UNIT 1

Introduction

Researcher with Nassau grouper

Giant panda cub with caretaker at Wolong Nature Reserve in China

Ecological survey of mountain eucalyptus

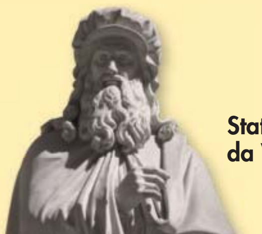
UNIT 1

DISCOVERIES IN SCIENCE

Milestones in Biology

1489

Leonardo da Vinci applies architectural techniques to anatomical drawing. His detailed drawings of the human skull revolutionize scientific illustration.



Statue of Leonardo da Vinci in Italy

1811

At 12 years old, Mary Anning, a British fossil collector, discovers the first complete fossil skeleton of an ichthyosaur. Other scientists use her discoveries to support the theory that fossils are evidence of extinct species.

1898

Marie Curie, a scientist born in Poland, demonstrates that isotopes of certain elements, such as radium and polonium, are the source of radioactive energy in radioactive rocks.

Marie Curie in her laboratory

1910

Alex Carrel publishes a paper reporting his success in using cold storage to preserve blood vessels for long periods of time before transplanting them. His work, related to developing organ-transplant processes, earns him the Nobel Prize in physiology or medicine in 1912.

1918–1919

An influenza epidemic kills between 20 million and 40 million people worldwide. In less than a year, about 675,000 Americans die of the disease, 10 times the number of Americans who died in World War I.

1927

George Washington Carver, American inventor and botanist, patents a process for making paints from soybean extracts.

George Washington Carver

1971

Louis Leaky sponsors Biruté Mary Galdikas to study the orangutans of Borneo. In 1975, Galdikas begins publishing articles about her observations of orangutan behavior. Many articles and lectures follow. Her work helps educate the public about the need to preserve wild habitats.

1996

David Ho is recognized as *Time* magazine's Man of the Year for his pioneering work developing "cocktails" of medicines that fight HIV.

David Ho

Mason wasp with prey

BIOLOGY CAREER

UNIT 1

Forensic Scientist

Wayne Moorehead

Wayne Moorehead is a forensic scientist. Forensic scientists use scientific processes to investigate legal matters. Moorehead works with the Trace Evidence and Fire Division of the Orange County Sheriff–Coroner Crime Laboratory in California. He specializes in forensic microscopy, trace evidence, and the analysis of explosives, fire debris, and unusual evidence. Moorehead enjoys his work, especially using critical thinking to answer questions about crimes.

Moorehead traces his interest in forensic science back to his childhood, when he enjoyed using a chemistry set and microscope and reading forensic science books. He still collects books in his field.

Moorehead enjoys using forensic science in criminal investigations but considers his greatest accomplishment to be teaching forensic science to high school students, college students, professors, and the public.

Yellow crinoid and reef fish on a coral reef

Chapter Planner 3

Chemistry of Life

	Time	Standards	Teach Key Ideas
CHAPTER OPENER, pp. 48–49	15 min.	*National Science Education Standards*	
SECTION 1 Matter and Substances, pp. 51–54 › Atoms › Chemical Bonds › Polarity	45 min.	LSInter 1, UCP2, PS1, PS2, PS3	**Bellringer Transparency** **Visual Concepts** Matter • Atom • Element Compound • Covalent Bonding • Molecule Hydrogen Bonding • Ionic Bonding • Ion • Comparing Polar and Nonpolar Bonds
SECTION 2 Water and Solutions, pp. 55–57 › Properties of Water › Solutions	45 min.	LSCell 2, LSCell 4, LSInter 1, LSMat 4, UCP5	**Bellringer Transparency** **Visual Concepts** Comparing Cohesion and Adhesion • Solutes, Solvents, and Solutions • Acids • Bases pH
SECTION 3 Carbon Compounds, pp. 59–63 › Building Blocks of Cells › Carbohydrates › Lipids › Proteins › Nucleic Acids	45 min.	LSCell 1, LSCell 2, LSCell 3, LSCell 4, LSGene 1, LSInter 1, UCP1, UCP2, UCP5, PS1, PS2, PS3, HNS1, HNS2, HNS3	**Bellringer Transparency** **Transparencies** A27 Saturated and Unsaturated Fatty Acids • A28 Structure of Nucleic Acids **Visual Concepts** Carbohydrates • Monosaccharides • Disaccharides • Types of Lipids • Fats, Fatty Acids • Proteins • Amino Acid • Nucleic Acid • Nucleotide DNA Overview • Ribonucleic Acid (RNA) • Comparing ADP and ATP
SECTION 4 Energy and Metabolism, pp. 64–69 › Changing Matter › Chemical Reactions › Biological Reactions	90 min.	LSCell 2, LSCell 4, LSMat 3, LSMat 4, LSMat 6, UCP3, UCP5, PS2, PS3, PS4, PS5, PS6	**Bellringer Transparency** **Transparencies** A16 Energy and Chemical Reactions • A17 Activation Energy With and Without Enzymes A25 Enzyme Activity **Visual Concepts** Biology • Energy • Activation Energy and Chemical Reactions • Enzyme • Factors Affecting Reaction Rates

See also PowerPoint® Resources

Chapter Review and Assessment Resources

- **SE** Super Summary, p. 70
- **SE** Chapter Review, p. 71
- **SE** Standardized Test Prep, p. 73
- Review Resources
- Chapter Tests A and B
- go.hrw.com Holt Online Assessment

CHAPTER **Fast Track**

This chapter contains necessary prerequisite content for the study of cells. The Quick Labs in Sections 1, 2, and 3 can be eliminated.

Basic Learners

- **TE** Electron Sharing Model, p. 52
- **TE** Ionic Bonding by the Numbers, p. 53
- **TE** Relating Diagrams, p. 56
- **TE** Comparing Carbon Compounds, p. 62
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- **TE** Artifical Sweeteners, p. 60
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key
SE Student Edition
TE Teacher's Edition
Chapter Resource File
Workbook
Transparency
CD or CD-ROM
* Datasheet or blackline master available
■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Yeast Activity, p. 49*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 48 SE **Reading Toolbox,** p. 50	
	SE **Quick Lab** Atom Models, p. 53*■	TE **Reading Toolbox** Visual Literacy, p. 52 SE **Reading Toolbox** Comparison Table, p. 52 TE **Reading Toolbox** Comparison Table, p. 52 TE **Reading Toolbox** Visual Literacy, p. 54	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Demonstration** Oil and Water, p. 55 TE **Demonstration** Acids and Bases, p. 56 SE **Water Wonders,** p. 58	SE **Quick Lab** Telltale Cabbage, p. 57*■	TE **Reading Toolbox** Everyday Words in Science, p. 56 SE **Reading Toolbox** Everyday Words in Science, p. 57	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Demonstration** Carbon, p. 59 TE **Demonstration** Oil and Water Don't Mix, p. 59	SE **Quick Lab** Brown Paper Test, p. 61*■ **Exploration Lab** Identifying Food Nutrients*	TE **Reading Toolbox** Everyday Words in Science, p. 60 SE **Reading Toolbox** Quantifiers, p. 62 TE **Reading Toolbox** Quantifiers, p. 62 TE **Reading Toolbox** Visual Literacy, p. 62	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Carbonic Acid,** p. 65 TE **Onions and Enzymes,** p. 66 TE **Demonstration** Pineapple Enzymes, p. 67	SE **Inquiry Lab** Enzymes in Detergents, p. 68*■ **Skills Practice Lab** Observing the Effect of Temperature on Enzyme Activity*	TE **Reading Toolbox** Visual Literacy, p. 18	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■

See also Lab Generator

See also Holt Online Assessment Resources

Resources for Differentiated Instruction

English Learners
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*■
- Note-taking Workbook*
- Multilingual Glossary

Struggling Readers
- TE Electron Sharing Model, p. 52
- TE Ionic Bonding by the Numbers, p. 53
- TE Reading Symbols, p. 56
- TE Summarizing, p. 61
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*

Special Education Students
- TE Reaction Conditions, p. 65
- TE Text Text
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Alternative Assessment
- Science Skills Worksheets*
- Section Quizzes*■
- Chapter Tests A, B, and C*■

Chapter 3

Overview

This chapter introduces the basic chemistry students need to understand biochemical systems. Much of the body is composed of organic compounds, and students learn the fundamentals of chemical bonding and the characteristics of the important classes of biomolecules (proteins, lipids, carbohydrates, and nucleic acids). These compounds are involved in many metabolic reactions that help organisms maintain homeostasis.

READING TOOLBOX

Assessing Prior Knowledge Students should understand the following concepts:
- states of matter
- characteristics of solutions
- forms of energy

Visual Literacy Ask students what is required to produce heat from the fire. (wood) Ask students to name the type of reaction that occurs when wood burns. (combustion) Tell students that this combustion reaction requires oxygen from the air. Ask them to predict the most likely products of the reaction. (carbon dioxide and water) Ask students what fuel enables humans to generate heat. (food) Ask what gas we inhale that our bodies need. (oxygen) What gas is released when we exhale? (carbon dioxide)

