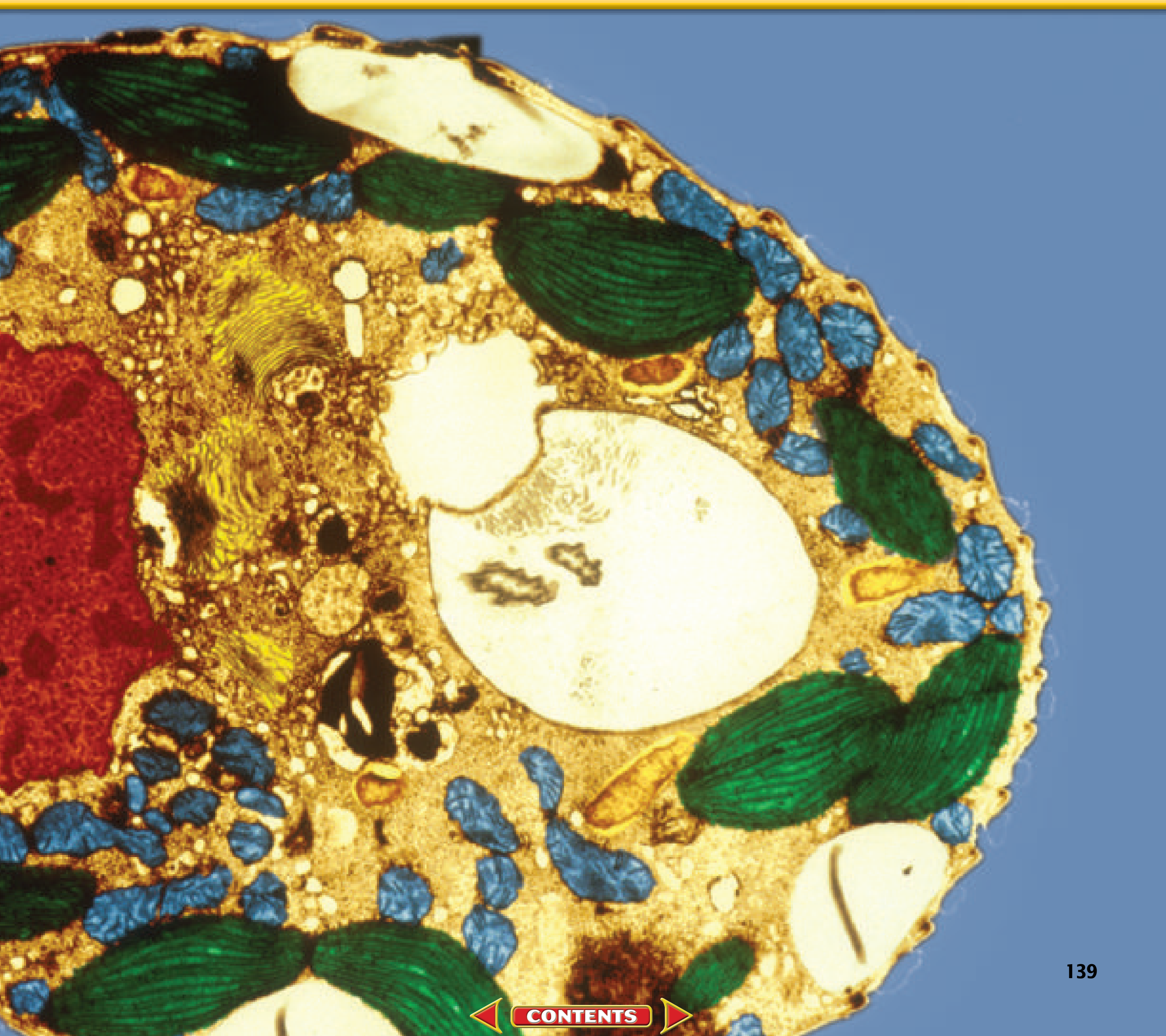
1838 It is determined that all living plants consist of cells.

1839 It is determined that all animals consist of cells.

1950s Development of the electron microscope allows cell biologists to see organelles.

1972 A model for the structure of the membrane that surrounds the cell is proposed.

1991 Molecular motors, which move molecules through the cell along the cytoskeleton, are discovered.



Chapter 6

The Chemistry of Life

What You'll Learn

- You will relate an atom's interactions with other atoms to its structure.
- You will explain why water is important to life.
- You will compare the role of biomolecules in organisms.

Why It's Important

Living organisms are made of simple elements as well as complex carbon compounds. With an understanding of these elements and compounds, you will be able to relate them to how living organisms function.

Understanding the Photo

This butterfly, as well as the colorful flower, is made of atoms. Atoms also make up the breakfast you ate this morning, the air you breathe, and the pages of this book. Why, then, are all these things different?

Biology Online

Visit ca.bdol.glencoe.com to
- study the entire chapter online
- access Web Links for more information and activities on the chemistry of life
- review content with the Interactive Tutor and self-check quizzes

Robert Lubeck/Animals Animals/Earth Scenes

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Section 6.1

Atoms and Their Interactions

California Standards Standard 1l Students will analyze situations and solve problems that require combining and applying concepts for more than one area of science.

SECTION PREVIEW

Objectives

Relate the structure of an atom to the identity of elements.

Relate the formation of covalent and ionic chemical bonds to the stability of atoms.

Distinguish mixtures and solutions.

Define acids and bases and relate their importance to biological systems.

Review Vocabulary

energy: the ability to cause change (p. 9)

New Vocabulary

element
atom
nucleus
isotope
compound
covalent bond
molecule
ion
ionic bond
metabolism
mixture
solution
pH
acid
base

Atoms: The Building Blocks of Rocks—and You!

Using Prior Knowledge The difference between living and nonliving things may be readily apparent to you. For example, these corals are responding to their surroundings, something you would not expect a rock to do. We know, however, that living things have a great deal in common with rocks, CDs, computer chips, and other nonliving objects. Both living and nonliving things are composed of the basic building blocks called atoms.

Cup corals eat a juvenile octopus.

Compare and Contrast *What makes a living thing different from a nonliving thing? How are the particles that make up a rock similar to those of a coral?*

Elements

Everything—whether it is a rock, frog, or flower—is made of substances called **elements.** Suppose you find a nugget of pure gold. You could grind it into a billion bits of powder and every particle would still be gold. You could treat the gold with every known chemical, but you could never break it down into simpler substances. That's because gold is an element. An element is a substance that can't be broken down into simpler chemical substances.

Natural elements in living things

Of the naturally occurring elements on Earth, only about 25 are essential to living organisms. ***Table 6.1*** on the next page lists some elements found in the human body. Notice that four of the elements—carbon, hydrogen, oxygen, and nitrogen—together make up more than 96 percent of the mass of a human body. Each element is identified by a one- or two-letter abbreviation called a symbol. For example, the symbol C represents the element carbon, Ca represents the element calcium, and Cl represents the element chlorine.

Table 6.1 Some Elements That Make Up the Human Body

Element	Symbol	Percent By Mass in Human Body	Element	Symbol	Percent By Mass in Human Body
Oxygen	O	65.0	Iron	Fe	trace
Carbon	C	18.5	Zinc	Zn	trace
Hydrogen	H	9.5	Copper	Cu	trace
Nitrogen	N	3.3	Iodine	I	trace
Calcium	Ca	1.5	Manganese	Mn	trace
Phosphorus	P	1.0	Boron	B	trace
Potassium	K	0.4	Chromium	Cr	trace
Sulfur	S	0.3	Molybdenum	Mo	trace
Sodium	Na	0.2	Cobalt	Co	trace
Chlorine	Cl	0.2	Selenium	Se	trace
Magnesium	Mg	0.1	Fluorine	F	trace

Trace elements

Some of the elements listed in ***Table 6.1***, such as iron and copper, are present in living things in very small amounts. Such elements are known as trace elements. They play a vital role in maintaining healthy cells in all organisms, as shown by the examples in ***Figure 6.1***. Plants obtain trace elements by absorbing them through their roots; animals get them from the foods they eat.

Atoms: The Building Blocks of Elements

Whether elements are found in living things, like cup corals, mammals, or plants, or in nonliving things, like rocks, they are made of atoms. An **atom** is the smallest particle of an element that has the characteristics of that element. Atoms are the basic building blocks of all matter. The way they are structured affects their properties and their chemical behavior.

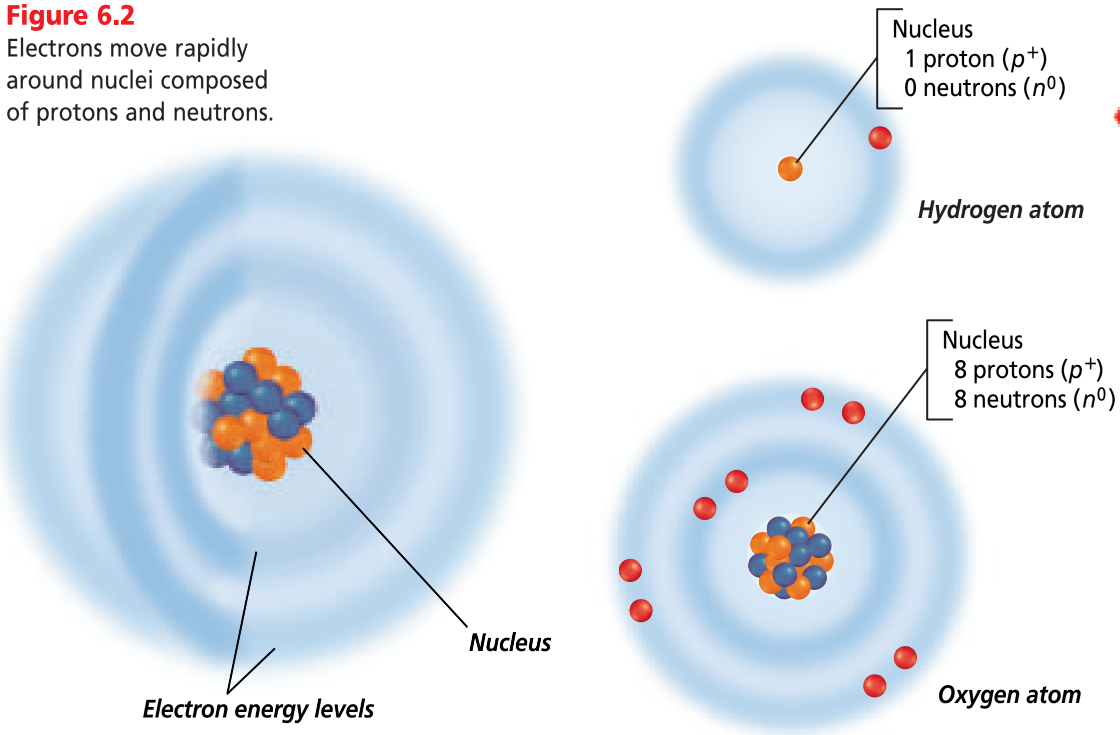
Figure 6.1
Some elements that are needed in small amounts are involved in cell metabolism.

A Mammals use iodine (I) to produce hormones, substances that affect chemical activities in the body.

B Plants use magnesium (Mg) to form chlorophyll, which captures light energy for sugar production.

(l)A.B. Joyce/Photo Researchers, (r)F. Stuart Westmoreland/Photo Researchers

Figure 6.2
Electrons move rapidly around nuclei composed of protons and neutrons.



A An atom has a nucleus and electrons in energy levels.

B Hydrogen, the simplest atom, has just one electron in its first energy level and one proton in its nucleus.

C Oxygen has two electrons in its first energy level and six electrons in the second level.

The structure of an atom

All atoms have the same general structure. The center of an atom is called the **nucleus** (NEW klee us) (plural, nuclei). All nuclei contain positively charged particles called protons (p^+). Most contain particles that have no charge, called neutrons (n^0). All nuclei are positively charged because of the presence of protons. Each element has distinct characteristics that result from the number of protons in the nuclei of the atoms that compose the element. For example, the element iron differs from the element aluminum because iron atoms have a different number of protons than aluminum atoms.

The region of space surrounding the nucleus contains extremely small, negatively charged particles called electrons (e^-). The electrons are held in this region by their attraction to the positively charged nucleus. You can visualize this region as an electron cloud. Although it is impossible to pinpoint the exact location of an electron, the electron cloud is the area where it is most likely to be found.

Electron energy levels

Electrons exist around the nucleus in regions known as energy levels, as indicated in ***Figure 6.2A.*** The first energy level can hold only two electrons. The second level can hold a maximum of eight electrons. The third level can hold up to 18 electrons. The oxygen atom in ***Figure 6.2C*** has a total of eight electrons. Two electrons fill the first energy level. The remaining six electrons occupy the second energy level.

Atoms contain equal numbers of electrons and protons; therefore, they have no net charge. The hydrogen (H) atom in ***Figure 6.2B*** has just one electron and one proton. Oxygen (O) has eight electrons and eight protons.

Figure 6.3
The properties of an element are determined by its atoms. As you can see, carbon, gold, and sulfur have very different properties.

Figure 6.3 shows three other elements whose properties differ because of the number of protons in their nuclei.

Reading Check **Describe** the structure of an oxygen atom.