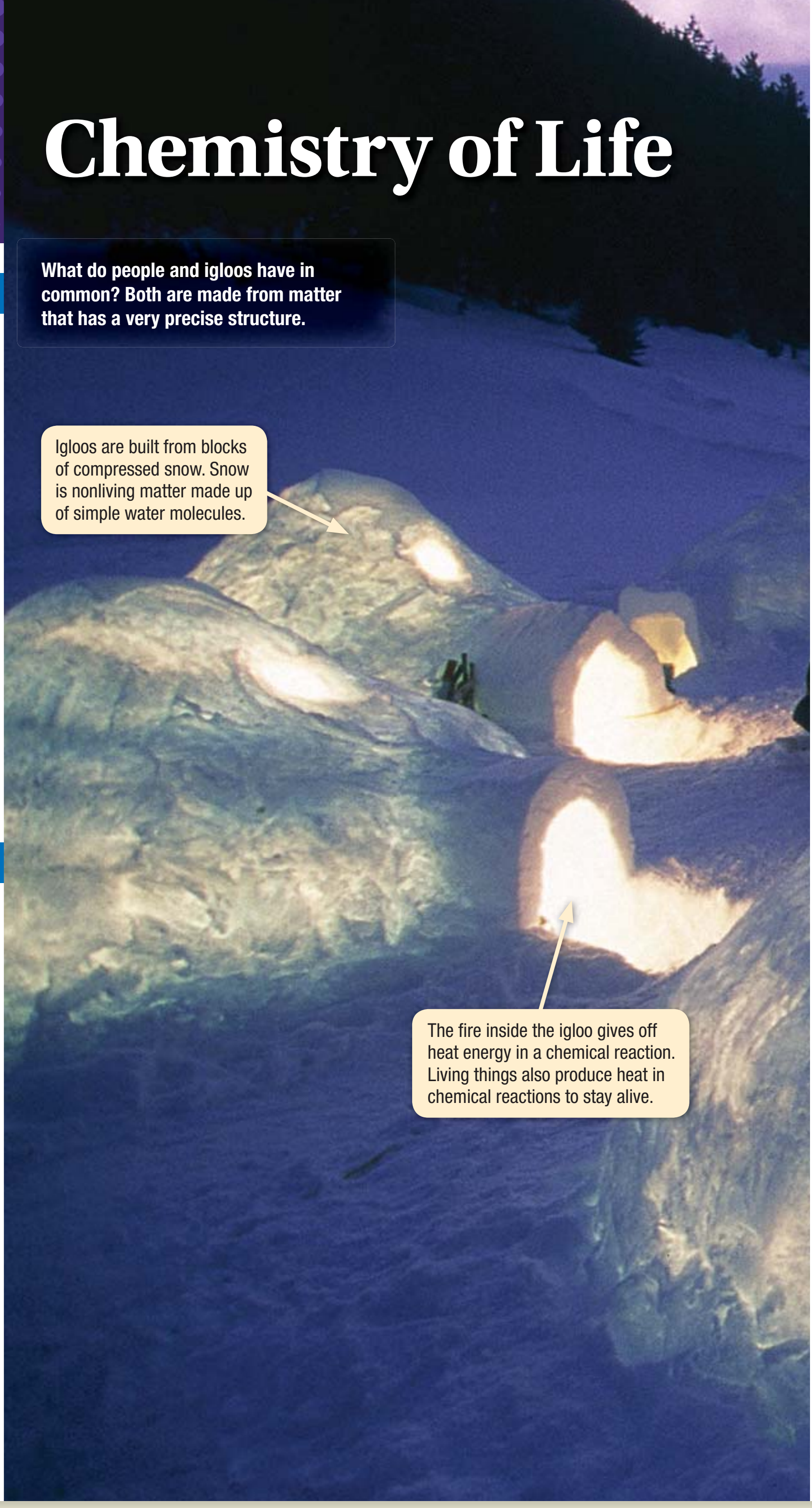
Chapter 3 Chemistry of Life

Preview

Why It Matters

The chemicals that make up living things are more complex than those in nonliving things. Learning the chemical basis of biology can help you understand how processes occur and how living things respond to their environment.

What do people and igloos have in common? Both are made from matter that has a very precise structure.



Chapter Correlations *National Science Education Standards*

LSCell 1 Cells have particular structures that underlie their functions.

LSCell 2 Most cell functions involve chemical reaction.

LSCell 3 Cells store and use information to guide their functions.

LSCell 4 Cell functions are regulated.

LSGene 1 In all organisms, the instructions for specifying the characteristics of the organisms are carried in DNA.

LSInter 1 The atoms and molecules on earth cycle among the living and nonliving components of the biosphere.

LSMat 3 The chemical bonds of food molecules contain energy.

LSMat 4 The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism.

LSMat 6 As matter and energy flows through different levels of organization of living systems-cells, organs, communities-and between living systems and the physical environment, chemical elements are recombined in different ways.

UCP1 Systems, order, and organization

UCP2 Evidence, models, and explanation

UCP3 Change, constancy, and measurement

UCP5 Form and function

PS1 Structure of atoms

PS2 Structure and properties of matter

PS3 Chemical reactions

PS4 Motions and forces

InquiryLab

15 min

Yeast Activity

Yeast are microscopic fungi that chemically break down sugar to obtain the energy needed for life processes.

Procedure

1. Fill **two small beakers** one-third full with **warm water.** Add a half **packet of sugar** to each beaker.
2. Add **1 tsp of fresh yeast grains** to one beaker. Add **1 tsp of deactivated yeast grains** to the other.
3. Swirl and set aside both mixtures.

Analysis

1. **Compare** the appearance of the two mixtures after several minutes.
2. **Describe** any evidence of a reaction that you observed.
3. **Propose** why was sugar added to this mixture.
4. **Explain** why baking bread that has been prepared from yeast-containing dough rises.

InquiryLab

Teacher's Notes Make sure that you use fresh baker's yeast for a vigorous, gas-generating reaction. Warm water will also accelerate the reaction, producing a visible froth within minutes. Deactivated yeast is dead yeast. Mix the materials in a small beverage container, then slip a balloon over the opening of the container. The carbon dioxide that is produced will inflate the balloon.

Materials

- beakers, 100 mL (2)
- packets of sugar
- fresh baker's yeast
- deactivated yeast grains

Answers to Analysis

1. The mixture with the fresh yeast took on a frothy appearance. The other mixture did not appear to change.
2. Bubbles were evidence that a gas-producing reaction was occurring.
3. Sugar was one of the reactants in this chemical reaction. It was broken down into products that included carbon dioxide gas.
4. The yeast in the dough created tiny bubbles of carbon dioxide. As the yeast converts more starch to CO_2 and sugar, larger pockets of CO_2 are formed causing the dough to rise.

PS5 Conservation of energy and increase in disorder
PS6 Interactions of energy and matter
HNS1 Science as a human endeavor
HNS2 Nature of scientific knowledge
HNS3 Historical perspectives

READING TOOLBOX

Using Words

1. Answers will vary. Have the students return to complete the last column of the table after they have completed the lesson.

Word	Everyday meaning	Scientific meaning
compound	something consisting of several parts	a substance made from two or more different elements
solution	mixture with water; answer to a problem	a homogeneous mixture with a solute and solvent
energy	enthusiasm, excitement	the capacity to do work

Using Language

1. April, March, February, January
2. younger

Using Graphic Organizers

See table below.

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Everyday Words in Science Many words that we use every day have special meanings in science. For example, *matter* in everyday use is "an issue or problem." In science, matter means "anything that has mass and takes up space."

Everyday Words in Science

Word	Everyday meaning	Scientific meaning
compound		
solution		
energy		

Your Turn Make a table like the one shown here.

1. Before you read, write in your own words the everyday meaning of the terms in the table.
2. As you read, fill in the scientific meaning for the terms in the table.

Using Language

Quantifiers Quantifiers are words that describe how much, how large, and how often. Quantifiers can also describe the order in which things occur. Words that describe an order include *first, second, third, fourth, primary, secondary, tertiary,* and *quaternary.*

Your Turn Use what you have learned about quantifiers to answer the following questions.

1. Place the following months in order of fourth, third, second, and first: January, March, April, February.
2. Would a student attending primary school be younger or older than a student attending secondary school?

Taking Notes

Comparison Table A comparison table is useful for comparing characteristics of topics in science. All topics in a table are described in terms of the same characteristics. This approach helps you compare several topics at one time.

Your Turn Make a comparison table to compare carbohydrates and lipids.

1. Draw a table like the one shown here.
2. In the top row, write the topics *Carbohydrates* and *Lipids.*
3. In the left column, write the general characteristics *Structure, Function,* and *Energy Content.* As you read the chapter, fill in the characteristics for each topic in the appropriate cells.

	Carbohydrates	*Lipids*
Structure		
Function		
Energy Content		

	Carbohydrates	Lipids
Structure	• contain carbon, hydrogen, and oxygen	• contain carbon, hydrogen, and oxygen
Function	• source of energy • structural support • cellular ID • breaks down quickly during metabolism, limited storage capacity	• source of energy and energy storage • controls movement of water
Energy Content	• less energy per gram than lipids	• stores more energy per gram than carbohydrates

Section 1 Matter and Substances

Key Ideas	Key Terms	Why It Matters
❯ What makes up matter? ❯ Why do atoms form bonds? ❯ What are some important interactions between substances in living things?	atom element valence electron compound molecule ion	All living things are made of matter, so understanding the structure and behavior of matter can help you understand how your body works.

Every living and nonliving thing is made of matter. Matter is anything that has mass and takes up space. To understand how living things work and interact, you must first understand the structure of matter.

Atoms

What does all matter have in common? It is made of very small particles called atoms. An **atom** is the smallest unit of matter that cannot be broken down by chemical means. ❯ **All matter is made up of atoms. An atom has a positively charged core surrounded by a negatively charged region.**

Atomic Structure Atoms are made of three types of particles. *Protons* have a positive charge, *electrons* have a negative charge, and *neutrons* have no charge. Atoms have no overall charge because each atom has as many electrons as protons. Protons and neutrons have about the same mass and make up the core, or nucleus, of an atom. Electrons have very little mass and move around the nucleus in a region called the *electron cloud*, which is much larger than the nucleus.

Elements An **element** is a substance made up of atoms that have the same number of protons. For example, each atom of the element carbon has six protons, as **Figure 1** shows. Atoms of an element may have different numbers of neutrons. These atoms are called *isotopes* of elements.

❯ **Reading Check** *What is a proton? (See the Appendix for answers to Reading Checks.)*

atom the smallest unit of an element that maintains the chemical properties of that element

element a substance that cannot be separated or broken down into simpler substances by chemical means

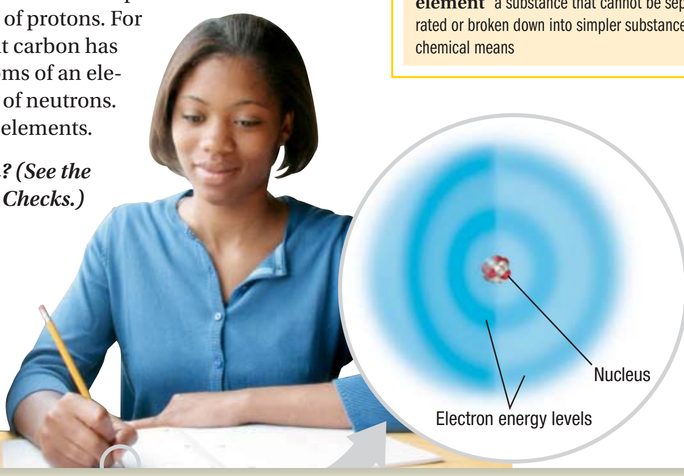


Figure 1 The graphite in pencil lead is made of atoms of the element carbon. ❯ If an uncharged carbon atom (inset) has six protons in its nucleus, how many electrons does it have?

Section 1

❯ Focus

This section introduces students to atoms, the fundamental units of matter. Students learn that atoms can bond to form compounds.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Teaching Key Ideas

Atomic Particles Students will know about protons, electrons, and neutrons from previous science classes. Show students a periodic table, which includes all of the elements. Tell them that an element's identity is based on its atomic number, which is the number of protons in an atom of that element. If the number of protons in an atom were to change, then the atom would become a different element. The chemical reactions covered in this chapter involve electrons. A change in the number of electrons does not change an atom's identity.

Answers to Caption Questions

Figure 1: six electrons

Key Resources

Visual Concepts

- Matter
- Atom
- Element
- Compound
- Covalent Bonding
- Molecule
- Hydrogen Bonding
- Ionic Bonding
- Ion
- Comparing Polar and Nonpolar Bonds

Teach, continued

READING TOOLBOX

Visual Literacy Have students look at the models in **Figure 2.** Tell them that atoms, molecules, and compounds are represented in different ways. Each representation best conveys an idea. Ask what each model shows and how they differ. (The electron cloud model shows an interior view of water. The space-filling model shows an exterior view, which emphasizes the 3-dimensional geometry of water.) Students will see other representations in **Figures 9** and **10.** LS **Visual**

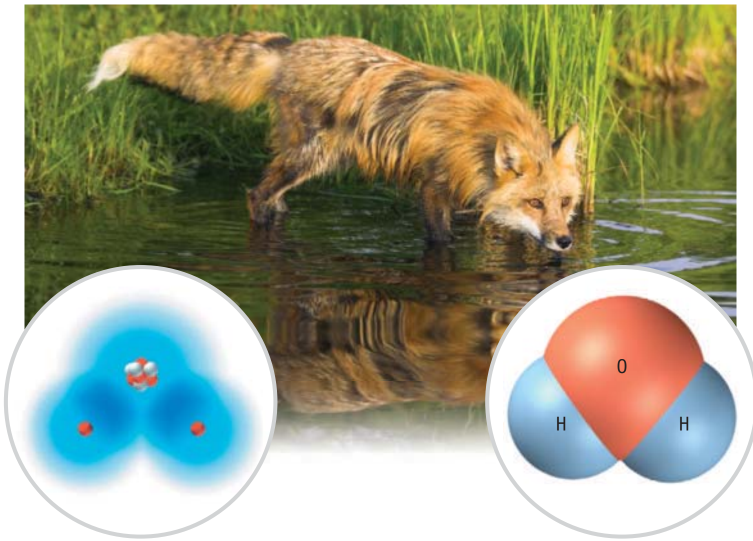
READING TOOLBOX

Comparison Table The answer is shown in a linear way, to fit in the margin.

Covalent Bonding
Electron pairs are shared.
Molecules are produced.
Bond is the attraction for shared electrons.

Ionic Bonding
Elections are transferred.
Ions are produced.
Bond is the attraction between ions of opposite charge. LS **Verbal**

Figure 2 A water molecule consists of an oxygen atom covalently bonded to two hydrogen atoms. The electron cloud model (left) shows the interaction between the atoms of the molecule. The space-filling model (right) shows the three-dimensional structure of a molecule.



Electron cloud model

Space-filling model

READING TOOLBOX

Comparison Table Make a comparison table that compares covalent bonding and ionic bonding.

Chemical Bonds

The electron cloud of an atom may have levels. The innermost level can hold only two electrons. Levels farther from the nucleus can usually hold eight electrons. Electrons in the outermost level, or shell, are called **valence electrons.** Atoms tend to combine with each other such that eight electrons will be in the valence shell.

When atoms combine, a force called a *chemical bond* holds them together. **Chemical bonds form between groups of atoms because most atoms become stable when they have eight electrons in the valence shell.** However, the smallest atoms, such as hydrogen, are stable when they have only two valence electrons. When atoms of different elements bond, a compound forms. A **compound** is a substance made of the bonded atoms of two or more different elements.

Covalent Bonding One way that atoms bond is by sharing valence electrons to form a *covalent bond.* A **molecule** is a group of atoms held together by covalent bonds. Not all substances that have covalent bonds are compounds. The oxygen in the air you breathe consists of molecules made of two oxygen atoms sharing electrons in a covalent bond. To represent an oxygen molecule, write "O_2," not "O." A carbon dioxide molecule has two oxygen atoms bonded to a single carbon atom, so its formula is CO_2.

Water: A Covalent Compound As **Figure 2** shows, a water molecule, H_2O, forms when an oxygen atom combines with two hydrogen atoms. The atoms form chemical bonds by sharing electrons in a way that gives oxygen eight valence electrons, making it stable. The hydrogen atoms become stable because sharing gives each two valence electrons.

Reading Check *What is a chemical bond?*

valence electron an electron that is found in the outermost shell of an atom and that determines the atom's chemical properties

compound a substance made up of atoms of two or more different elements joined by chemical bonds

molecule a group of atoms that are held together by chemical forces

ion an atom, radical, or molecule that has gained or lost one or more electrons and has a negative or positive charge

Differentiated Instruction

Basic Learners/Struggling Readers

Electron Sharing Model The concepts of valence electrons and electron sharing are easier to understand if you use Lewis Dot structures to illustrate valence electrons. Draw the Lewis structure for an oxygen atom and two hydrogen atoms. Describe how a hydrogen atom needs one electron to have a filled energy level and how an oxygen atom needs two electrons to fill its outer energy level. Covalent bonds in water satisfies this condition.

H• H• :Ö: LS **Visual**

Hands-On

QuickLab

15 min

Atom Models

Scientists use models to represent their understanding of things that they cannot directly observe.

Procedure

1. Using **assorted materials** provided by your teacher, work in groups to make model atoms for hydrogen, carbon, oxygen, sodium, and chlorine.
2. Model the covalent bonds in a water molecule.
3. Model an ionic bond in sodium chloride.

Analysis

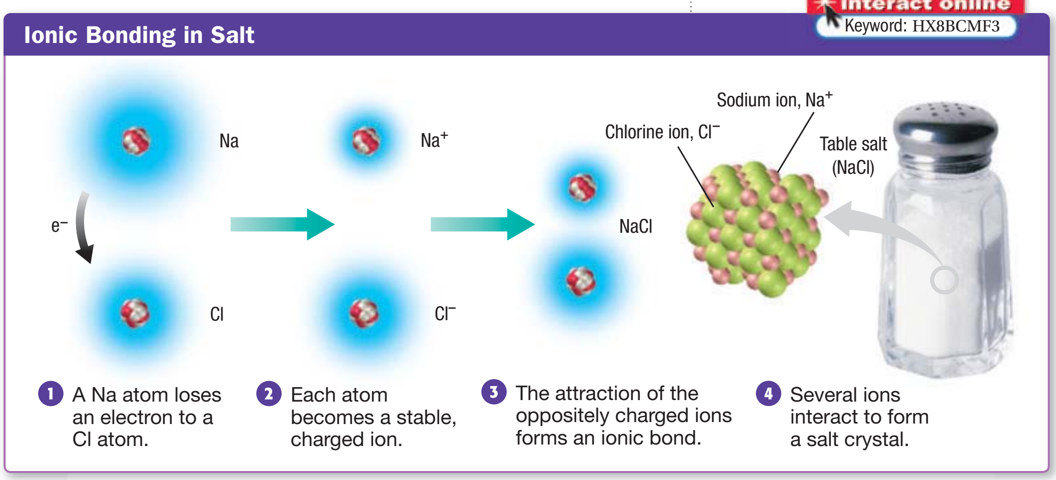
1. **Model** the covalent bonds in a carbon dioxide molecule, CO_2. How many electrons are shared?
2. CRITICAL THINKING **Critiquing Models** Exchange models with another group. What is accurate and useful about those models? What could be improved? Write down your comments for the other group.

Ionic Bonding Atoms can achieve a stable valence level in another way—by losing or gaining electrons. This results in a positive or negative charge. An **ion** is an atom or group of atoms that has an electric charge because it has gained or lost electrons. The attractive force between oppositely charged ions is an *ionic bond.*

Table Salt: An Ionic Compound One familiar example of an ionic compound is table salt, NaCl, shown in **Figure 3.** A sodium atom has one valence electron, while a chlorine atom has seven. (1) Sodium readily gives up its electron, while chlorine readily accepts an electron. (2) The sodium atom is now a sodium ion, Na^+. The chlorine atom is now a chloride ion, Cl^-. (3) The positively charged sodium ion and negatively charged chloride ion attract each other and form sodium chloride, NaCl. (4) The attractive forces between several sodium ions and chloride ions form a crystal of table salt.

Figure 3 Salt crystals in sodium chloride, NaCl, are formed by the interaction between sodium ions, Na^+, and chloride ions, Cl^-. **How many electrons are in the valence shell of a chloride ion?**

go.hrw.com
interact online
Keyword: HX8BCMF3



QuickLab

Teacher's Notes You'll want to review the electron structures for hydrogen, carbon, oxygen, sodium, and chlorine before students begin the lab. To avoid frustration, tell students about electron sharing in double bonds (for carbon dioxide). Using Lewis Dot structures is suggested.

Materials

- gum drops, toothpicks, colored marshmallows, raisins, cotton candy, paper plates, pipe cleaners

Answers to Analysis

1. In carbon dioxide, a carbon atom shares two electrons with an oxygen atom. Carbon also shares its other two valence electrons with the other oxygen atom. Eight electrons are shared (four electrons from carbon and two from each oxygen atom).
2. When critiquing other models, students should note that protons and neutrons should be approximately the same size and that electrons are smaller. Protons and neutrons should be packed together tightly, while electrons surround this nucleus.

Answers to Caption Questions

Figure 3: eight

go.hrw.com
interact online

Students can interact online with "Ionic Bonding in Salt" by going to go.hrw.com and typing in the keyword HX8BCMF3.

Differentiated Instruction

Basic Learners/Struggling Readers

Ionic Bonding by the Numbers Use Lewis Dot models to represent the process shown in **Figure 3.** Show students mathematically how atoms take on a charge. Sodium atoms have 11 protons and 11 electrons. The loss of an electron means that the particle now has 11 protons, 10 electrons, and a resulting positive charge results. Ask students to tell you why the chloride ion has a negative charge. (It has 17 protons and 18 electrons.) LS Logical/Visual

MISCONCEPTION ALERT

Atomic Size Students often do not realize that atoms consist mostly of empty space. If the nucleus of an atom were the size of a typical marble, the first electron level would be about 0.8 km (0.5 miles) away from the nucleus. LS Visual

READING TOOLBOX

Visual Literacy Have students look at **Figure 4.** Emphasize that the water molecule has a partially positive pole and partial negative pole (at oxygen). When ionic solids dissolve in water the hydrogen ends of water molecules surround negative ions. The oxygen side of the water molecules surround positive ions. Draw these examples on the board. **LS Visual**

Close

Formative Assessment

Which of the following is *not* considered a reason for why atoms form bonds?