Isotopes of an Element

Atoms of the same element always have the same number of protons but may contain different numbers of neutrons. Atoms of the same element that have different numbers of neutrons are called **isotopes** (I suh tohps) of that element. For example, most carbon nuclei contain six neutrons. However, some have seven or eight neutrons. Each of these atoms is an isotope of the element carbon. Scientists refer to isotopes by stating the combined total of protons and neutrons in the nucleus. Thus, the most common carbon atom is referred to as carbon-12 because it has six protons and six neutrons. Other isotopes of carbon include carbon-13 and carbon-14.

Isotopes are often useful to scientists. The nuclei of some isotopes, such as carbon-14, are unstable and tend to break apart. As nuclei break, they give off radiation. These isotopes are said to be radioactive. Because radiation is detectable and can damage or kill cells, scientists have developed some useful applications for radioactive isotopes, as described in *Figure 6.4.*

Atomic models like those discussed in the *Problem-Solving Lab* on the next page help scientists and students visualize the structure of atoms and understand complex intermolecular interactions.

(tl)Elaine Shay, (tc)Ross Frid/Photo Researchers, (tr)Photolibrary/Photolibrary/PictureQuest, (b)Matt Meadows/Peter Arnold, Inc.

Figure 6.4
Radioactive isotopes are used in medicine to diagnose and/or treat some diseases. Radiation given off when radioactive isotopes break apart is deadly to many rapidly growing cancer cells. This patient is being treated with radiation from a radioactive isotope of cobalt (Co).

CONTENTS

Compounds and Bonding

Table salt is a substance that is familiar to everyone; however, table salt is not an element. Rather, salt is a type of substance called a compound. A **compound** is a substance that is composed of atoms of two or more different elements that are chemically combined. Table salt (NaCl) is a compound composed of the elements sodium and chlorine. If an electric current is passed through molten salt in an industrial process, the salt breaks down into these elements. You can see in ***Figure 6.5*** that the properties of a compound are different from those of its individual elements.

How covalent bonds form

Most elements in nature are found combined in the form of compounds. But how and why do atoms combine, and what is it that holds the atoms together in a compound? Atoms combine with other atoms only when the resulting compound is more stable than the individual atoms.

For many elements, an atom becomes stable when its outermost energy level is full, as when eight electrons are in the second level. An exception is hydrogen, which becomes stable when its first energy level is full (two electrons). How do elements fill the energy levels and become stable? One way is to share electrons with other atoms.

Figure 6.5
Table salt is made from the elements sodium (Na) and chlorine (Cl). The flask contains the poisonous, yellow-green chlorine gas. The lump of silver-white metal is the element sodium. The white crystals of table salt no longer resemble either sodium or chlorine.

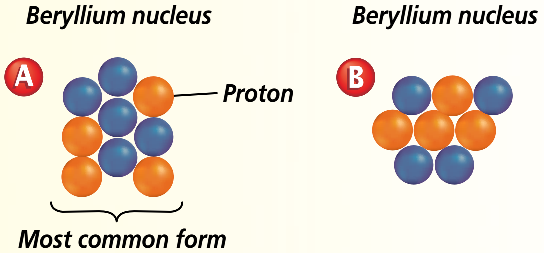
Problem-Solving Lab 6.1

Interpret Scientific Illustrations

What can be learned by studying the nucleus of an atom? Looking at a model of the particles in an atom's nucleus can reveal certain information about that particular atom. Models may help predict electron number, the distribution of electrons in energy levels, and how isotopes of an element differ from each other.

Solve the Problem

Examine diagrams A and B. Both are models of an atom of beryllium. Only the nucleus of each atom is shown.

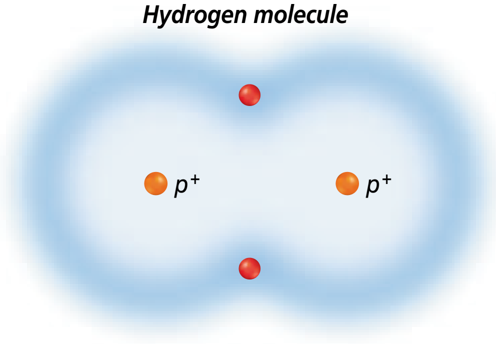


Thinking Critically

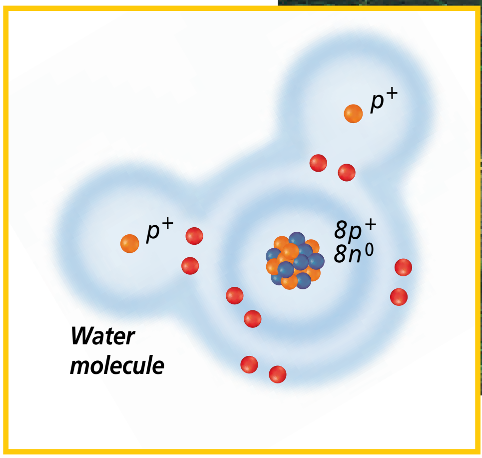
1. **Infer** What is the neutron number for A? For B?
2. **Evaluate** Which diagram represents an isotope of beryllium? Explain how you were able to tell.
3. **Predict** How many electrons are present in atoms A and B? Explain how you were able to tell.
4. **Predict** How many energy levels would be present in atoms of A and B? How might the electrons in A and B be distributed in these levels?

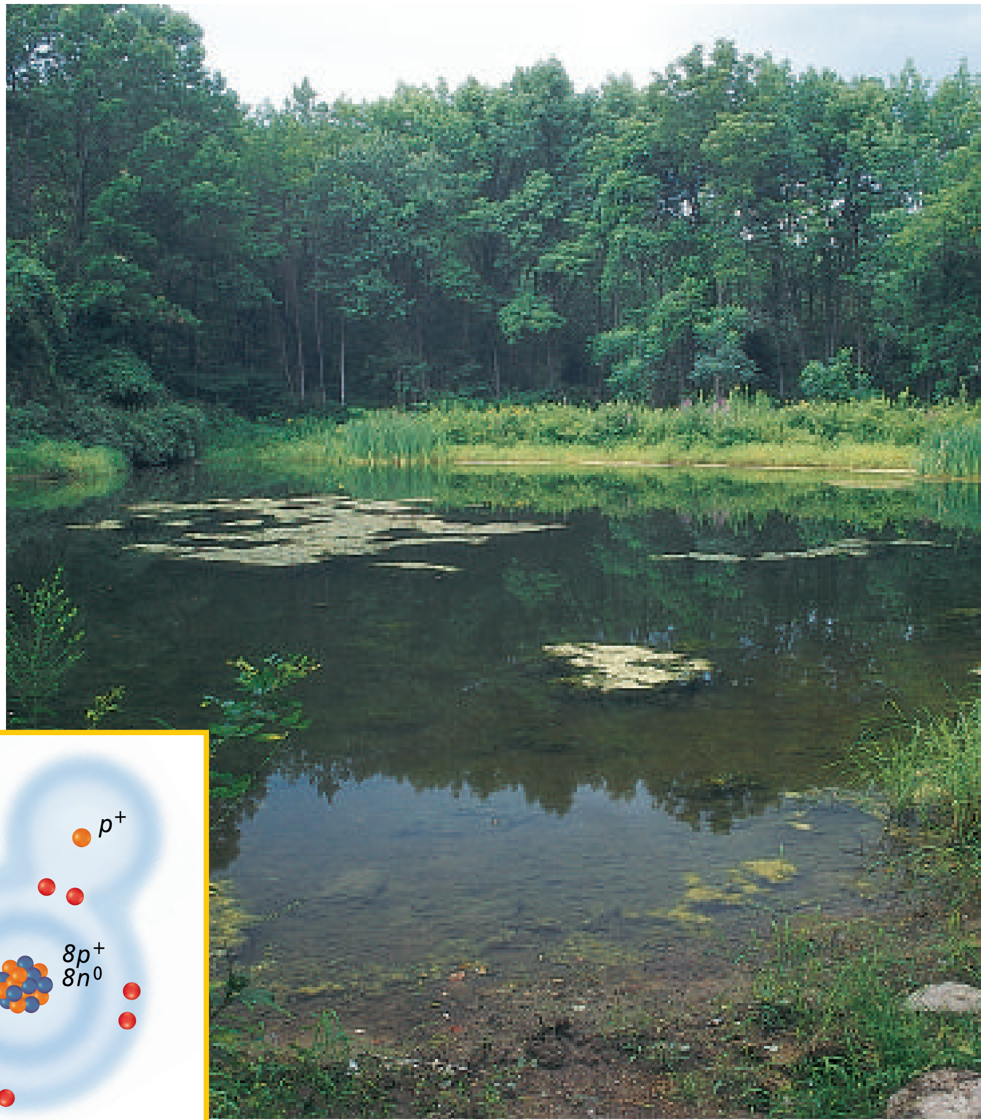
Figure 6.6
Sometimes atoms combine by sharing electrons to form covalent bonds.

A Hydrogen gas (H_2) exists as two hydrogen atoms sharing electrons with each other. The electrons move around the nuclei of both atoms.



B When two hydrogens share electrons with oxygen, they form covalent bonds to produce a molecule of water (H_2O).





Physical Science Connection

Chemical bonding and the periodic table Living things are made up mainly of four elements: hydrogen, carbon, nitrogen, and oxygen. Nonmetal elements that are close to each other on the periodic table tend to combine by forming covalent bonds. As a result, almost all the compounds formed from these four elements are covalently bonded.

Look at ***Figure 6.6A.*** You will see that two hydrogen atoms can combine with each other by sharing their electrons. As you know, hydrogen atoms contain only one electron. Each atom becomes stable by sharing its electron with the other atom. The two shared electrons move about the nuclei of both atoms. The attraction of the positively charged nuclei for the shared, negatively charged electrons holds the atoms together. When two atoms share electrons, such as two hydrogen atoms sharing electrons, the force that holds them together is called a **covalent** (koh VAY lunt) **bond.** Most compounds in organisms have covalent bonds. Examples include sugars, fats, proteins, and water.

A **molecule** is a group of atoms held together by covalent bonds. It has no overall charge. In a molecule of water, ***Figure 6.6B,*** two hydrogen atoms and one oxygen atom share eight electrons. Each of the hydrogen atoms contributes one electron, and the oxygen atom contributes six electrons. Thus, all three atoms are stable.

Michael P. Gadomski/Photo Researchers

A molecule of water is represented by the chemical formula H_2O. The subscript 2 represents two atoms of hydrogen (H) combined with one atom of oxygen (O). As you will see, many compounds in living things have more complex formulas.

How ionic bonds form

Not all atoms bond with each other by sharing electrons. Sometimes atoms combine with each other by first gaining or losing electrons in their outer energy levels. An atom (or group of atoms) that gains or loses electrons has an electrical charge and is called an ion. An **ion** is a charged particle made of atoms.

A different type of chemical bond holds ions together. The bond formed between a sodium atom (Na) and chlorine atom (Cl) in table salt is a good example of this. A sodium atom contains 11 electrons, including one in the third energy level. A chlorine atom has 17 electrons, with the outer level holding seven electrons. The sodium atom loses one electron to the chlorine atom, and the chlorine atom gains one electron from the sodium atom. With eight electrons in its outer level, the chloride ion formed is stable and has a negative charge. The sodium ion has eight electrons in its outer energy level. The sodium ion is stable and has a positive charge. The attractive force between two ions of opposite charge is known as an **ionic bond.** The bond between sodium and chlorine when they combine is an ionic bond, as shown in *Figure 6.7.*

Ionic compounds are less abundant in living things than are covalent molecules, but ions are important in biological processes. For example, sodium and potassium ions are required for transmission of nerve impulses. Calcium ions are necessary for muscles to contract. Plant roots absorb essential minerals in the form of ions.

Chemical Reactions

Chemical reactions occur when bonds are formed or broken, causing substances to recombine into different substances. In organisms, chemical reactions occur inside cells. All of the chemical reactions that occur within an organism are referred to as that organism's **metabolism.** These reactions break down and build molecules that are important for the functioning of organisms. Scientists represent chemical reactions by writing chemical equations.

Word Origin

metabolism from the Greek word *metabole,* meaning "change"; Metabolism involves many chemical changes.