A. to turn into other atoms (Correct! Atoms don't become other atoms when forming bonds.)

B. to make stable compounds (Incorrect. Atoms do bond to become more stable.)

C. to gain electrons (Incorrect. Some atoms achieve stability in forming bonds by gaining electrons.)

D. to share electrons (Incorrect. Some atoms achieve stability in forming bonds by sharing electrons.)

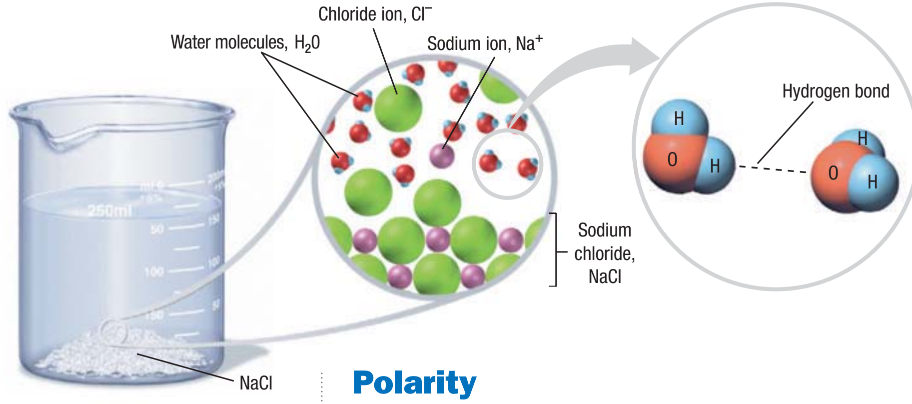


Figure 4 Water dissolves ionic compounds. When sodium chloride, NaCl, is dissolved in water, sodium ions, Na^+, and chloride ions, Cl^-, become surrounded by water molecules, H_2O.

SCILINKS. www.scilinks.org
Topic: Hydrogen Bonding
Code: HX80777

Polarity

In some covalent bonds, the shared electrons are attracted more strongly to one atom than to the other. As a result, one end, or pole, of the molecule has a partial negative charge, while the opposite end has a partial positive charge. Molecules with partial charges on opposite ends are said to be *polar*. The water molecule is polar.

Solubility The partially charged ends of polar molecules attract opposite charges. Because of this behavior, water can dissolve polar molecules, such as sugar, and ionic compounds, such as the salt in **Figure 4.** Nonpolar substances, such as oil, grease, and wax, do not dissolve well in water. Instead, they remain together in clumps or a separate layer. The reason is that water molecules are more attracted to each other than to the nonpolar molecules.

Hydrogen Bonds When bonded to an oxygen, nitrogen, or fluorine atom, a hydrogen atom has a partial charge nearly as great as a proton's charge. It attracts the negative pole of other nearby molecules. This attraction, called a *hydrogen bond*, is stronger than attractions between other molecules, but not as strong as a covalent bond. **Hydrogen bonding plays an important role in many of the molecules that make up living things.** For example, the two strands of a DNA molecule are held together by hydrogen bonds between the bases.

Reading Check ***Why does salt dissolve in water?***

Section 1 Review

KEY IDEAS

1. **Identify** the parts of atoms and their locations.
2. **Name** two ways that atoms can combine to become more stable in compounds.
3. **Explain** how charges cause salt and sugar to dissolve in water.

CRITICAL THINKING

4. **Analyzing Information** Scientists use the isotope carbon-14 in radiocarbon dating. How many protons, neutrons, and electrons are in a carbon-14 atom?
5. **Recognizing Differences** Explain the difference between polar and nonpolar molecules. Give an example of a polar molecule, and describe its structure.

USING SCIENCE GRAPHICS

6. **Periodic Table** Elements on the periodic table are arranged in groups based on how many electrons their atoms have in the valence shell. Using the periodic table in the Appendix, propose why the noble gases in Group 18 rarely form chemical bonds.

Answers to Section Review

1. The positively charged nucleus contains protons and neutrons and is surrounded by a negatively charged cloud that contains electrons.
2. Forming covalent compounds enables atoms to share electrons so that each atom has a full valence level. Forming ionic compounds enables atoms to gain or lose electrons and become ions, which attract each other to form more stable compounds.
3. The partially positive poles of water molecules attract negatively-charged chloride ions and the partially negative poles of water molecules attract positively charged sodium ions. Sugar is a polar compound. Water molecules attract the poles in sugar molecules causing the forces between molecules to be overcome.
4. 6 protons, 8 neutrons, and 6 electrons.
5. Polar molecules have an unequal distribution of charge. Nonpolar molecules have an equal distribution of charge. An example of a polar molecule is water. Shared electrons are attracted to the oxygen nucleus more than the hydrogen nucleus, so the oxygen side of the molecule has a slight negative charge. The region around the two hydrogen nuclei has a slight positive charge.
6. Noble gases have eight electrons in the valence level (except helium, which has 2), so they are already stable.

Section 2

Water and Solutions

Key Ideas	Key Terms	Why It Matters
❯ What makes water a unique substance? ❯ How does the presence of substances dissolved in water affect the properties of water?	cohesion adhesion solution acid base pH buffer	The processes of life take place in water. Without water's unique properties, life as we know it could not exist.

Humans can survive for a few weeks without food but only a few days without water. In fact, all life on Earth depends on this simple substance.

Properties of Water

Water has many unique properties that make it an important substance for life. ❯ **Most of the unique properties of water result because water molecules form hydrogen bonds with each other.**

- **Ice floats.** When water freezes, hydrogen bonds lock water molecules into a crystal structure that has empty spaces. This structure makes water less dense as a solid than as a liquid, so ice floats. Floating ice prevents rivers, lakes, and oceans from freezing solid, so life can exist in the water under the ice.
- **Water absorbs and retains heat.** Hydrogen bonds are constantly breaking and forming between water molecules. Because of this, water can absorb a large amount of heat without changing temperature. It is also why water takes a long time to cool. Large bodies of water can help keep temperatures on Earth from changing too fast. This property of water can also help organisms maintain a constant internal temperature.
- **Water molecules stick to each other.** Hydrogen bonds hold water molecules together in much the same way holding hands keeps a crowd of people together. Thus small drops, such as the dewdrops on the flower in **Figure 5**, are pulled into a ball shape. **Cohesion** is the attraction of particles of the same substance. Water is a liquid at ordinary temperatures because such forces keep it from evaporating easily.
- **Water molecules stick to other polar substances.** Attraction between particles of different substances is called **adhesion.** As **Figure 5** shows, a combination of adhesion and cohesion causes water to move upward through the stem of a plant from the roots to the leaves.

cohesion the force that holds molecules of a single material together

adhesion the attractive force between two bodies of different substances that are in contact with each other

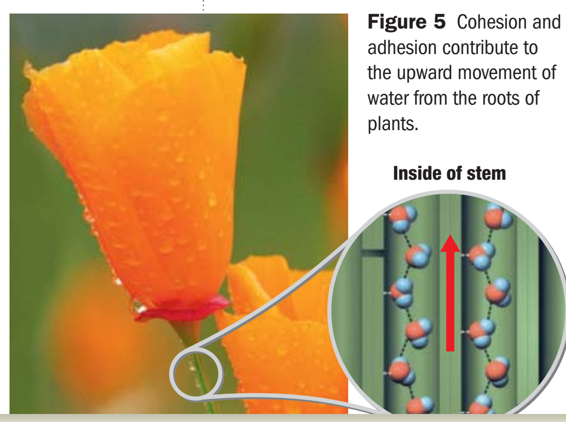


Figure 5 Cohesion and adhesion contribute to the upward movement of water from the roots of plants.

Key Resources

Visual Concepts
- Comparing Cohesion and Adhesion
- Solutes, Solvents, and Solutions
- Acids
- Bases
- pH

Section 2

❯ Focus

This section introduces students to the unique properties of water and why it is an essential compound for the survival of all living things. Students learn about the properties of solutions, the pH scale, and the characteristics of acids and bases.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

Oil and Water Prior to class, coat a sewing needle with petroleum jelly. Ask students to predict whether you can float the needle on the surface of water. The jelly keeps the water molecules from being more attracted to the needle than they are to each other. Using a pair of forceps, carefully lay the needle flat on the surface of the water. Have students observe the floating needle. Then, push the needle slightly beneath the surface of the water. Ask students why the needle floated, and why it sank once the water's surface was disturbed. (At first, the surface tension of the water supported the needle. When the surface tension was broken, the needle sank.) LS **Visual**

Teach, *continued*

Teaching Key Ideas

Water Density Fill a drinking glass with water and add ice cubes. Ask students why the ice floats. (Ice is less dense than liquid water. The molecules align in the solid to form a network structure.) On the board, draw a network arrangement for ice, and the close-packed arrangement of molecules in liquid water. **LS Visual**

READING TOOLBOX

Everyday Words in Science *Basic* commonly refers to something fundamental or primary. Sample answers: My brother is in *basic* training. Many soaps and cleaning products are *basic* materials.

Answers to Caption Questions

Figure 7: An antacid is a basic compound that reacts with acids to form a salt and water.

Demonstration

Acids and Bases Use pH paper or and phenolphthalein solution dilute solutions of vinegar and sodium hydroxide to show the neutralization process. Prepare the vinegar solution using 25 mL vinegar and 25 mL of water. Prepare the sodium hydroxide using 0.4 g NaOH in 100 mL of water. Test each solution, and note the color and pH of each. Add NaOH in 10 mL increments to the vinegar solution. Test the pH after each addition. Use the indicator to show when the solution reaches the neutral point. Then, add another 10 mL of base so students can see the solution is now basic. **LS Visual**

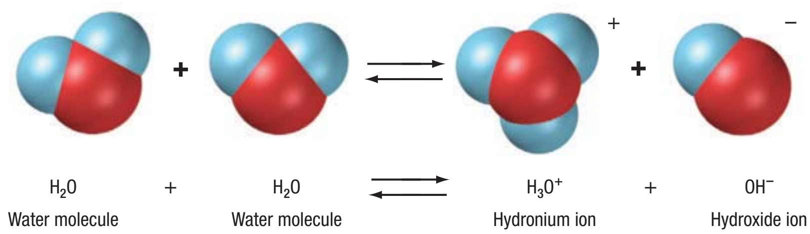


Figure 6 A hydronium ion, H_3O^+, and a hydroxide ion, OH^-, form when a hydrogen ion, H^+, separates from a water molecule and bonds to another. This reaction can also re-form two water molecules from a hydronium ion and a hydroxide ion.

solution a homogeneous mixture throughout which two or more substances are uniformly dispersed

acid any compound that increases the number of hydronium ions when dissolved in water

base any compound that increases the number of hydroxide ions when dissolved in water

pH a value that is used to express the acidity or alkalinity (basicity) of a system

buffer a solution made from a weak acid and its conjugate base that neutralizes small amounts of acids or bases added to it

Solutions

A **solution** is a mixture in which ions or molecules of one or more substances are evenly distributed in another substance. Many substances are transported throughout living things as solutions of water. Dissolved substances can move more easily within and between cells. Water dissolves many ionic and polar substances but does not dissolve nonpolar substances.

Acids and Bases Some water molecules break apart to form ions, as **Figure 6** shows. In pure water, hydronium ions and hydroxide ions are present in equal numbers. **In solutions, some substances change the balance of these ions.** **Acids** are compounds that form extra hydronium ions when dissolved in water. Your stomach uses a solution of hydrochloric acid, HCl, to digest food.

In contrast, **bases** are compounds that form extra hydroxide ions when dissolved in water. Many bases contain hydroxide ions. An example is sodium hydroxide, NaOH, which is used to remove clogs from drains. Other bases react with water molecules. For example, ammonia, NH_3, reacts with a water molecule, H_2O, to form an ammonium ion, NH_4^+, and a hydroxide ion, OH^-.

When acids and bases are mixed, the extra hydronium and hydroxide ions react to form water. Depending on the amounts of extra ions, the solution will be either less acidic, less basic, or neutral.

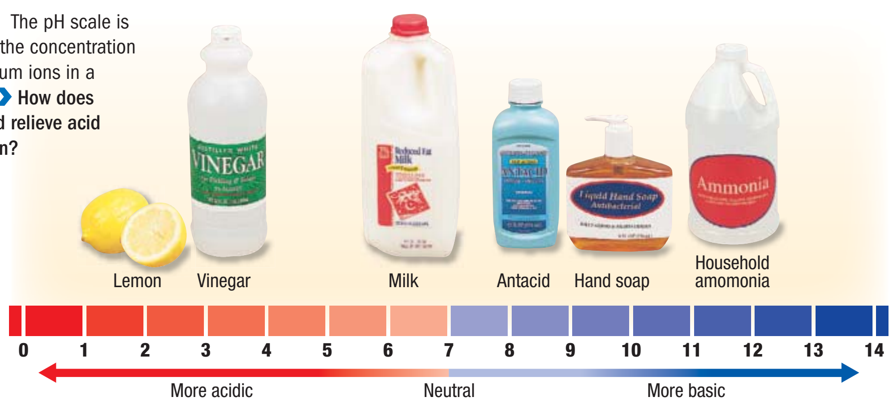


Figure 7 The pH scale is based on the concentration of hydronium ions in a solution. **How does an antacid relieve acid indigestion?**

Differentiated Instruction

Struggling Readers

Reading Symbols Have students look at **Figure 6.** To help students focus on important subtleties ask: What makes a molecule different from an ion? (Ions are charged.) How does water differ from a hydronium ion? (Water has two hydrogen atoms and no charge. The hydronium ion has three hydrogen atoms and a positive charge.) Why are there two water molecules but only one of each of the ions? (Two water molecules are needed to produce one of each ion.) Which ion imparts acidic properties? (H_3O^+ or H^+) **LS Verbal**

Basic Learners

Relating Diagrams Refer students to **Figures 6** and **7,** and ask the following: Which ion in **Figure 6** predominates in the solutions on the left side of **Figure 7?** (H_3O^+) What do the different colors represent on the scale in **Figure 7?** (indicator changes at each pH) What is the mathematical relationship between the numbers on the scale? (As the numbers increase, the H_3O^+ concentration decreases by a factor of 10 times.) **LS Visual**

Hands-On

QuickLab

15 min

Telltale Cabbage

Red cabbage contains a natural indicator that can be used to identify how acidic or basic a solution is.

Procedure

1. Cut up a **cabbage leaf** into very tiny clippings by using **scissors.**
2. Put on **safety goggles.** Place the clippings in a **beaker** of **warm water.** Swirl the mixture. Wait several minutes until the water changes color.
3. Add several drops of **lemon juice.** Note any changes in appearance.
4. Add about **1/4 tsp of baking soda.** Note any changes in appearance. Continue adding small amounts of baking soda, and observe additional color changes.

Analysis

1. **Describe** what happened when the leaf clippings were placed in warm water.
2. **Describe** what happened when lemon juice (an acid) was added to the indicator solution.
3. **Describe** what happened when the baking soda was added to the acidic solution.
4. CRITICAL THINKING **Inferring Relationships** From your observations, what probably happened when the baking soda was added to the acidic solution?

pH and Buffers pH is a measure of how acidic or basic a solution is. The pH scale is shown in **Figure 7.** Each one-point increase in pH represents a 10-fold decrease in hydronium ion concentration. So, the H_3O^+ concentration in a solution of pH 2 is 10 times as great as it is in a solution of pH 3. Pure water has a pH of 7. Acidic solutions have a pH below 7, and basic solutions have a pH above 7.

The pH of the solutions in living things must be stable. The pH of human blood is about 7.4. If the pH goes down to 7.0 or up to 7.8, an individual will die within minutes. For a stable pH to be maintained, the solutions in living things contain buffers. A **buffer** is a substance that reacts to prevent pH changes in a solution. An important buffer in living things is the bicarbonate ion, HCO_3^-.

READING TOOLBOX

Everyday Words in Science Write a sentence that uses the everyday meaning of the word *basic.* Then, write a sentence that uses the scientific meaning of the word *basic.*

Section 2 Review

KEY IDEAS

1. **Identify** four unique properties of water that make life on Earth possible.
2. **Differentiate** between acids and bases.
3. **Explain** the role of buffers in maintaining homeostasis.

CRITICAL THINKING

4. **Recognizing Relationships** Cells contain mostly water. If cells contained mostly oil, how would an organism's ability to maintain homeostasis be affected?
5. **Applying Information** The active ingredient in aspirin is acetylsalicylic acid. Why would doctors recommend buffered aspirin, especially for people with a sensitive stomach?

MATH SKILLS

6. **Exponents** The pH of solution A is 2. The pH of solution B is 4. Which solution has the greater concentration of hydronium ions? The concentration of that solution is how many times the concentration of the other solution?

Answers to Section Review

1. Water's density enables life to exist under a layer of ice in freezing temperatures because ice floats. Water's capacity to absorb and retain heat helps moderate temperatures near large bodies of water. Water's cohesive properties reduce its evaporation rate. Water's adhesion properties enable it to overcome the force of gravity and travel upward (helpful to plants).
2. Compounds that increase the concentration of hydronium ions in a solution are acids. Compounds that reduce the concentration of hydronium ions in a solution are bases.
3. Living things must maintain a stable pH. A buffer reacts with acids and bases to help keep pH stable in living things.
4. An organism's internal temperature would likely change more abruptly and drastically in response to environmental temperature changes.
5. The buffer reduces the acidity of the aspirin, which makes aspirin less irritating to the stomach.
6. Each consecutive value on the pH scale represents a factor of 10. The lower the pH, the more acidic, and therefore the higher the concentration of hydronium ions. Therefore the concentration of hydronium ions in solution A is 100 times the concentration of the hydronium ions in solution B.

QuickLab

Teacher's Notes To speed up the extraction, use smaller clippings and hotter water. Remove the clippings and allow the solution to cool before giving it to students. Remind students to never eat in the laboratory.

Materials

- baking soda
- beaker, 250 mL
- cabbage leaves
- lemon juice
- scissors
- water

Answers to Analysis

1. The purple substance was released into the warm water.
2. The color of the solution changed from purple to pink.
3. The color changed back to purple, then to blue-green.
4. The baking soda reacted with the lemon juice caused the indicator to once again change colors.

Close

Formative Assessment

Which of the following examples illustrates cohesion?

A. Water molecules adhere to the polar molecules of another substance. (Incorrect. This is an example of adhesion.)
B. Water freezes and the ice floats on water. (Incorrect. Floating is related to density.)
C. Water takes a longer time to heat and cool compared to the air above it. (Incorrect. Heat retention relates to specific gravity.)
D. Water drops on the surface of a car pull together into a ball shape. (Correct!)

Why It Matters

Teacher's Notes Ask students to identify the which property of water that allows the water strider to walk on the surface of the water. (Cohesion creates surface tension.)

Students may have heard the phrase "It's only the tip of the iceberg." Tell them that only about 10% of an iceberg is visible above water.

Students can model an iceberg by putting a piece of ice in water and measuring the volume of ice above and below the water line. Have them experiment with different sizes and shapes of ice to see the if percentage stays roughly the same.

Answers to Research

Sea ice is frozen ocean water found in the Arctic and Antarctic polar oceans. Fast ice is sea ice formed along coasts. Pack ice is freely floating sea ice. Ice floes are floating chunks of sea ice that measure more than 10 km in length.

Why It Matters

Water Wonders

A water spider can live underwater by capturing air bubbles at the surface. Most of the life cycle of this "bubble breather" occurs below the water surface. All organisms depend on water. Water has many unique properties that make life on Earth possible.

Bergy Bits

An iceberg is a floating mass of freshwater ice that has broken off from a glacier or an ice sheet. Icebergs vary greatly in size. Very large tabular icebergs are known as *ice islands*. Icebergs that are about the size of a small house are called *bergy bits*. Because freshwater ice is slightly less dense than sea water, only a small portion of an iceberg projects above water.

Ice Hotel Winter travelers to Canada, Alaska, China, and Sweden can spend the night at a hotel that is entirely chiseled from chunks of ice and snow!

Walking on Water This water strider can run across the surface of water! Its feet are covered with fine, water-repellent hairs that enable the insect to "skate" over the surface film of water.

Research Find out the difference between icebergs and four other types of ocean ice: sea ice, pack ice, ice floes, and fast ice.

Section **3**

Carbon Compounds

Key Ideas	Key Terms	Why It Matters
❯ What are chemicals of life made from? ❯ What is the role of carbohydrates in cells? ❯ What do lipids do? ❯ What determines the functions of proteins? ❯ What do nucleic acids do?	carbohydrate lipid protein amino acid nucleic acid nucleotide DNA RNA ATP	Your body works by using the same four types of molecules that bacteria and plants do.

Suppose that you are building a house. You need wood for framing and metal for nails, screws, and electrical wiring. You also need concrete for the foundation, glass for windows, and drywall siding. This complex structure is made of a few basic materials that must be assembled in a highly organized way. The same is true of the molecules that make up living things.

Building Blocks of Cells

The parts of a cell are made up of large, complex molecules, often called *biomolecules.* ❯ **Large, complex biomolecules are built from a few smaller, simpler, repeating units arranged in an extremely precise way.** These simple units are like the toy blocks in **Figure 8,** which connect to build the large sculpture. Not all of the blocks are exactly the same, but they all connect with other blocks in a few different ways.

Carbon Compounds The basic units of most biomolecules contain atoms of carbon. Carbon atoms have four valence electrons, so they can form covalent bonds with as many as four other atoms. Carbon atoms can bond with each other to form chains or rings. The carbon atoms in these chains and rings can also connect with atoms of other elements to form the basic units of most biomolecules.