Figure 6.7
The positive charge of a sodium ion attracts the negative charge of a chloride ion. This attraction is called an ionic bond. **Use Models** ***How many electrons does sodium lose in bond formation?***

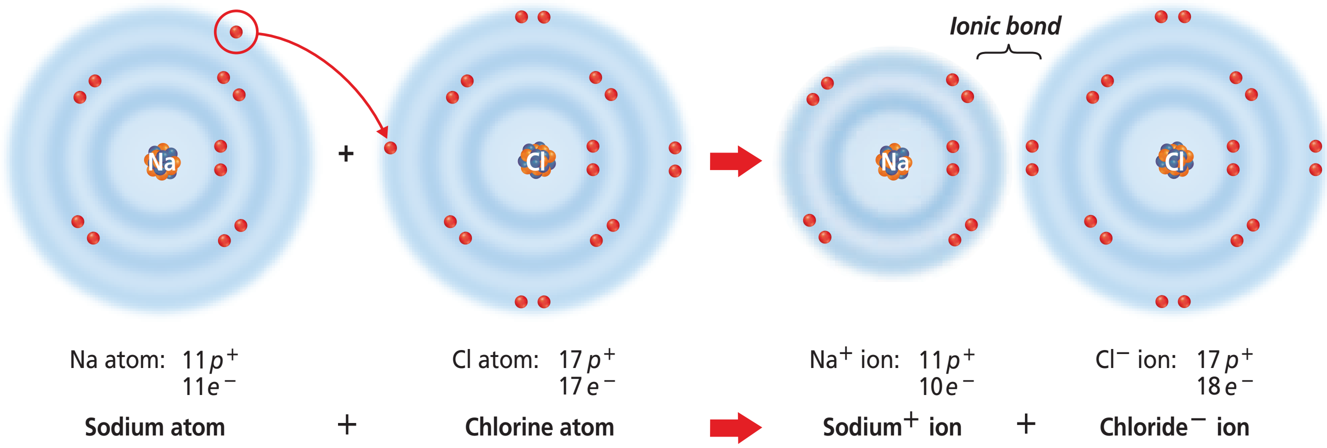
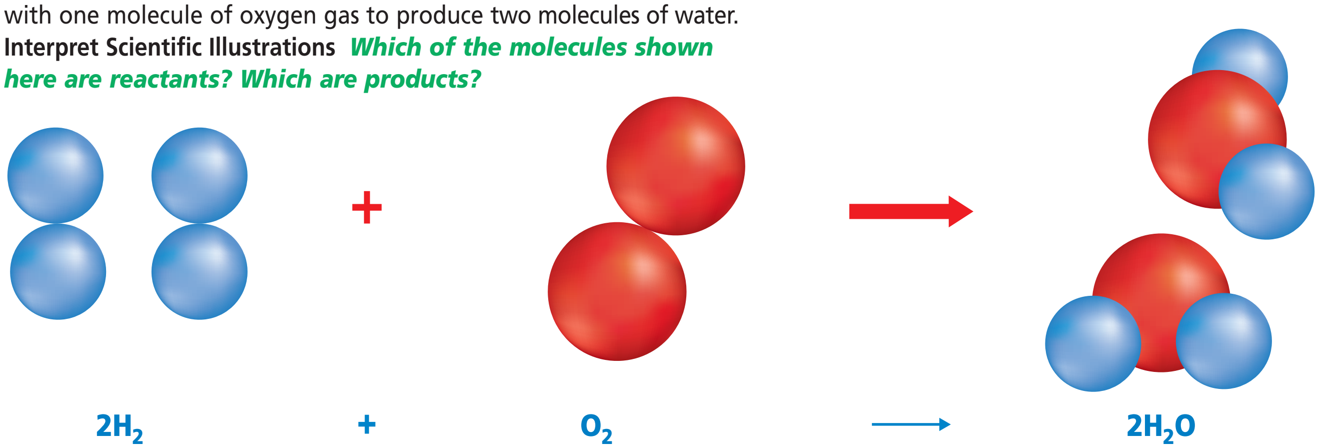


Figure 6.8
This balanced equation shows two molecules of hydrogen gas reacting with one molecule of oxygen gas to produce two molecules of water.
Interpret Scientific Illustrations ***Which of the molecules shown here are reactants? Which are products?***



Physical Science Connection

Conservation of mass in chemical reactions In a chemical reaction, atoms are neither created nor destroyed. As a result, mass is conserved as a chemical reaction. This means that the mass of the reactants equals the mass of the products.

Writing chemical equations

The reaction that takes place when hydrogen gas combines with oxygen gas is shown in ***Figure 6.8.*** In a chemical reaction, substances that undergo chemical reactions, such as hydrogen and oxygen, are called reactants. Substances formed by chemical reactions, such as water, are called products.

It's easy to tell how many molecules are involved in a reaction. In a chemical equation the number before each chemical formula indicates the number of molecules of each substance. The subscript numbers in a formula indicate the number of atoms of each element in a molecule of the substance. A molecule of table sugar can be represented by the formula $C_{12}H_{22}O_{11}$. The lack of a number before a formula or under a symbol indicates that only one molecule or atom is present.

Looking at ***Figure 6.8,*** you can see that each molecule of hydrogen gas is composed of two atoms of hydrogen. Likewise, a molecule of oxygen gas is made of two oxygen atoms. Perhaps the easiest way to understand chemical equations is to know that atoms are neither created nor destroyed in chemical reactions. They are simply rearranged. An equation is written so that the same numbers of atoms of each element appear on both sides of the arrow. In other words, equations must always be written so that they balance.

Figure 6.9
In this illustration of a mixture, both the sand and sugar retain their original properties.

Mixtures and Solutions

When elements combine chemically to form a compound, the elements no longer have their original properties. What happens if substances are just mixed together and do not combine chemically? A **mixture** is a combination of substances in which the individual components retain their own properties. ***Figure 6.9*** shows a mixture of sand and sugar crystals.

Matt Meadows
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When you stir sand and sugar together, you can still tell the sand from the sugar. Neither component of the mixture changes; that is, the components would not combine chemically. You can easily separate them by adding water to dissolve the sugar and then filtering the mixture to collect the sand.

A **solution** is a mixture in which one or more substances (solutes) are distributed evenly in another substance (solvent). In other words, one substance is dissolved in another and will not settle out of solution. You may remember using powdered drink mix when you were younger. The sugar molecules in the powdered drink mix dissolve easily in water to form a solution, as shown in ***Figure 6.10.***

Solutions are important in living things. In organisms, many vital substances, such as sugars and mineral ions, are dissolved in water. The more solute that is dissolved in a given amount of solvent, the greater is the solution's concentration. The concentration of a solute is important to organisms. Organisms can't live unless the concentration of dissolved substances stays within a specific, narrow range. Organisms have many mechanisms to keep the concentrations of molecules and ions within this range. For example, the pancreas and other organs in your body produce substances such as insulin and glucagon that keep the amount of sugar dissolved in your bloodstream within a critical range.

Acids and bases

Chemical reactions can occur only when conditions are right. A reaction may depend on available energy, temperature, or a certain concentration of a substance dissolved in solution.

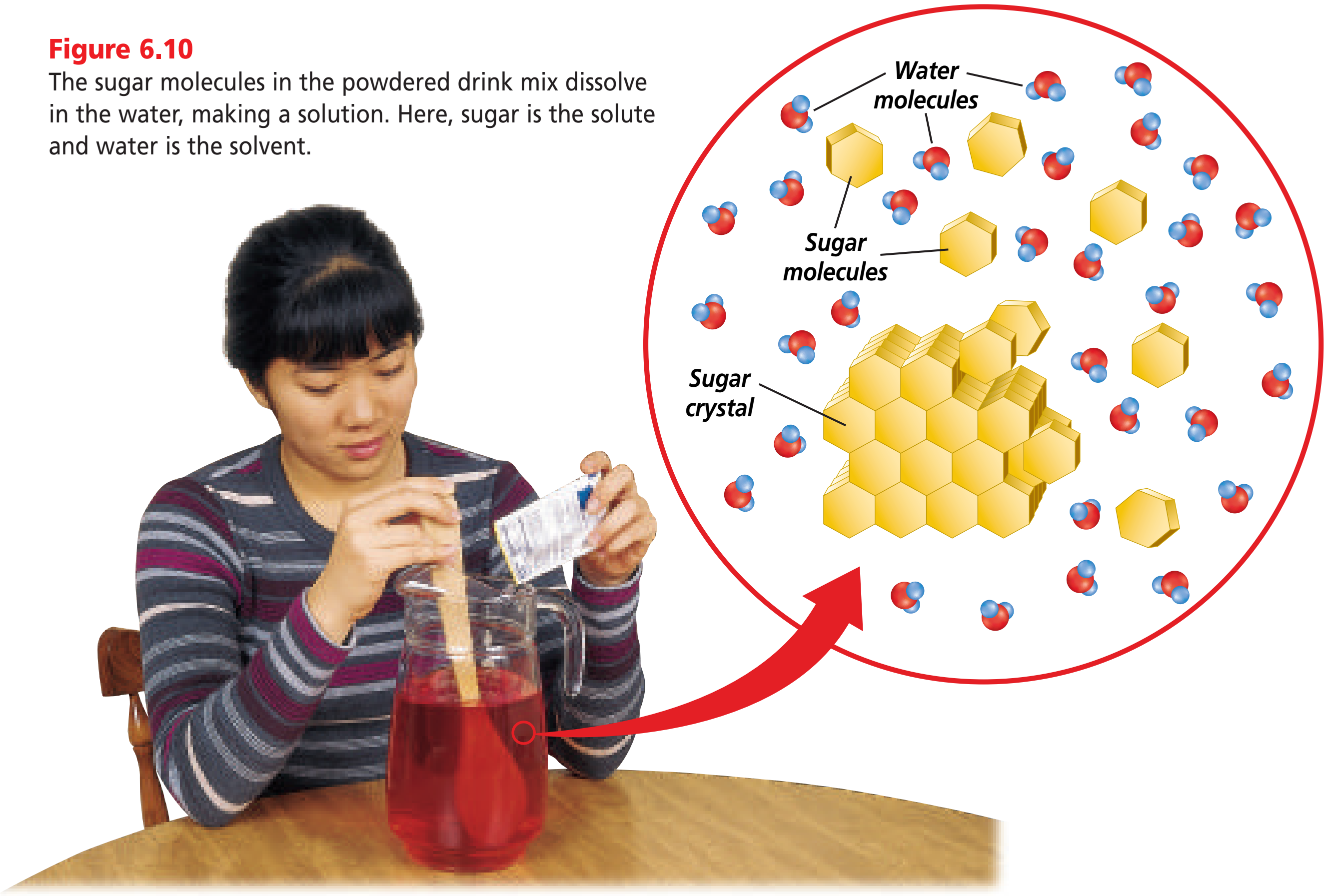


Figure 6.10
The sugar molecules in the powdered drink mix dissolve in the water, making a solution. Here, sugar is the solute and water is the solvent.

Aaron Haupt

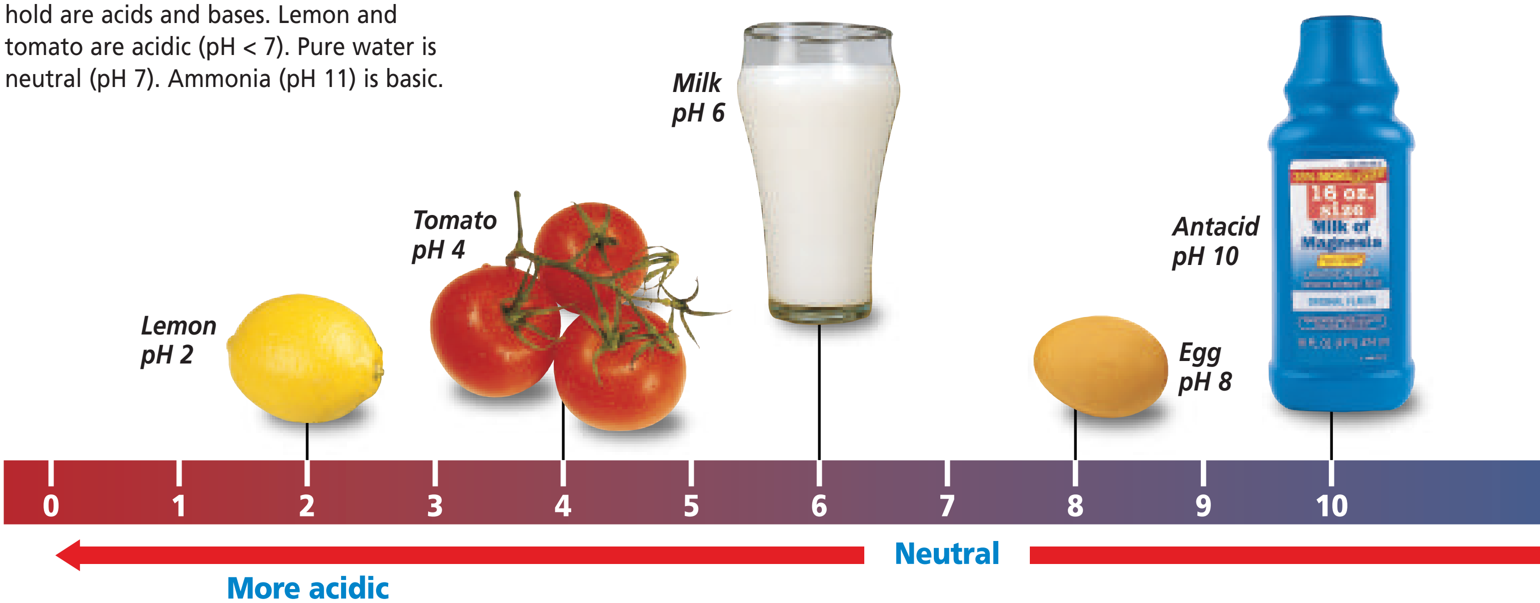


Figure 6.11
Substances commonly found in the household are acids and bases. Lemon and tomato are acidic (pH < 7). Pure water is neutral (pH 7). Ammonia (pH 11) is basic.