❯ **Reading Check** ***What element is the basis of biomolecules?***

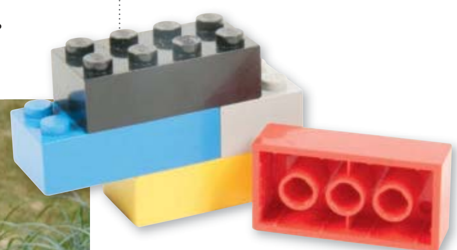


Figure 8 Large, complex structures can be built from a few basic units arranged in a precise way. ❯ **Describe two shapes that you could make from these five blocks.**

Section **3**

❯ Focus

This section introduces students to the kinds of organic compounds that are found in living organisms that are essential for biological processes.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

Carbon Draw the structural formula for methane (CH_4) on the board. Then, draw the structural formula for butane (C_4H_8), so students can see what is meant by the term *carbon chain.* Emphasize that this simple chain can get much longer and branch to form complex structures, such as ATP. **LS Visual**

Answers to Caption Questions

Figure 8: Answers will vary.

Key Resources

Transparencies

A27 Saturated and Unsaturated Fatty Acids

A28 Structure of Nucleic Acids

Visual Concepts

Carbohydrates
Monosaccharides
Disaccharides
Types of Lipids
Fats, Fatty Acids
Proteins
Amino Acid
Nucleic Acid
Nucleotide
DNA Overview
Ribonucleic Acid (RNA)
Comparing ADP and ATP

Teach, *continued*

Teaching Key Ideas

Chemical Representations Point out that biomolecules can be shown in different ways. When students look at **Figure 9,** they should notice that the condensed formula and structural formula are both correct ways to represent glucose. The hexagon shapes in **Figure 10** are still another representation, though not quite as accurate. Ask students how the three models vary and why they are all useful. (Structural formulas show a 2-dimensional representation and the bonding patterns. Condensed formulas show the number of atoms for each element in the compound. Stylized representations provide a simple way to display more complex structures.) **LS Visual**

READING TOOLBOX

Everyday Words in Science Ask students to define *sugar*. Most students will probably refer to the white crystalline substance they use to sweeten foods. Tell them that sugar also the common name for carbohydrates. When they say *sugar,* what do they really mean sucrose, or any one of a number of different compounds such as fructose, glucose, or maltose? **LS Verbal**

Answers to Caption Questions

Figure 10: lactose

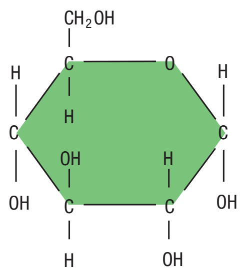


Figure 9 The sugar glucose, $C_6H_{12}O_6$, is made from carbon, hydrogen, and oxygen atoms. Sugars are the building blocks of carbohydrates.

carbohydrate a class of molecules that includes sugars, starches, and fiber; contains carbon, hydrogen, and oxygen

lipid a fat molecule or a molecule that has similar properties, including waxes and steroids

ACADEMIC VOCABULARY

vary to make a minor or partial change in

Carbohydrates

You may have heard about carbohydrates in foods such as grains, fruits, and vegetables. **Carbohydrates** are molecules made of sugars. A sugar contains carbon, hydrogen, and oxygen in a ratio of 1:2:1. **Figure 9** shows the ring structure of glucose, a common sugar found in grape juice. Glucose is a *monosaccharide,* or "single sugar."

Two sugars can be linked to make a *disaccharide.* Examples of disaccharides are sucrose (table sugar) and lactose (found in milk). Many sugars can be linked together to make a *polysaccharide.* Starch consists of hundreds of glucose units bonded together. Glycogen (found in animals) consists of many branched chains of glucose.

Monosaccharides and disaccharides are considered simple carbohydrates. Polysaccharides are considered complex carbohydrates. **Figure 10** shows an example of each carbohydrate. **Cells use carbohydrates for sources of energy, structural materials, and cellular identification.**

Energy Supply Carbohydrates are a major source of energy for many organisms, including humans. Plants store the sun's energy for future use by making glucose and converting it to starch. Organisms release chemical energy for cell activities by breaking down glucose.

Structural Support *Chitin* and *cellulose* are two complex carbohydrates that provide support. The shells of crabs, lobsters, and insects are made of chitin. Chitin is also found in the cell walls of mushrooms and molds. The cell walls of plants are made of cellulose. Bundles of cellulose are stiff enough to hold plants upright.

Cell Recognition Cells may have short, branched chains of varying sugar units on their outer surface. In a complex organism, cells recognize neighboring cells by these carbohydrates. Carbohydrates on the outside of invading cells allow the body to recognize them as not being part of the body so that they can be destroyed.

Reading Check ***What is the basic unit of a carbohydrate?***

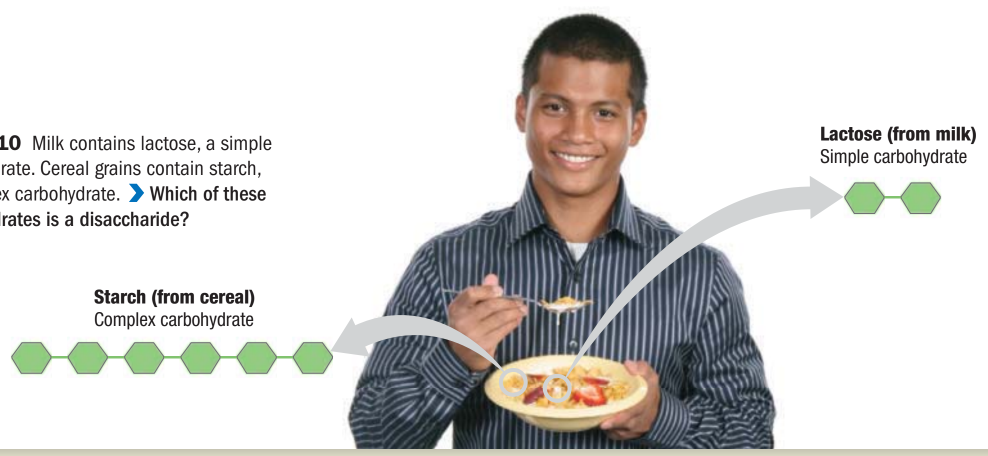


Figure 10 Milk contains lactose, a simple carbohydrate. Cereal grains contain starch, a complex carbohydrate. **Which of these carbohydrates is a disaccharide?**

MISCONCEPTION ALERT

Carbohydrates Due to trendy diets, some people think foods with "carbs" are different than those containing carbohydrates. Tell students that vegetables like broccoli, carrots, and spinach contain carbohydrates just like "high carb" potatoes and bread.

Differentiated Instruction

Advanced Learners/GATE

Artificial Sweeteners Have students research artificial sweeteners and how they are used to create foods that taste sweet but have fewer calories than foods with sucrose. Have the students explore the structure of these compounds and explain how they provide the taste without the calories. Ask students to find out how the taste buds are stimulated. **LS Logical**

Lipids

Lipids are another class of biomolecules, which includes fats, phospholipids, steroids, and waxes. Lipids consist of chains of carbon atoms bonded to each other and to hydrogen atoms. This structure makes lipids repel water. ❯ **The main functions of lipids include storing energy and controlling water movement.** Lipids also include steroid hormones, used as signaling molecules, and some pigments, which absorb light.

Energy Stores The main purpose of fats is to store energy. Fats can store energy even more efficiently than carbohydrates. Many animals, such as the dormouse in **Figure 11,** can survive without a steady diet because of fat storage. When food is plentiful, the animal converts the excess food into fats for long-term energy storage. When food is scarce, the animal can break down the fat molecules to release energy for life processes. Plant oils are stored in seeds to provide energy to start the growth of a new plant.

Water Barriers The cell's boundary is made of phospholipids. One end of this molecule is attracted by water molecules. The other end, which is made of long carbon chains, is not. You will learn more about the behavior of these molecules when you study the structure of cell membranes.

The stems and leaves of many plants are covered with a thin layer of wax, another type of lipid. This wax helps prevent the evaporation of water from the cells at the surface of a plant. Waxy feathers can also help keep ducks and other aquatic birds dry. One type of wax molecule found on bird feathers is shown in **Figure 11.**

Hands-On

QuickLab

15 min

Brown Paper Test

You can test substances for fats by using ordinary brown paper. Oils are fats that are liquid at room temperature. This test also works for oils.

Procedure

1. Place a drop of **water** in one area of your **brown paper.** Place a drop of **oil** in another area. Rub a spot of **butter** into a third area.
2. Fan the paper to evaporate any of these substances. Hold the stained paper to the light. What do you see?
3. Now, test **other substances** provided by your teacher.

Analysis

1. **Compare** how the butter, oil, and water affected the paper.
2. **Describe** how each of the other substances that you tested affected the paper. Which ones contained lipids?

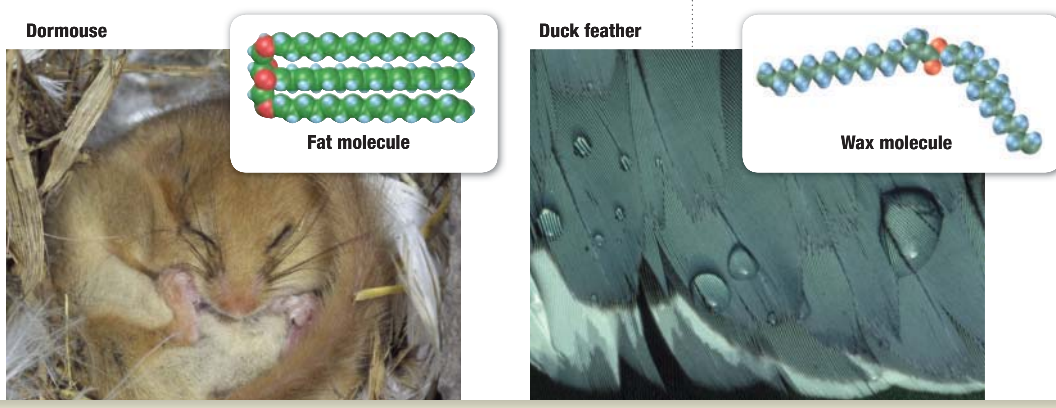


Figure 11 Many fat molecules have three long chains of carbons. Waxes may be composed of chains of about 24 to 34 carbon atoms.

❯ Teach, *continued*

QuickLab

Teacher's Notes Fats and oils belong to a group of substances called lipids. Fats are solids at room temperature. Oils are liquids at room temperature. Saturated fats have backbones comprised of single carbon-carbon bonds. Unsaturated oils have double bonds between carbon atoms within the fatty acid carbon chain. Ask students what saturated means in *saturated fat.* (All bonds other than the C–C backbone are saturated with hydrogen.)