Careers in Biology

Weed/Pest Control Technician

A career working with chemicals does not always require a Ph.D. Weed and pest control technicians use chemicals to get rid of unwanted weeds, insects, and other pests.

Skills for the Job

After high school, most technicians receive on-the-job training in pest control or take correspondence courses to earn a degree in this field. In many states, you must pass a test to become licensed.

As a technician, you may visit homes, office buildings, restaurants, hotels, and other places where insects, animals, or weeds have become a problem. You will choose the correct chemical and form, such as a spray or gas, to get rid of or prevent infestations of flies, roaches, termites, or other creatures. You will select different chemicals to deal with weeds. You might also set traps to catch rats, mice, moles, or other animals.

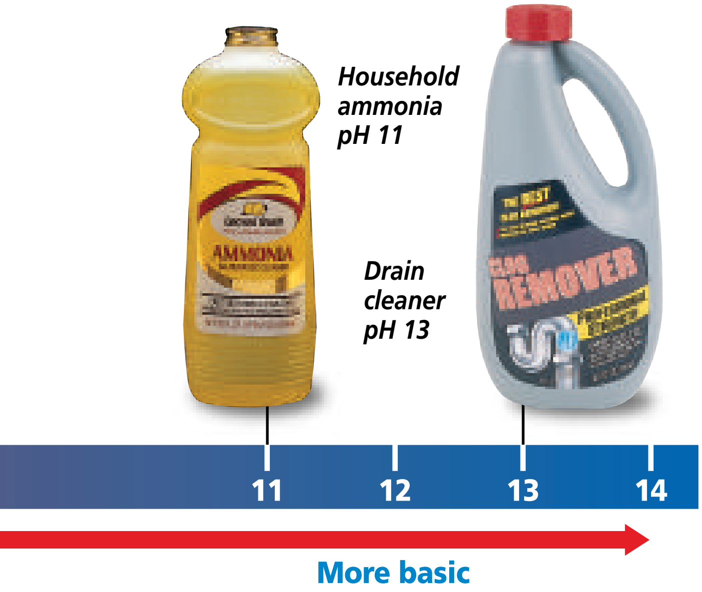
For more careers in related fields, visit ca.bdol.glencoe.com/careers

Chemical reactions in organisms also depend on the pH of the environment within the organism. The **pH** is a measure of how acidic or basic a solution is. A scale with values ranging from below 0 to above 14 is used to measure pH. ***Figure 6.11*** shows the pH of some common substances.

Substances with a pH below 7 are acidic. An **acid** is any substance that forms hydrogen ions (H^+) in water. When hydrogen chloride (HCl) is added to water, hydrogen ions (H^+) and chloride ions (Cl^-) are formed. Thus, hydrogen chloride in solution with water as a solvent is called hydrochloric acid. This acidic solution contains an abundance of H^+ ions and has a pH below 7. A solution is neutral if its pH equals 7.

Substances with a pH above 7 are basic. A **base** is any substance that forms hydroxide ions (OH^-) in water. For example, if sodium hydroxide ($NaOH$) is dissolved in water, it forms sodium ions (Na^+) and hydroxide ions (OH^-). This basic solution contains an abundance of OH^- ions and has a pH above 7.

(top, l to r)Mark Steinmetz, Mark Burnett, J. Sekowski, Mark Burnett, Aaron Haupt, (b)Aaron Haupt



Many of the foods you eat, such as oranges and grapefruits, are acidic. Some plants grow well only in acidic soil, whereas others require soil that is basic. Acids and bases are important to living systems, but strong acids and bases can be dangerous. The *MiniLab* describes how you can investigate several household solutions to determine if they are acids or bases.

Reading Check **Describe** the behavior of an acid in water.

MiniLab 6.1

Experiment

Determine pH The pH of a solution is a measurement of how acidic or basic that solution is. An easy way to measure the pH of a solution is to use pH paper.

Household solutions

Procedure

1. Pour a small amount (about 5 mL) of each of the following into separate clean, labeled beakers or other small glass containers: lemon juice, prepared household ammonia solution, liquid detergent, shampoo, and vinegar.
2. Dip a fresh strip of pH paper briefly into each solution and remove.
3. Compare the color of the wet paper with the pH color chart; record the pH of each material. **CAUTION:** ***Wash your hands with soap after handling lab materials.***

Analysis

1. **Evaluate Data** Which solutions are acids?
2. **Evaluate Data** Which solutions are bases?
3. **Draw Conclusions** What ions in the solution caused the pH paper to change color? Which solution contained the highest concentration of hydroxide ions? How do you know?

Section Assessment

Understanding Main Ideas

1. Describe where the electrons are located in an atom.
2. A nitrogen atom contains seven protons, seven neutrons, and seven electrons. Make a labeled drawing of the structure of a nitrogen atom. How can this atom become stable?
3. How does the formation of an ionic bond differ from the formation of a covalent bond?
4. What can you say about the amount of hydrogen ions relative to the amount of hydroxide ions in a solution that has a pH of 2?

Thinking Critically

5. Are all mixtures solutions? Are all solutions mixtures? Give an example.

Skill Review

6. **Interpret Scientific Illustrations** *Figure 6.10* shows the process of a compound dissolving in water. Describe what is happening to the molecules. Describe the nature of the mixture after the sugar completely dissolves. For more help, refer to *Interpret Scientific Illustrations* in the **Skill Handbook.**

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Section 6.2

Water and Diffusion

California Standards Standard 1l Students will analyze situations and solve problems that require combining and applying concepts for more than one area of science.

SECTION PREVIEW

Objectives

Relate water's unique features to polarity.

Identify how the process of diffusion occurs and why it is important to cells.

Review Vocabulary

homeostasis: regulation of the internal environment of a cell or organism to maintain conditions suitable for life (p. 9)

New Vocabulary

polar molecule
hydrogen bond
diffusion
dynamic equilibrium

Water—It's One of a Kind!

Finding Main Ideas Most of us take water for granted. We turn on the kitchen faucet at home to get a drink and expect water to come out of the faucet. We don't think about how important water's properties are to life.

Organize Information *As you read this section, make a list of the properties of water. Next to each property, write how it is important in maintaining homeostasis in living organisms.*

Water is vital to the living world.

Physical Science Connection

The structure of water molecules Water is sometimes called the universal solvent because of its ability to dissolve a wide range of materials. This ability is related to the polarity of the water molecule, which is due to its "V" shape as well as the polarity of the hydrogen-oxygen bonds. Water molecules would not be polar if they were linear, with hydrogen atoms on opposite sides of the oxygen atom.

Water and Its Importance

Water is perhaps the most important compound in living organisms. Most life processes can occur only when molecules and ions are free to move and collide with one another. This condition exists when they are dissolved in water. Water also serves to transport materials in organisms. For example, blood and plant sap, which are mostly water, transport materials in animals and plants. In fact, water makes up 70 to 95 percent of most organisms.

Water is polar

Sometimes, when atoms form covalent bonds, they do not share the electrons equally. The water molecule pictured in ***Figure 6.12A*** shows that the shared electrons are attracted by the oxygen nucleus more strongly than by the hydrogen nuclei. As a result, the electrons spend more time near the oxygen nucleus than they do near the hydrogen nuclei.

When atoms in a covalent bond do not share the electrons equally, they form a polar bond. A **polar molecule** is a molecule with an unequal distribution of charge; that is, each molecule has a positive end and a negative end. As illustrated in ***Figure 6.12B***, water is an example of a polar molecule. Polar water molecules attract ions as well as other polar molecules. Because of this attraction, water can dissolve many ionic compounds, such as salt, and many other polar molecules, such as sugar.

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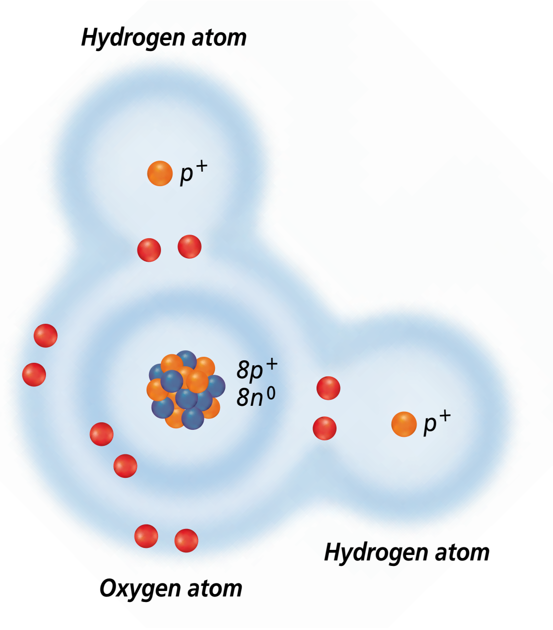
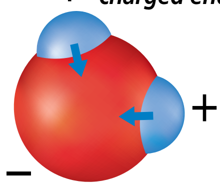
Figure 6.12
Electrons are not shared equally in a water molecule.

A In a covalent bond between hydrogen and oxygen, the electrons spend more time near the oxygen nucleus than near the hydrogen nucleus.





B Because oxygen tends to attract the shared electrons more strongly than hydrogen does, the protruding oxygen end of a water molecule has a slight negative charge, and the ends with protruding hydrogen atoms have a slight positive charge.

Water molecules also attract other water molecules. The positively charged hydrogen atoms of one water molecule attract the negatively charged oxygen atoms of another water molecule. This attraction of opposite charges between hydrogen and oxygen forms a weak bond called a **hydrogen bond.** Hydrogen bonds are important to organisms because they help hold many biomolecules, such as proteins, together.

Also because of its polarity, water has the unique property of being able to creep up thin tubes. Plants in particular take advantage of this property, called capillary action, to get water from the ground. Capillary action and the tension on the water's surface, which is also a result of polarity, play major roles in getting water from the soil to the tops of even the tallest trees.

Water resists temperature changes

Water resists changes in temperature. Therefore, water requires more heat to increase its temperature than do most other common liquids. Likewise, water loses a lot of heat when it cools. In fact, water is like an insulator that helps maintain a steady environment when conditions fluctuate. Because cells exist in an aqueous environment, this property of water is extremely important to cellular functions as it helps cells maintain homeostasis.

Water expands when it freezes

Water is one of the few substances that expands when it freezes. Because of this property, ice is less dense than liquid water so it floats as it forms in a body of water. Use the *Problem-Solving Lab* on the next page to investigate this property. Water expands as it freezes inside the cracks of rocks. As it expands, it often breaks apart the rocks. Over long time periods, this process helps form soil.

The properties of water make it an excellent vehicle for carrying substances in living systems. One way to move substances is by diffusion.

Reading Check **Infer** why coastal communities usually experience milder temperatures than cities that are not located near large bodies of water.

Physical Science Connection

Density of liquids Water is most dense at about 4°C. When the surface of a lake cools to 4°C, the surface water sinks and warmer water takes its place. This process continues until all the water has cooled to 4°C. Only then can the surface start freezing if it is cooled further. Even if the surface is frozen and air temperatures are well below freezing, the water near the bottom of the lake is at 4°C—warm enough for aquatic life to survive.

Problem-Solving Lab 6.2

Use Numbers

Why does ice float? Most liquids contract when frozen. Water is different; it expands. The density of water changes when ice forms, allowing ice to float. Density refers to compactness and is often described as the mass of a substance per unit of volume. A mathematical expression of density would read as follows:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Solve the Problem

Examine the following table. It shows the volume and mass for a sample of water and ice.

Data Table

Source of Sample	Volume (cm^3)	Mass (g)
Water	126	126
Ice	140	126

Thinking Critically

1. **Compare** How does the density of ice compare with the density of water? Use specific values and proper units expressing density in your answer. Which of the two, ice or water, is less compact? Explain your answer.
2. **Think Critically** Are the molecules of water moving closer together or farther apart as water freezes? Explain.
3. **Infer** Explain why a glass bottle filled with water might shatter if placed in a freezer.
4. **Recognize Cause and Effect** Explain why ice forming within a living organism may result in its death.

Diffusion

All objects in motion have energy of motion called kinetic energy. A moving particle of matter moves in a straight line until it collides with another particle, much like the table tennis balls shown in ***Figure 6.13***. After the collision, both particles rebound. Particles of matter, like the table tennis balls, are in constant motion, colliding with each other.

Early observations: Brownian motion

In 1827, Scottish scientist Robert Brown used a microscope to observe pollen grains suspended in water. He noticed that the grains moved constantly in little jerks, as if being struck by invisible objects. This motion, he thought, was the result of a life force hidden within the pollen grains. However, when he repeated his experiment using dye particles, which are nonliving, he saw the same motion. This motion is now called Brownian motion. Brown had no explanation for the motion, but today we know that Brown was observing evidence of the random motion of atoms and molecules. The random movement that Brown observed is characteristic of gases, liquids, and some solids.

Figure 6.13
Like these table tennis balls, atoms and molecules have kinetic energy, the energy of motion. **Describe** ***What happens when two balls collide?***

The process of diffusion

Particles of different substances that are in constant motion have an effect on each other. For example, if you layer pure corn syrup on top of corn syrup colored with food coloring in a beaker as illustrated in ***Figure 6.14***, over time you will observe that the colored corn syrup has mixed with the pure corn syrup. This mixture is the result of the random movement of corn syrup and water molecules. **Diffusion** is the net movement of particles from an area of higher concentration to an area of lower concentration. Diffusion results because of the random movement of particles (Brownian motion).