Materials

- brown paper
- samples of water, oils, and butter
- food samples, such as cookies, pretzels, potato chips, muffins, cake, ketchup, mustard, salad dressings, candy, and chocolate

Answers to Analysis

1. The places where paper contacted fats and oils were translucent. The place where water was dropped appeared translucent at first but then returned to its opaque appearance after the water evaporated.
2. Substances that contain high quantities of lipids should turn the paper translucent.

Demonstration

Oil and Water Don't Mix Show the insoluble nature of fats and oils by mixing some samples with water. To show the hydrophobic qualities of waxes, drip some wax from a burning candle into a container of water. Students will need to recall these properties when they study the cell membrane. **LS Visual**

Differentiated Instruction

Struggling Readers

Summarizing Have students read Section 3 silently. After a designated time, assign students to cooperative pairs. Have one student summarize what he or she read while the other student listens. The listener should point out inaccuracies and mention concepts that the other left out. Both students should work together during the final clarification process, referring to the text as needed. **LS Interpersonal**

Teach, *continued*

READING TOOLBOX

Quantifiers **primary** order of amino acids in the chain; **secondary** the bending and twisting of the chain; **tertiary** the overall shape of a single folded protein; **quaternary** the overall shape of a folded multi-subunit protein complex

Teaching Key Ideas

Enzymes Enzymes are proteins that affect the rate of chemical reactions in the body. Enzymes are a very important part of the metabolic process because they assist in vital processes such as digestion. Enzymes work by speeding up reactions by providing an alternate reaction pathway at a lower E_a.

READING TOOLBOX

Visual Literacy Have students look at the generalized formula for an amino acid in **Figure 12.** Ask students if it makes sense that hooves, horns, hair, and muscles can all have the same building blocks. (Though it may seem odd, all of these body parts contain proteins. Use the analogy in **Figure 8** to make the point that combinations of the same building blocks, amino acids coupled with the primary, secondary, tertiary, and quaternary structure of the protein results in different properties.)

READING TOOLBOX

Quantifiers Describe the levels of protein structure, and identify the quantifier used to describe each level.

protein an organic compound that is made of one or more chains of amino acids and that is a principal component of all cells

amino acid a compound of a class of simple organic compounds that contain a carboxyl and an amino group and that combine to form proteins

SCILINKS. www.scilinks.org Topic: Proteins Code: HX81241

Proteins

Proteins are the workhorse molecules of all living things. There are many types of proteins that perform many types of functions. **Proteins are chains of amino acids that twist and fold into certain shapes that determine what the proteins do.** Some proteins provide structure and support. Others enable movement. Some proteins aid in communication or transportation. Others help carry out important chemical reactions.

Amino Acids A **protein** is a molecule (usually a large one) made up of **amino acids,** building blocks that link to form proteins. **Figure 12** shows the basic structure of an amino acid. Every amino acid has an amino group ($-NH_2$), a carboxyl group ($-COOH$), and a variable side group. The carboxyl group of one unit can link to the amino group of another. This link is a *peptide bond.*

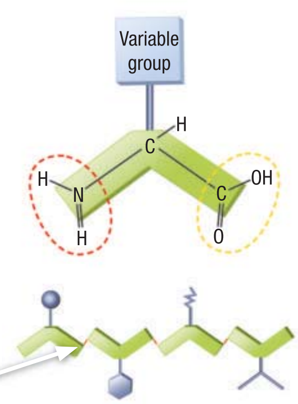
The side group gives an amino acid its unique properties. Twenty different amino acids are found in proteins. In order to build proteins, the body requires a supply of the correct amino acids. The body can make many amino acids from other substances, but a few amino acids must be included in the diet. To get these amino acids, your body breaks apart the proteins in the foods you eat.

Levels of Structure For each type of protein, amino acids are arranged in a specific order. This order is the protein's primary structure. The various side groups interact to bend and twist the chain. Portions of the chain may form coils and folds. These patterns are known as the protein's secondary structure.

Some small proteins consist of only one chain, but most proteins consist of two or more chains. The tertiary structure of proteins is the overall shape of a single chain of amino acids. The quaternary structure is the overall shape that results from combining the chains to form the protein. This shape suits the function of each protein.

Reading Check *What is a protein's primary structure?*

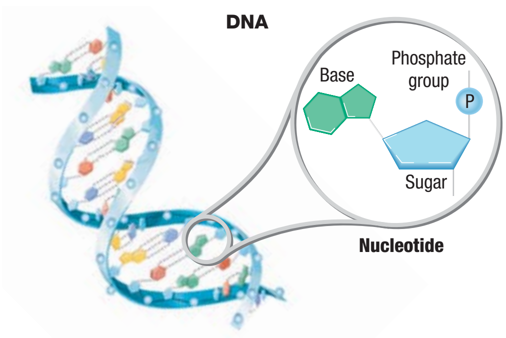
Figure 12 Proteins are chains of amino acids linked by peptide bonds. An amino acid (top) has a side group (blue). Various combinations of amino acids result in specific types of proteins, such as the proteins that make up the muscles, hair, horns, and hooves of this highland cow.



Differentiated Instruction

Basic Learners

Comparing Carbon Compounds Have students make a table that lists information about carbon compounds. Along the top, have them write *Carbohydrates, Lipids, Proteins,* and *Nucleic acids*. Along the sides, have them write *Characteristics* and *Examples*. As they review this section, have students add information to their tables. LS Logical



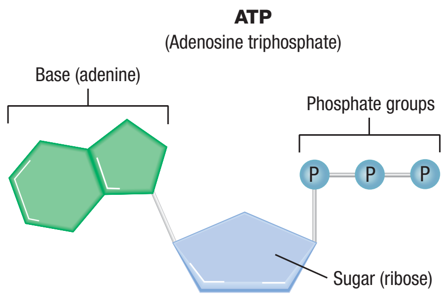


Figure 13 DNA is made of two strands of multiple nucleotides (inset) linked by hydrogen bonds. ATP is also a nucleotide and is made up of a sugar, a base, and three phosphate groups. **What is the function of ATP?**

Nucleic Acids

All of your cells contain nucleic acids. A **nucleic acid** is a long chain of nucleotide units. A **nucleotide** is a molecule made up of three parts: a sugar, a base, and a phosphate group. Nucleotides of deoxyribonucleic acid, or **DNA,** contain the sugar deoxyribose. Nucleotides of ribonucleic acid, or **RNA,** contain the sugar ribose.

Hereditary Information DNA molecules act as "instructions" for the processes of an organism's life. These instructions, called the *genetic code,* depend on the order of bases in the nucleotides of the DNA molecule. DNA consists of two strands of nucleotides that spiral around each other, as **Figure 13** shows. The bases in one strand of nucleotides form hydrogen bonds with the bases on the other to hold the DNA molecule together and protect the code. RNA also interacts with DNA to help decode the information. **Nucleic acids store and transmit hereditary information.**

Energy Carriers Some single nucleotides have other important roles. Cells need a steady supply of adenosine triphosphate, or **ATP,** to function. ATP, shown in **Figure 13,** is a nucleotide that has three phosphate groups. Energy is released in the reaction that breaks off the third phosphate group. Other single nucleotides transfer electrons or hydrogen atoms for other life processes.

nucleic acid an organic compound, either RNA or DNA, whose molecules are made up of one or two chains of nucleotides and carry genetic information

nucleotide an organic compound that consists of a sugar, a phosphate, and a nitrogenous base

DNA deoxyribonucleic acid, the material that contains the information that determines inherited characteristics

RNA ribonucleic acid, a natural polymer that is present in all living cells and that plays a role in protein synthesis

ATP adenosine triphosphate, an organic molecule that acts as the main energy source for cell processes

Section 3 Review

KEY IDEAS

1. **Discuss** how one type of atom (carbon) can be the basis of so many types of biomolecules.
2. **List** three major functions of carbohydrates.
3. **Describe** two functions of lipids.
4. **Explain** how two different proteins will have two different shapes.
5. **Summarize** the role of nucleic acids in a cell.

CRITICAL THINKING

6. **Applying Information** Before a long race, runners often "carbo load." In other words, they eat substantial quantities of carbohydrates. How might this practice help their performance?

METHODS OF SCIENCE

7. **Identifying Unknown** Analysis of an unknown substance shows that the substance contains carbon, hydrogen, and oxygen and is soluble in oil, but not in water. Which of the four types of biomolecules could this substance be?

Teaching Key Ideas

It's Exothermic! Explain that the reaction of ATP to form ADP results in the release of energy that can be used by cells. Ask students how cells keep a steady supply of ATP. (The breakdown of ATP is a reversible reaction. ADP can once again become ATP through another reaction that adds a phosphate group.)

Answers to Caption Questions

Figure 13: ATP supplies energy to cells.

Close

Formative Assessment

Which class of carbon compounds is used as long-term energy storage in the human body?

A. lipids (Correct! Lipids, or fats, are used to store energy and can be broken down for use when food is scarce.)
B. proteins (Incorrect. Proteins can provide some immediate energy.)
C. nucleic acids (Incorrect. Nucleic acids are used to encode information and also are a part of ATP, which supplies immediate energy.)
D. carbohydrates (Incorrect. Carbohydrates can supply short-term energy and can form other structures.)

Answers to Section Review

1. Carbon atoms can bond to four other atoms, including other carbon atoms. Carbon that bond to each other can form long-chain molecules with complex shapes. Small, simple building blocks are put together in a coordinated fashion to produce large complex biomolecules.
2. Carbohydrates are sources of energy, structural materials, and structures for cellular identification.
3. storing energy and controlling water movement
4. Proteins are a class of compounds, not a specific compound. Proteins vary depending on their amino acid sequences. Different amino acid sequences result in proteins that will likely have different shapes.
5. Nucleic acids store and transmit hereditary information.
6. Carbohydrates breakdown quickly in reactions that release energy.
7. It would be a lipid-based substance. Carbohydrates and lipids contain carbon, hydrogen, and oxygen. Carbohydrates dissolve in water, but lipids do not.

Section 4

Focus

This section helps students understand that chemical reactions provide the energy needed by living things. The important role of enzymes in biochemical reactions is also discussed.

Bellringer
Use the Bellringer transparency to prepare students for this section.

Teach

Teaching Key Ideas

Physical versus Chemical Changes
Remind students that adding sucrose (sugar) to water results in a physical change. Weak bonds *between* sucrose molecules in the crystal are broken. Adding sucrose to concentrated sulfuric acid causes a chemical change. In this case, bonds *within* the molecule are broken. Carbon and water are produced. Do not run this reaction in the classroom; it is too hazardous. You can easily find images of this demonstration on the Internet.

Answers to Caption Questions

Figure 14: mechanical energy

Section 4

Energy and Metabolism

Key Ideas	Key Terms		Why It Matters
Where do living things get energy? How do chemical reactions occur? Why are enzymes important to living things?	energy reactant product activation energy	enzyme substrate active site	All living things need energy to survive. You get that energy by breaking complex molecules from food you eat into simpler, stabler molecules.