Diffusion is a slow process because it relies on the random motion of atoms and molecules. You will see evidence that the corn syrup in ***Figure 6.14*** has begun to diffuse within hours but it will take months to mix completely if undisturbed.

Three key factors—concentration, temperature, and pressure—affect the rate of diffusion. The concentration of the substances involved is the primary controlling factor. The more concentrated the substances, the more rapidly diffusion occurs because there are more collisions between the particles of the substances. Two external factors—temperature and pressure—can change the rate of diffusion. An increase in temperature increases energy and will cause more rapid particle motion. This will increase the rate of diffusion. Similarly, increasing pressure will accelerate particle motion and, therefore, diffusion. With common materials, you can use the *MiniLab* shown here to learn more about diffusion in a cell.

Reading Check **Explain** why diffusion is a slow process.

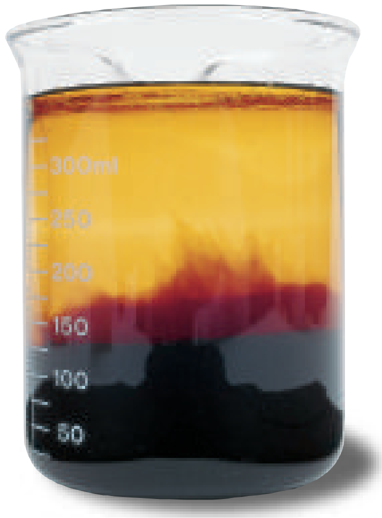
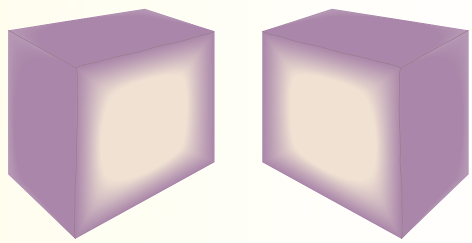


Figure 6.14
The random movement of molecules of corn syrup and water will cause the uncolored sample to diffuse into the colored sample.

MiniLab 6.2

Apply Concepts

Investigate the Rate of Diffusion In this lab, you will place a small potato cube in a solution of purple dye and observe how far the dark purple color diffuses into the potato after a given length of time.



Procedure

1. Using a single-edge razor blade, cut a cube 1 cm on each side from a raw, peeled potato. **CAUTION:** ***Be careful with sharp objects. Do not cut objects while holding them in your hand.***
2. Use forceps to carefully place the cube in a cup or beaker containing the purple solution. The solution should cover the cube. Note and record the time. Let the cube stand in the solution for between 10 and 30 minutes.
3. Using forceps, remove the cube from the solution and note the time. Cut the cube in half.
4. Measure, in millimeters, how far the purple solution has diffused, and divide this number by the number of minutes you allowed your potato to remain in the solution. This is the diffusion rate.

Analysis

1. **Measure** How far did the purple solution diffuse?
2. **Calculate** What was the diffusion rate per minute?

Aaron Haupt

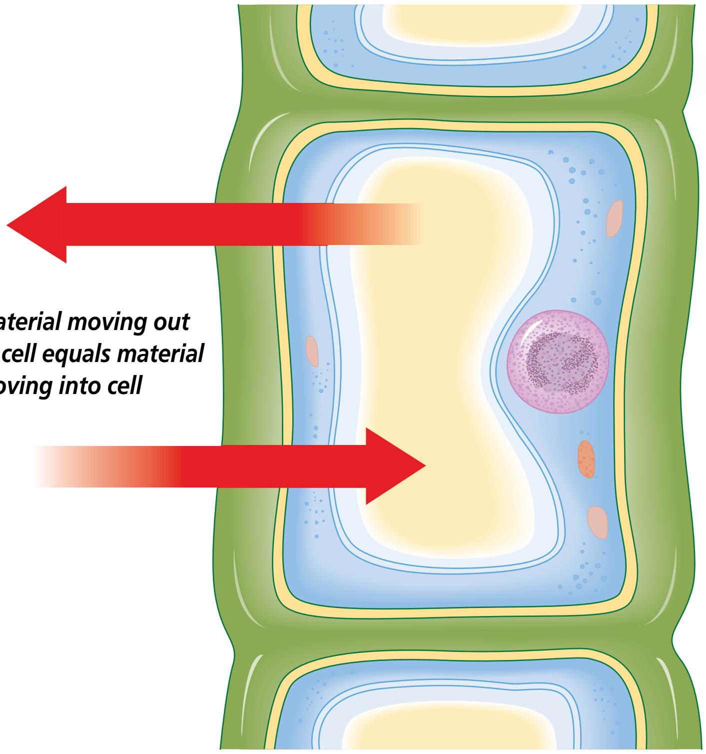


Figure 6.15
When a cell is in dynamic equilibrium with its environment, materials move into and out of the cell at equal rates. As a result, there is no net change in concentration inside or outside the cell.

The results of diffusion

As the pure corn syrup continues to diffuse into the colored corn syrup, the two will become evenly distributed eventually. After this point, the molecules continue to move randomly and collide with one another; however, no further change in concentration will occur. This condition, in which there is continuous movement but no overall concentration change, is called **dynamic equilibrium.** ***Figure 6.15*** illustrates dynamic equilibrium in a cell.

Diffusion in living systems

Most substances in and around a cell are in water solutions where the ions and molecules of solute are distributed evenly among water molecules, as in the powdered drink mix and water example. The difference in concentration of a substance across space is called a concentration gradient. Because ions and molecules diffuse from an area of higher concentration to an area of lower concentration, they are said to move with the gradient. If no other processes interfere, diffusion will continue until there is no longer a concentration gradient. At this point, dynamic equilibrium occurs. Diffusion is one of the methods by which cells move substances in and out of the cell.

Diffusion in biological systems is also evident outside of the cell and can involve substances other than molecules in an aqueous environment. For example, oxygen (a gas) diffuses into the capillaries of the lungs because there is a greater concentration of oxygen in the air sacs of the lungs than in the capillaries.

Section Assessment

Understanding Main Ideas

1. Explain why water is a polar molecule.
2. How does a hydrogen bond compare to a covalent bond?
3. What property of water explains why it can travel to the tops of trees?
4. What is the eventual result of the cellular process of diffusion? Describe concentration prior to and at this point.

Thinking Critically

5. If a substance is known to enter a cell by diffusion, what effect would raising the temperature have on the cell? Why does it have this effect?

Skill Review

6. **Get the Big Picture** Explain why water dissolves so many different substances. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

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Section 6.3

Life Substances

California Standards **Standard 1h** Students know most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.

SECTION PREVIEW

Objectives

Classify the variety of organic compounds.

Describe how polymers are formed and broken down in organisms.

Compare the chemical structures of carbohydrates, lipids, proteins, and nucleic acids, and relate their importance to living things.

Identify the effects of enzymes.

Review Vocabulary

organism: anything that possesses all the characteristics of life (p. 6)

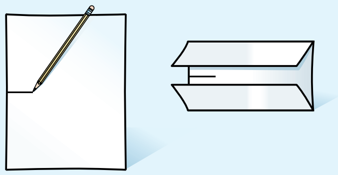
New Vocabulary

isomer
polymer
carbohydrate
lipid
protein
amino acid
peptide bond
enzyme
nucleic acid
nucleotide

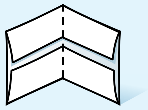
FOLDABLES™ Study Organizer

Biomolecules Make the following Foldable to help you compare the structures and functions of four types of organic compounds called biomolecules.

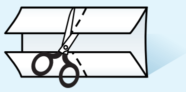
STEP 1 **Draw** a mark at the midpoint of a sheet of paper along the side edge. Then **fold** the top and bottom edges in to touch the midpoint.



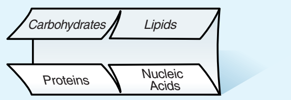
STEP 2 **Fold** in half from side to side.



STEP 3 **Open and cut** along the inside fold lines to form four tabs.



STEP 4 **Label** each tab.



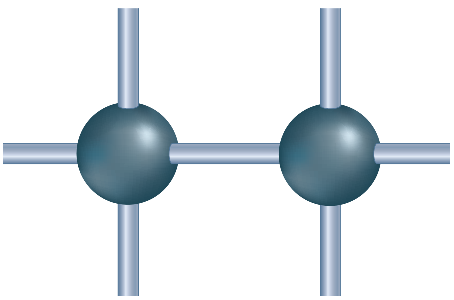
Classify As you read Section 6.3, draw the structure and list the characteristics of carbohydrates, lipids, proteins, and nucleic acids under the appropriate tab.

The Role of Carbon in Organisms

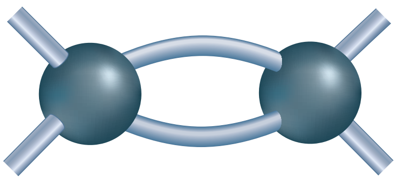
A carbon atom has four electrons available for bonding in its outer energy level. In order to become stable, a carbon atom forms four covalent bonds that fill its outer energy level. Look at the model showing carbon atoms and bond types in ***Figure 6.16.*** Carbon can bond with other carbon atoms, as well as with many other elements. When each atom shares two electrons, a double bond is formed. A double bond is represented by two bars between carbon atoms. When each atom shares three electrons, a triple bond is formed. Triple bonds are represented by three bars between carbon atoms.

Figure 6.16
When two carbon atoms form a covalent bond, they can share one, two, or three electrons each.

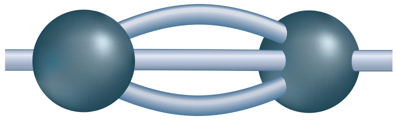
Single Bond



Double Bond



Triple Bond



When carbon atoms bond to each other, they can form straight chains, branched chains, or rings. These chains and rings can have almost any number of carbon atoms and can include atoms of other elements as well. This ability to bond in so many ways makes a huge number of carbon structures possible. In addition, compounds with the same chemical formula often differ in structure. Compounds that have the same chemical formula but different three-dimensional structures are called **isomers** (I suh murz). The glucose and fructose molecules shown in ***Figure 6.17*** have the same formula, $C_6H_{12}O_6$, but different structures.

Word Origin

polymer from the Greek words *poly,* meaning "many," and *meros,* meaning "part"; A polymer has many bonded subunits (parts).

hydrolysis from the Greek words *hydro,* meaning "water," and *lysis,* meaning "to split or loosen"; In hydrolysis, molecules are split by water.

Molecular chains

Carbon compounds vary greatly in size. Some compounds contain just one or two carbon atoms, whereas others contain tens, hundreds, or even thousands of carbon atoms. These large organic compounds are called biomolecules. Proteins are examples of biomolecules that are found in organisms. Cells build biomolecules by bonding small molecules together to form chains called polymers. A **polymer** is a large molecule formed when many smaller molecules bond together.

Many polymers are formed by a chemical reaction known as condensation. In condensation, the small molecules that are bonded together to make a polymer have an –H and an –OH group that can be removed to form H–O–H, a water molecule. The subunits become bonded by a covalent bond, as shown in ***Figure 6.18.*** These polymers can be broken apart by hydrolysis. Hydrogen and hydroxyl groups from water attach to the bonds between the subunits that make up the polymer, thus breaking the polymer as shown in ***Figure 6.18.***

The structure of carbohydrates

You may have heard of runners eating large quantities of spaghetti or bread the day before a race. This practice is called "carbohydrate loading." It works because carbohydrates are used by cells to provide energy. A **carbohydrate** is a biomolecule composed of carbon, hydrogen, and oxygen with a ratio of about two hydrogen atoms and one oxygen atom for every carbon atom.

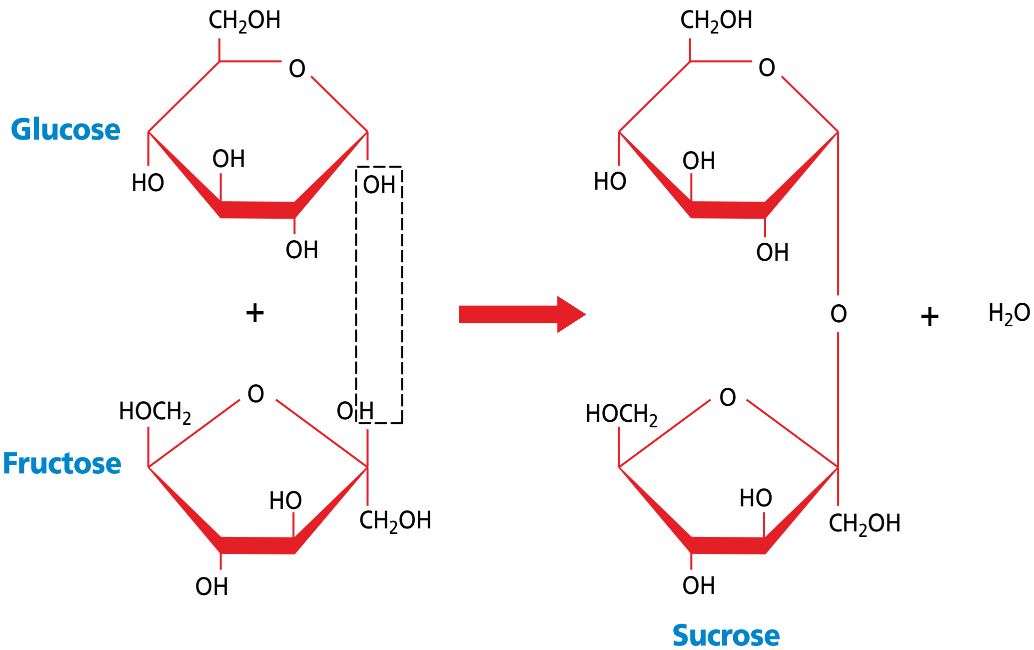
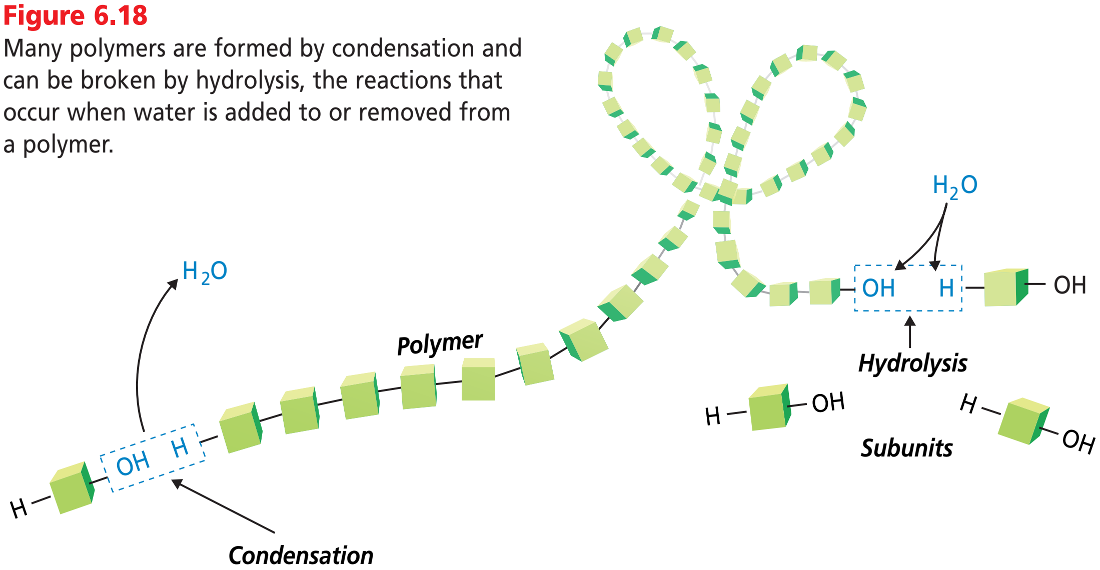


Figure 6.17
The different arrangement of hydrogen (–H) and hydroxide (–OH) groups around each carbon atom gives glucose and fructose molecules different chemical properties. When glucose and fructose combine, they form the disaccharide sucrose, also known as table sugar. **Use Models** ***What other product is formed in this reaction?***

Figure 6.18
Many polymers are formed by condensation and can be broken by hydrolysis, the reactions that occur when water is added to or removed from a polymer.

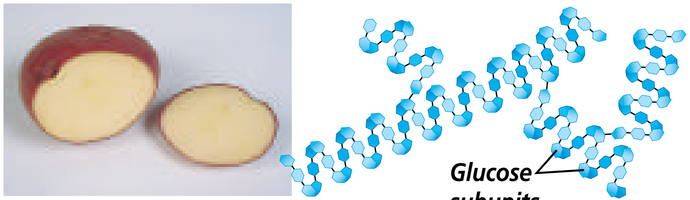


The simplest type of carbohydrate is a simple sugar called a monosaccharide (mah noh SA kuh ride). Common examples are the isomers glucose and fructose. Two monosaccharide molecules can combine to form a disaccharide, a two-sugar carbohydrate. When glucose and fructose link together by a condensation reaction, a molecule of sucrose, known as table sugar, is formed.

The largest carbohydrate molecules are polysaccharides, polymers composed of many monosaccharide subunits. The starch, glycogen, and cellulose pictured in ***Figure 6.19*** are examples of polysaccharides. Starch consists of branched chains of glucose units and is used as energy storage by plant cells and as food reservoirs in seeds and bulbs. Mammals store energy in the liver in the form of glycogen, a highly branched glucose polymer. Cellulose is another glucose polymer that forms the cell walls of plants and gives plants structural support. Cellulose is made of long chains of glucose units linked together in arrangements somewhat like a chain-link fence.

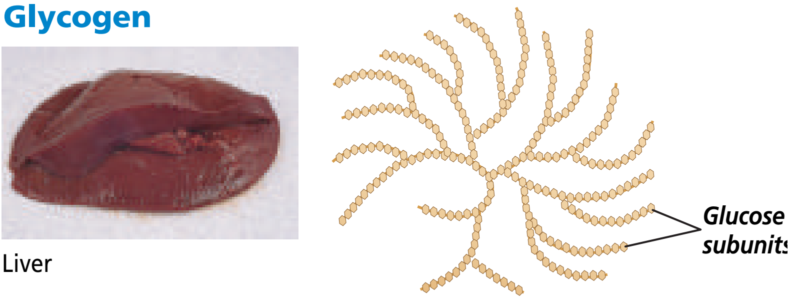
Figure 6.19
Look at the structural differences among the polysaccharides starch, glycogen, and cellulose. Notice that all three are polymers of glucose.
Compare and Contrast ***What are some similarities and differences between these polysaccharides?***

Starch



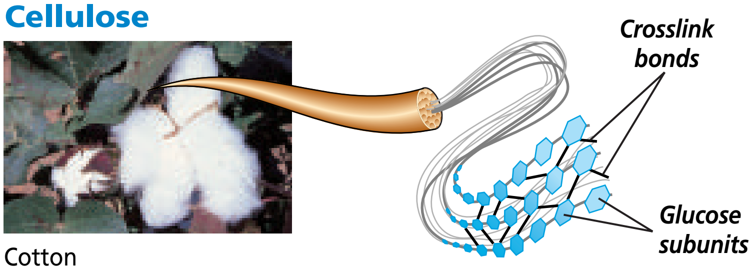
Potato

Glycogen



Liver

Cellulose



Cotton

The structure of lipids

Lipids are large biomolecules that are made mostly of carbon and hydrogen with a small amount of oxygen. Fats, oils, waxes, and steroids are all lipids. They are insoluble in water because their molecules are nonpolar and are not attracted by water molecules.

A common type of lipid, shown in ***Figure 6.20***, consists of three fatty acids linked with a molecule of glycerol. A fatty acid is a long chain of carbon and hydrogen. If each carbon in the chain is bonded to other carbons by single bonds, the fatty acid is said to be saturated. If a double bond is present in the chain, the fatty acid is unsaturated. Fatty acids with more than one double bond are polyunsaturated.

Lipids are very important for the proper functioning of organisms. Cells use lipids for energy storage, insulation, and protective coverings. In fact, lipids are the major components of the membranes that surround all living cells. To learn more about lipids in your body, read the *Biotechnology* feature at the end of this chapter.

The structure of proteins

Proteins are essential to all life. They provide structure for tissues and organs and carry out cell metabolism. A **protein** is a large, complex polymer composed of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur.

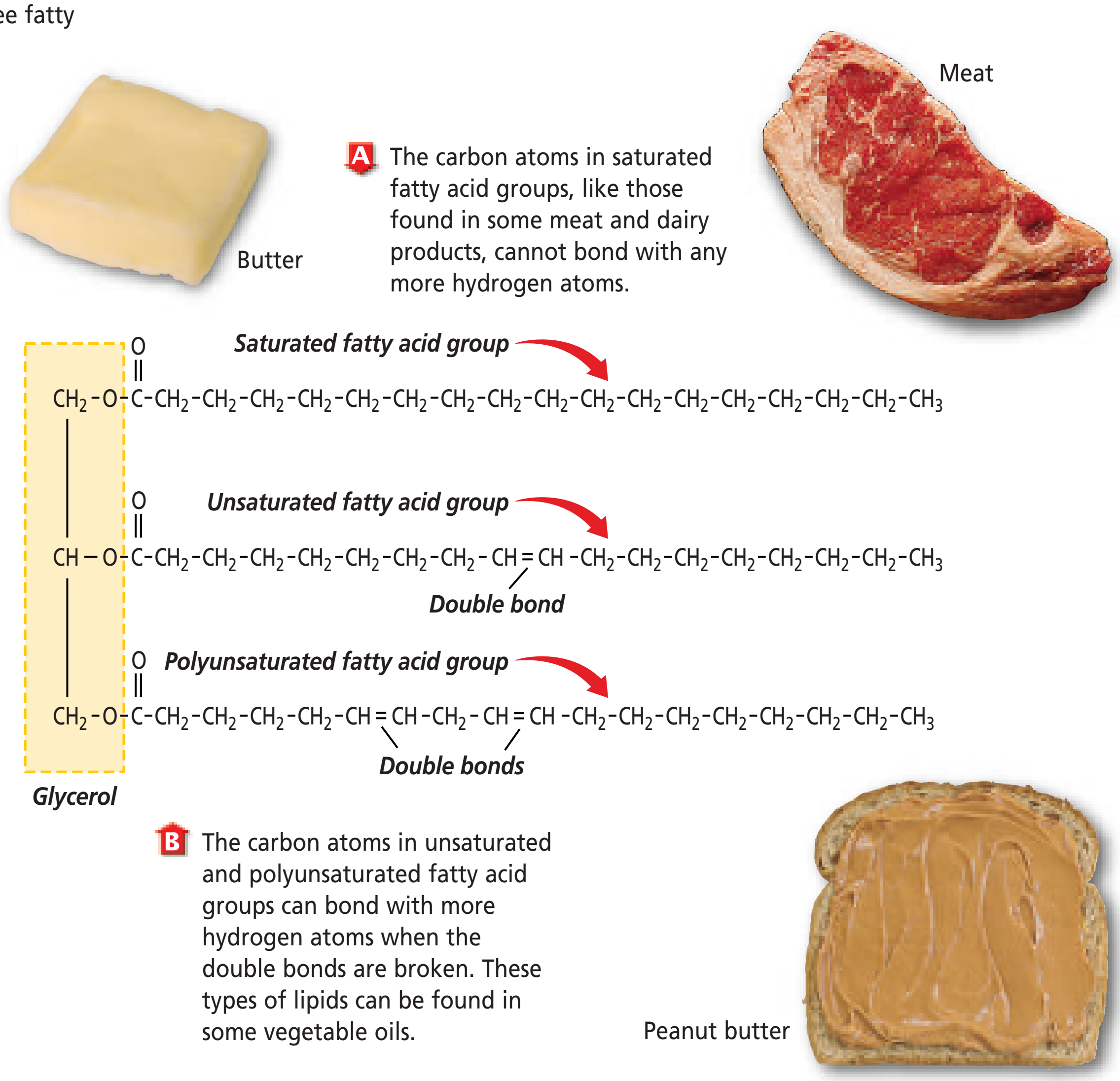


Figure 6.20
Glycerol is a three-carbon molecule that serves as a backbone for a lipid molecule. Attached to the glycerol are three fatty acid groups.

(tl b)Aaron Haupt, (tr)Elaine Shay
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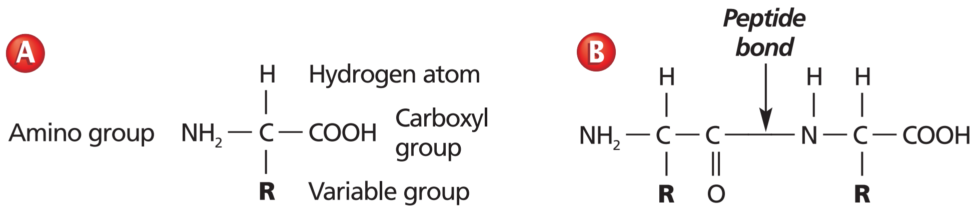


Figure 6.21
(A) Each amino acid contains a central carbon atom to which are attached a carboxyl group (–COOH), a hydrogen atom, an amino group ($–NH_2$), and a variable group (–R) that makes each amino acid different. **(B)** Amino acids are linked together by peptide bonds.

The basic building blocks of proteins are called **amino acids,** shown in ***Figure 6.21A.*** There are about 20 common amino acids. These building blocks, in various combinations, make literally thousands of proteins.

Amino acids are linked together when an –H from the amino group of one amino acid and an –OH group from the carboxyl group of another amino acid are removed to form a water molecule. The covalent bond formed between the amino acids, like the bond labeled in ***Figure 6.21B,*** is called a **peptide bond.**

Proteins come in a large variety of shapes and sizes. The number and sequence of amino acids that make up a protein are important in determining its shape. Certain amino acids are acidic, some are basic, and some are not charged. These properties cause the amino acids to attract or repel each other in different ways. The amino acid chain that makes up the protein twists and turns as the amino acids interact. Many proteins consist of two or more amino acid chains that are held together by hydrogen bonds. The ultimate three-dimensional shape that the protein folds into is extremely important to the functioning of the protein. If the sequence of amino acids in the protein were to change, the protein might fold differently and not be able to carry out its function in the cell.

Proteins are the building blocks of many structural components of organisms, as illustrated in ***Figure 6.22.*** Proteins are also important in the contracting of muscle tissue, transporting oxygen in the bloodstream, providing immunity, regulating other proteins, and carrying out chemical reactions.

Enzymes are important proteins found in living things. An **enzyme** is a protein that changes the rate of a chemical reaction. In some cases, enzymes increase the speed of reactions that would otherwise occur slowly.

Enzymes are involved in nearly all metabolic processes. They speed the reactions in digestion of food. The activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings.

Figure 6.22
Proteins, such as those found in hair, fingernails, horns, and hoofs, make up much of the structure of organisms.

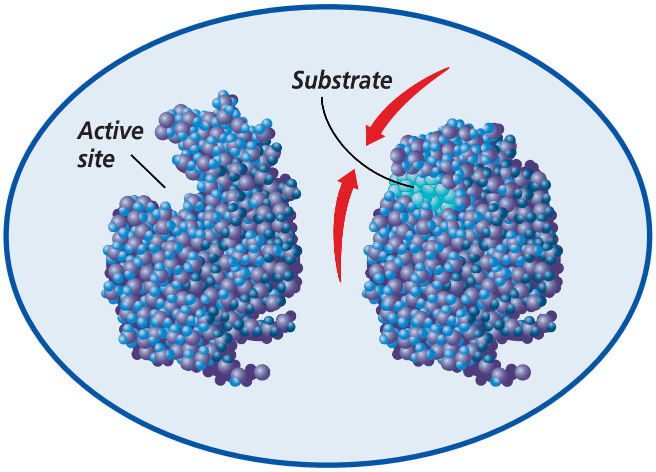
William S. Lea

INSIDE STORY

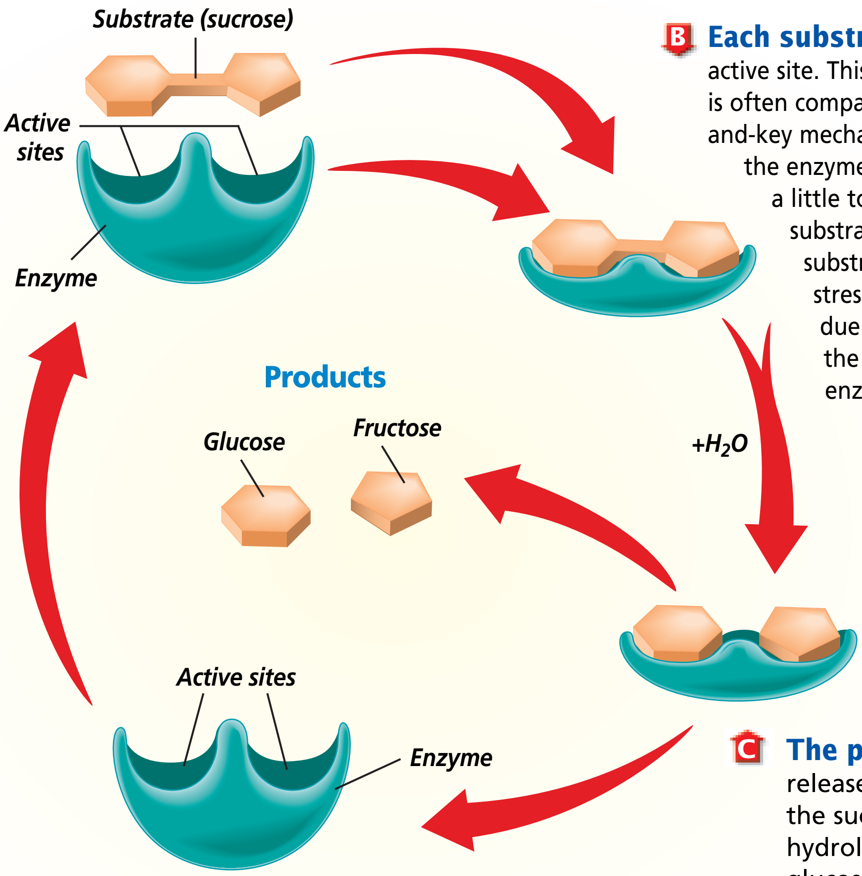
Action of Enzymes

Figure 6.23

An enzyme enables molecules, called substrates, to undergo a chemical change to form new substances, called products. The enzyme has an area called an active site on its surface that fits the shape of the substrate. When the substrate binds to the active site, the enzyme alters its shape slightly as shown below. Enzymes change the rate of a reaction but they do not change the amount of end product. **Critical Thinking** ***Carefully evaluate this model. What is another way that enzyme activity could be represented?***



Lysozyme action



A **Enzymes** act on specific substrates, such as sucrose, a disaccharide made up of glucose and fructose bonded together.

B **Each substrate** fits into the active site. This fitting together is often compared to a lock-and-key mechanism. However, the enzyme changes shape a little to fit with the substrate. The enzyme-substrate complex puts stress on the substrate due to the binding of the substrate to the enzyme.

C **The products** are released; in this case the sucrose bonds are hydrolyzed, releasing glucose and fructose.

D **After the reaction,** the enzyme released is in its original shape and can go on to carry out the same reaction again and again. In doing so, enzymes change the speed at which chemical reactions occur without being altered themselves by the reaction.

How do enzymes act like a lock and key to facilitate chemical reactions within a cell? Examine ***Figure 6.23*** to find out. The *BioLab* at the end of this chapter also experiments with enzymes.

Reading Check **Identify** what determines the shape of a protein.

The structure of nucleic acids

Nucleic acids are another important type of organic compound that is necessary for life. A **nucleic** (noo KLAY ihk) **acid** is a complex biomolecule that stores cellular information in the form of a code. Nucleic acids are polymers made of smaller subunits called **nucleotides.**

Nucleotides consist of carbon, hydrogen, oxygen, nitrogen, and phosphorus atoms arranged in three groups—a nitrogenous base, a simple sugar, and a phosphate group—as shown in ***Figure 6.24.*** You have probably heard of the nucleic acid DNA, which stands for deoxyribonucleic acid. DNA is the master copy of an organism's information code. The information coded in DNA contains the instructions used to form all of an organism's enzymes and structural proteins. Thus, DNA forms the genetic code that determines how an organism looks and acts. DNA's instructions are passed on every time a cell divides and from one generation of an organism to the next.

Another important nucleic acid is RNA, which stands for ribonucleic acid. RNA is a nucleic acid that forms a copy of DNA for use in making proteins. The chemical differences between RNA and DNA are minor but important. A later chapter discusses how DNA and RNA work together to produce proteins.

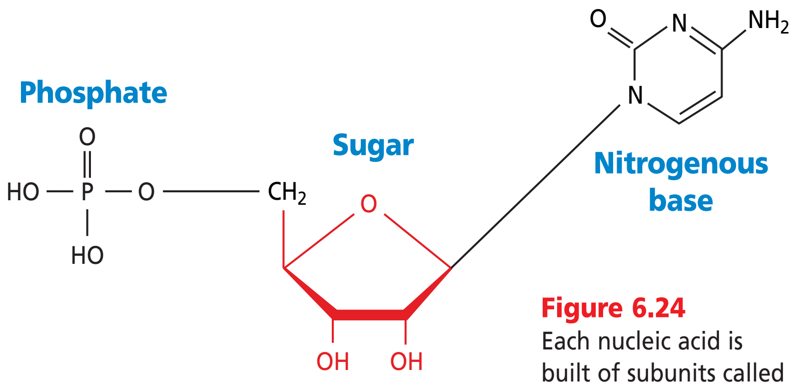
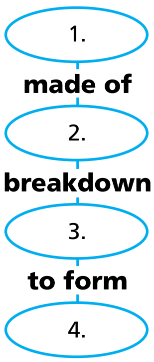


Figure 6.24
Each nucleic acid is built of subunits called nucleotides that are formed from a sugar molecule bonded to a phosphate group and a nitrogenous base.

Section Assessment

Understanding Main Ideas

1. List three important functions of lipids in living organisms.
2. Describe the process by which many polymers in living things are formed from smaller molecules.
3. How does a monosaccharide differ from a disaccharide?
4. Describe the basic components of DNA (deoxyribonucleic acid).
5. Complete the concept map by using the following vocabulary terms: nucleotides, protein, enzymes, nucleic acids.



Thinking Critically

6. Enzymes are proteins that facilitate chemical reactions. Based on your knowledge of enzymes, what might the result be if one particular enzyme malfunctioned or was not present?

Skill Review

7. **Make and Use Tables** Make a table comparing polysaccharides, lipids, proteins, and nucleic acids. List these four types of biomolecules in the first column. In the second column, list the subunits that make up each substance. In the third column, describe the functions of each of these organic compounds in living organisms. In the last column, provide some examples of each from the chapter. For more help, refer to *Make and Use Tables* in the **Skill Handbook.**

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DESIGN YOUR OWN
BioLab

Does temperature affect an enzyme reaction?

INQUIRY Before You Begin

The compound hydrogen peroxide, H_2O_2, is a by-product of metabolic reactions in most living things. However, hydrogen peroxide is damaging to delicate molecules inside cells. As a result, nearly all organisms, such as potatoes, contain the enzyme peroxidase, which speeds up the breakdown of H_2O_2 into water and gaseous oxygen. You will detect this reaction by observing the oxygen bubbles generated.

PREPARATION

Problem

Does the enzyme peroxidase work in cold temperatures? Does peroxidase work better at higher temperatures? Does peroxidase work after being frozen or boiled?

Hypotheses

Make a hypothesis regarding how you think temperature will affect the rate at which the enzyme peroxidase breaks down hydrogen peroxide. Consider both low and high temperatures.

Objectives

In this BioLab, you will:

- **Investigate** the activity of an enzyme.
- **Compare** the activity of the enzyme at various temperatures.

Possible Materials

clock or timer
400-mL beaker
kitchen knife
tongs or large forceps
5-mm thick potato slices
ice
hot plate
non-mercury thermometer or temperature probe
3% hydrogen peroxide

Safety Precautions

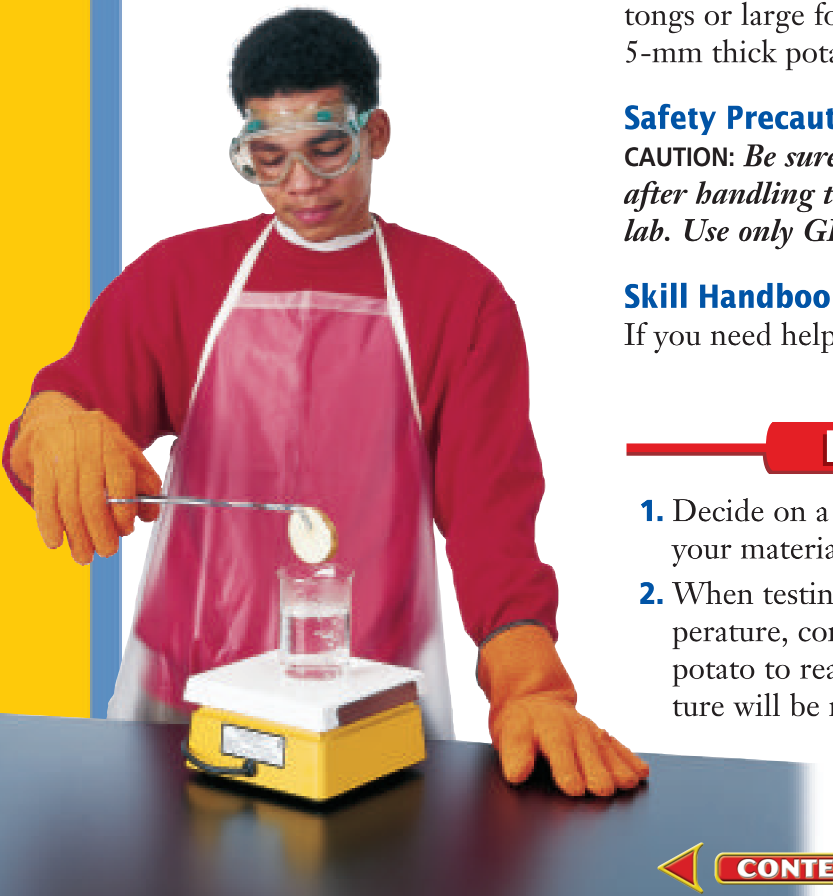
CAUTION: ***Be sure to wash your hands with soap before and after handling the lab materials. Always wear goggles in the lab. Use only GFCI protected circuits for electrical devices.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PLAN THE EXPERIMENT

1. Decide on a way to test your group's hypothesis. Choose your materials from those available.
2. When testing the activity of the enzyme at a certain temperature, consider the length of time it will take for the potato to reach that temperature, and how the temperature will be measured.



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3. To test for peroxidase activity, add 1 drop of hydrogen peroxide to the potato slice and observe what happens. **CAUTION:** ***Hydrogen peroxide is a skin and eye irritant.***

4. When heating a thin potato slice, first place it in a small amount of water in a beaker. Then heat the beaker slowly so that the temperature of the water and the temperature of the slice are always the same. Try to make observations at several temperatures between 10°C and 100°C.

Check the Plan

Discuss the following points with other groups to decide on the final procedure for your experiment.

1. What data will you collect? How will you record them?
2. What factors should be controlled?
3. What temperatures will you test?
4. How will you achieve those temperatures?
5. ***Make sure your teacher approves your experimental plan before you proceed further.***
6. Carry out your experiment. **CAUTION:** ***Be careful with chemicals and heat. Do not heat hydrogen peroxide.***
7. **CLEANUP AND DISPOSAL** Clean all equipment as instructed by your teacher and return everything to its proper place. Wash your hands thoroughly.

ANALYZE AND CONCLUDE

1. **Identify Effects** Describe your observations of the effects of peroxidase on hydrogen peroxide.
2. **Check Your Hypothesis** Do your data support or reject your hypothesis? Explain.
3. **Analyze Data** At what temperature did peroxidase work best?
4. **Recognize Cause and Effect** If you've ever used hydrogen peroxide as an antiseptic to treat a cut or scrape, you know that it foams as soon as it touches an open wound. How can you account for this observation?
5. **ERROR ANALYSIS** What factors did you need to control in your tests? What might have caused errors in your results?

Apply Your Skill

Change Variables To carry this experiment further, you may wish to use hydrogen peroxide to test for the presence of peroxidase in other materials, such as cut pieces of different vegetables. Also, test raw beef and diced bits of raw liver.

Web Links To find out more about enzymes, visit ca.bdol.glencoe.com/enzymes

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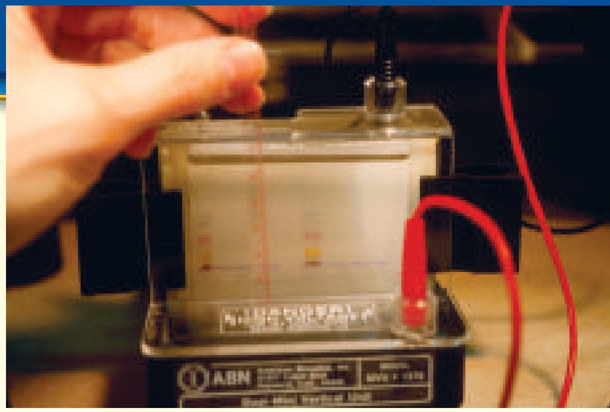
BIO TECHNOLOGY

The "Good" News and the "Bad" News About Cholesterol



An electrophoresis system is used to separate lipoproteins.

About 10 percent of people ages 12 to 19 have blood cholesterol levels which put them at risk later in life for developing heart disease—the leading cause of death in the United States. Biotechnology can help scientists understand the link between cholesterol and heart disease.

Cholesterol is critical to certain body functions, including the formation of cell membranes and some hormones. Cholesterol is a lipid; it will not dissolve in a watery liquid like blood. However, blood must absorb it so that it can be transported. Molecules called lipoproteins are the water-soluble "packages" that transport cholesterol and other lipids to the tissues where they are needed.

Are all lipoproteins created equal? Lipoproteins vary in density and function. High-density lipoproteins (HDL) and low-density lipoproteins (LDL) have both been studied extensively. HDL carries excess cholesterol from tissues and blood vessels to the liver where the cholesterol is discarded from the body. HDL is often called "good cholesterol" because higher levels of this substance appear to provide some protection against coronary artery disease. LDL ("bad cholesterol") deposits cholesterol in body tissues and on blood vessel walls. While body tissues need some cholesterol, excess buildup on arterial walls can lead to blockages and heart disease.

Using technology To measure the amount of HDL and LDL in the blood, the lipoproteins must be separated. A blood sample is spun at high speed in a centrifuge for a long period of time. This process of centrifugation causes the densest lipoproteins to settle to the bottom. Each type of lipoprotein is then measured with an electrophoresis system. Electrophoresis is based on the principle that lipoproteins, like all proteins, have an electric charge. The blood sample is placed in a gel and an electric current is applied. The lipoproteins migrate through the gel and each quantity is measured.

Changes in thinking Scientists once thought a person with a total cholesterol level below 200 milligrams per deciliter (mg/dL) was less likely to develop heart disease. Research has shown that the ratio of LDL to HDL, not the total amount of cholesterol, is a more accurate measure of the risk of heart disease. Based on this research, a person with a total cholesterol level below 200 mg/dL still may be at risk for heart disease.

Proactive measures Elevated cholesterol levels can begin in childhood so it is vital to form healthy habits early in life. A diet low in fat and cholesterol—including a variety of fruits, vegetables, and whole grains—can help keep LDL levels low. To keep HDL levels high, maintain a healthy weight, exercise regularly, and refrain from smoking. A healthy lifestyle in the teenage years can help reduce the risk of developing heart disease later on.

Applying Biotechnology

Think Critically Explain how a centrifuge works. How do electrophoresis and centrifugation differ?

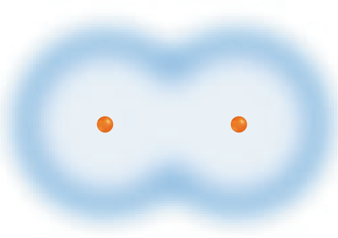
ca.bdol.glencoe.com/biotechnology

Chapter 6 Assessment

Study Guide

Section 6.1

Atoms and Their Interactions



Key Concepts

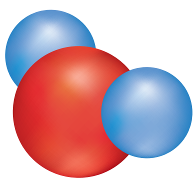
- Atoms are the basic building blocks of all matter.
- Atoms consist of a nucleus containing protons and usually neutrons. The positively charged nucleus is surrounded by rapidly moving, negatively charged electrons.
- Atoms become stable by bonding to other atoms through covalent or ionic bonds.
- Components of mixtures retain their properties.
- Solutions are mixtures in which the components are evenly distributed.
- Acids are substances that form hydrogen ions in water. Bases are substances that form hydroxide ions in water.

Vocabulary

acid (p. 150)
atom (p. 142)
base (p. 150)
compound (p. 145)
covalent bond (p. 146)
element (p. 141)
ion (p. 147)
ionic bond (p. 147)
isotope (p. 144)
metabolism (p. 147)
mixture (p. 148)
molecule (p. 146)
nucleus (p. 143)
pH (p. 150)
solution (p. 149)

Section 6.2

Water and Diffusion



Key Concepts

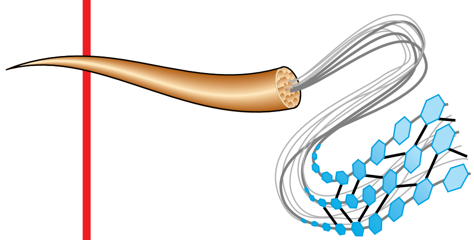
- Water is the most abundant compound in living things.
- Water is an excellent solvent due to the polar property of its molecules.
- Particles of matter are in constant motion.
- Diffusion occurs from areas of higher concentration to areas of lower concentration.

Vocabulary

diffusion (p. 155)
dynamic equilibrium (p. 156)
hydrogen bond (p. 153)
polar molecule (p. 152)

Section 6.3

Life Substances



Key Concepts

- All organic compounds contain carbon atoms.
- There are four principal types of organic compounds, or biomolecules, that make up living things: carbohydrates, lipids, proteins, and nucleic acids.
- The structure of a biomolecule will help determine its properties and functions.

Vocabulary

amino acid (p. 161)
carbohydrate (p. 158)
enzyme (p. 161)
isomer (p. 158)
lipid (p. 160)
nucleic acid (p. 163)
nucleotide (p. 163)
peptide bond (p. 161)
polymer (p. 158)
protein (p. 160)

FOLDABLES Study Organizer To help you review biomolecules, use the Organizational Study Fold on page 157.

Chapter 6 Assessment

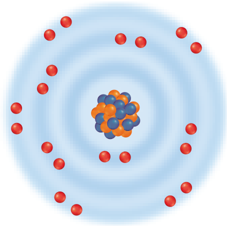
Vocabulary Review

Review the Chapter 6 vocabulary words listed in the Study Guide on page 167. Match the words with the definitions below.

1. the smallest particle of an element that has the properties of that element
2. all of the chemical reactions within an organism
3. the net movement of particles from an area of higher concentration to an area of lower concentration
4. a protein that changes the rate of a chemical reaction

Understanding Key Concepts

5. Which feature of water explains why water has high surface tension?
   A. water diffuses into cells
   B. water's resistance to temperature changes
   C. water is a polar molecule
   D. water expands when it freezes
6. Which of the following carbohydrates is a polysaccharide?
   A. glucose **C.** sucrose
   B. fructose **D.** starch
7. Which of the following pairs is unrelated?
   A. sugar—carbohydrate
   B. fat—lipid
   C. amino acid—protein
   D. starch—nucleic acid
8. An acid is any substance that forms ________ in water.
   A. hydroxide ions **C.** hydrogen ions
   B. oxygen ions **D.** sodium ions
9. Which of these is NOT made up of proteins?
   A. hair **C.** fingernails
   B. enzymes **D.** cellulose
10. Which of the following is NOT a smaller subunit of a nucleotide?
    A. phosphate **C.** sugar
    B. nitrogenous base **D.** glycerol
11. The calcium atom shown here has 20 protons. How many electrons does it have?



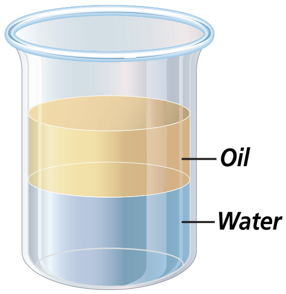
    A. 10 **C.** 40
    B. 20 **D.** 80
12. A(n) ________ bond involves sharing of electrons.
    A. ionic **C.** hydrogen
    B. covalent **D.** molecular
13. The first energy level of an atom holds a maximum of ________ electrons.
    A. 8 **C.** 16
    B. 2 **D.** 32

Constructed Response

14. **Open Ended** Explain how substrates and enzymes fit together.
15. **Open Ended** Discuss how the structure of a water molecule affects its properties.
16. **Open Ended** Explain why an increase in temperature would increase the rate of diffusion of substances into or out of cells.

Thinking Critically

17. **Interpret Scientific Illustrations** Is the liquid in the beaker classified as a solution? Explain your answer.



18. **REAL WORLD BIOCHALLENGE** Many genetic disorders are caused by proteins that are made incorrectly in the body. Visit **ca.bdol.glencoe.com** to investigate the protein error in hemoglobin that causes sickle cell anemia. How does the error in the hemoglobin affect the capacity of red blood cells to deliver oxygen to the tissues? Communicate your conclusions to the class.

Chapter 6 Assessment

California Standards Practice

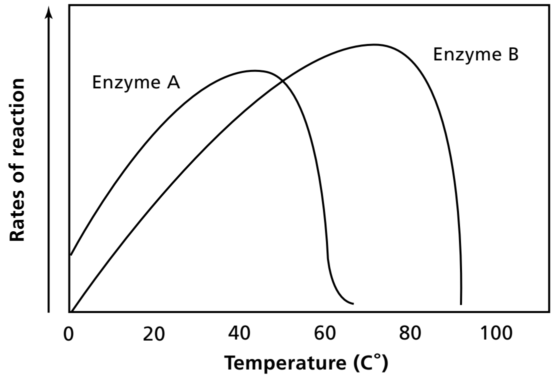
The assessed California standard appears next to the question.

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Two students were studying the effect of temperature on two naturally occurring enzymes. Study the graph of their data to answer questions 19–21.

Effects of Temperature on Two Naturally Occuring Enzymes



19. At what temperature does the maximum
1b activity of enzyme B occur?
- **A.** 0°
- **B.** 35°
- **C.** 60°
- **D.** 75°

20. At what temperature do both enzymes have
1b an equal rate of reaction?
- **A.** 10°
- **B.** 20°
- **C.** 50°
- **D.** 60°

21. Which description best explains the patterns
1b of temperature effects shown?
- **A.** Each enzyme has its own optimal temperature range.
- **B.** Both enzymes have the same optimal temperature ranges.
- **C.** Each enzyme will function at room temperature.
- **D.** Both enzymes are inactivated by freezing temperatures.

Use the table to answer questions 22 and 23.

Element	Number of Protons	Number of Neutrons
A	6	6
B	7	7
C	20	40
D	20	41

22. Which element listed above would have four electrons in its outer energy level?
- **A.** A
- **B.** B
- **C.** C
- **D.** D

23. Which two items listed above are isotopes of the same element?
- **A.** A and B
- **B.** C and D
- **C.** B and C
- **D.** A and D

Part 2 Constructed Response/Grid In

The graph at the right compares the abundance of four elements in living things to their abundance in Earth's crust, oceans, and atmosphere. Use it to answer questions 24 and 25. Record your answers on your answer document.

24. Open Ended Compare the general composition of living things to nonliving matter near Earth's surface.

25. Open Ended Explain why carbon is the most critical element to living things even though it is not the most abundant.

Abundance of Four Elements