Changes constantly occur in living things. In fact, you could say that a key feature of life is change. The ability to move or change matter is called **energy.** Energy exists in many forms—including light, heat, chemical energy, mechanical energy, and electrical energy—and can be converted from one form to another. The athlete in **Figure 14** is using mechanical energy to move the basketball.

Changing Matter

Living things are made of matter, which consists of a substance with a form. A physical change occurs when only the form or shape of the matter changes. The substances that make up the matter do not change into different substances. When you pour sugar into iced tea and stir, the sugar crystals disappear. The sweet taste shows that the sugar is still there but has changed form.

A chemical change occurs when a substance changes into a different substance. In a chemical change, the identity of the matter changes. When wood burns, the carbohydrates in the wood fibers combine with oxygen, O_2, in the air. The wood fibers change to different substances: carbon dioxide, CO_2, and water vapor, H_2O.

Figure 14 This athlete uses energy to move the basketball. **What form of energy is used to move the basketball?**

Conservation of Mass Matter is neither created nor destroyed in any change. The same mass is present before and after the wood burns and the sugar dissolves. This observation is called the *law of conservation of mass.*

Conservation of Energy Every change in matter requires a change in energy. Energy may change from one form to another, but the total amount of energy does not change. This observation is called the *law of conservation of energy*. In some changes, energy is taken in from the surroundings. In others, energy is released into the surroundings. The total amount of *usable* energy decreases because some energy is given off to the surroundings as heat. **Living things use different chemical reactions to get the energy needed for life processes.**

Reading Check *What is a chemical change?*

Key Resources

Transparencies
A16 Energy and Chemical Reactions
A17 Activation Energy With and Without Enzymes
A25 Enzyme Activity

Visual Concepts
Energy
Activation Energy and Chemical Reactions
Enzyme
Factors Affecting Reaction Rates

Chemical Reactions

Changing a substance requires a chemical reaction. During this process, bonds between atoms are broken, and new ones are formed. A **reactant** is a substance that is changed in a chemical reaction. A **product** is a new substance that is formed. Scientists summarize reactions by writing equations in the following form:

$$\text{Reactants} \longrightarrow \text{Products}$$

The arrow means "changes to" or "forms." For example, carbon dioxide and water can react to form carbonic acid, H_2CO_3, in your blood. The following equation represents this reaction:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

The double arrow indicates that the products can reform reactants. In this example, carbonic acid changes back to carbon dioxide and water in your lungs.

Activation Energy Chemical reactions can occur only under the right conditions. To form new bonds, particles must get close enough to share electron clouds. However, even though the particles move constantly, as they get close, their negatively charged electron clouds tend to push them apart. To react, the particles must collide fast enough to have kinetic energy to overcome the repulsion between them. The **activation energy** of the reaction is the minimum kinetic energy that colliding particles need to start a chemical reaction.

Alignment Even if enough energy is available, the product still may not form. When the reactant particles collide, the correct atoms must be brought close together in the proper orientation, as **Figure 15** shows. Otherwise, the product will not form. **Chemical reactions can occur only when the activation energy is available and the correct atoms are aligned.** In living things, chemical reactions occur between large, complex biomolecules. Life can only exist if these molecules collide in the correct orientation.

Reading Check *What causes particles to repel other particles?*

energy the capacity to do work

reactant a substance or molecule that participates in a chemical reaction

product a substance that forms in a chemical reaction

activation energy the minimum amount of energy required to start a chemical reaction

ACADEMIC VOCABULARY

orientation the relative position or direction of something

Reaction Conditions

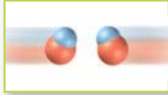
Reactants	Conditions	Result	Products
	not enough energy	no reaction	none
	enough energy; wrong orientation	no reaction	none
	enough energy; proper orientation	reaction	

Figure 15 Chemical reactions can occur only under the right conditions. The correct atoms of reactants must be aligned, and they must collide with enough energy. **What term describes the minimum amount of energy needed for a reaction to occur?**

go.hrw.com interact online Keyword: HX8BCMF15

Why It Matters

Carbonic Acid The reaction of carbon dioxide with water to form carbonic acid is used in the beverage industry to make carbonated drinks, such as soda. Carbon dioxide is forced into the beverage under high pressure during the bottling or canning process. When you open a can of soda, the release of pressure above the liquid allows carbon dioxide to escape the liquid. Over time, enough carbon dioxide will leave the liquid, and a "flat" tasting beverage results.

Answers to Caption Questions

Figure 15: activation energy

go.hrw.com interact online

Students can interact online with chemical reactions by going to go.hrw.com and typing in the keyword HX8BCMF15.

Differentiated Instruction

Special Education Students

Reaction Conditions Use molecular models or plastic foam balls of different sizes to demonstrate collision orientation. To create compound models attach the foam spheres with tooth picks or Velcro®. Follow the models shown in **Figure 15.** Have students demonstrate the three scenarios shown in the table.
LS Kinesthetic

Teach, *continued*

Teaching Key Ideas

Enzyme Names Enzymes are often named by incorporating the name of an enzyme's substrate with the function that the enzyme performs and then placing the suffix *–ase* at the end. For example, a dehydrogenase is an enzyme that removes hydrogen atoms from a substrate. Adding the suffix *–ase* to the name of the substrate without adding the functional name usually means that the enzyme breaks the substrate down into products. For example, sucrase breaks sucrose down to glucose and fructose. Ask students to suggest the function of the enzymes lactase and lipase. (Lactase breaks lactose down to glucose and galactose. Lipase breaks lipids down to glycerol and fatty acids.) Have the students research the names and functions of other enzymes.

Teaching Key Ideas

Enzymes Make It Happen Refer students to the photograph at the beginning of the chapter. Burning fuel generates a lot of heat. Because the body functions over a limited temperature range, burning fuel in the body has to occur at much lower temperatures. Help students understand that enzymes make it possible for these reactions to occur because the activation energy is lower for enzyme-catalyzed reactions.

Biological Reactions

Living things carry out many chemical reactions that help maintain a stable internal environment. Many of these reactions require large activation energies. Often, the reactants are large biomolecules that must collide in a very specific orientation. Many of these reactions would not occur without the help of enzymes.

Enzymes An **enzyme** is a molecule that increases the speed of biochemical reactions. Enzymes hold molecules close together and in the correct orientation. This way, the molecules do not have to depend on random collisions to react. An enzyme lowers the activation energy of a reaction, as **Figure 16** shows. **By assisting in necessary biochemical reactions, enzymes help organisms maintain homeostasis.** Without enzymes, chemical reactions would not occur quickly and easily enough for life to go on.

Enzyme Activity Enzymes fit with reactants like a lock fits a key. As **Figure 17** shows, each enzyme has an **active site,** the region where the reaction takes place. The shape of the active site determines which reactants, or **substrates,** will bind to it. Each different enzyme acts only on specific substrates.

Step 1 Two substrates bind to an enzyme's active site. The substrates fit in a specific position and location, like a key in a lock.

Step 2 Binding of the substrates causes the enzyme's shape to change slightly. The substrates fit more tightly in the enzyme's active site. The change in shape causes some bonds in the substrates to break and new bonds to form.

Step 3 The chemical reaction is complete when the product, a new substance, is formed. The unchanged enzyme releases the product, and can then be reused for another reaction.

Conditions Many enzymes are proteins. Changes in temperature and pH can change a protein's shape. If an enzyme changes shape, it won't work well. Most enzymes need a certain range of temperatures and pH.

enzyme a molecule, either protein or RNA, that acts as a catalyst in biochemical reactions

active site on an enzyme, the site that attaches to a substrate

substrate the reactant in reactions catalyzed by enzymes

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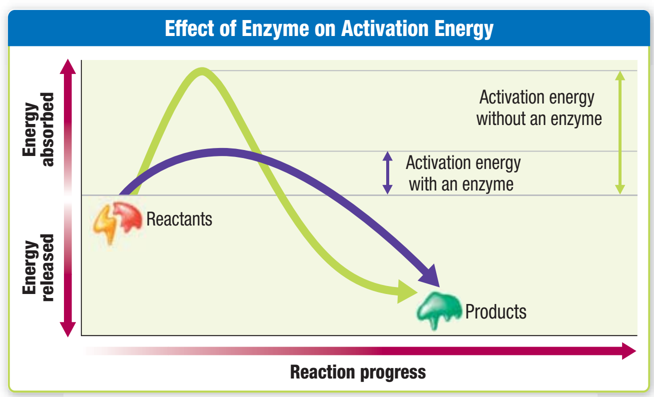

Figure 16 Enzymes decrease the amount of energy needed to start a chemical reaction without changing the amount of energy contained in either the reactants or the products.

Why It Matters

Onions and Enzymes Onions contain sulfur compounds called *amino acid sulfoxides.* When an onion is cut, peeled, or crushed, enzymes called *allinases* are released from the tissue of the onion. These enzymes convert the amino acid sulfoxides into sulfenic acids, which forms a gas. When the gas reacts with water on the surface of the eye, sulfuric acid forms. The acid stings and triggers tear production in the eyes.

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interact online
Keyword: HX8BCMF17

Enzyme Action

1. The substrates bind to the enzyme's active site.
2. The enzyme changes shape, which catalyzes the chemical reaction between the substrates.
3. The product is released when the reaction is complete.

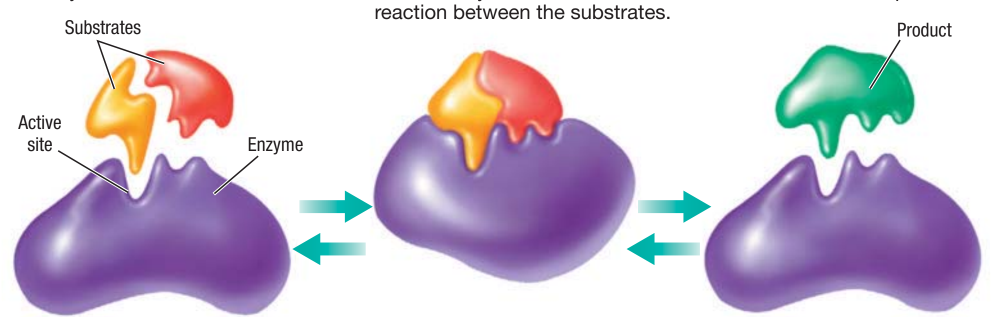

Figure 17 Enzymes catalyze specific reactions between specific reactants. **How would a change in the shape of the active site affect the enzyme's activity?**

Metabolism Your cells get most of the energy needed for metabolism from the food you eat. When food is digested, it is broken into small molecules that can enter the blood, which delivers them to cells. Here, chemical reactions release energy by breaking down these food molecules so that cells can use it. The release of energy from food molecules involves many steps and many enzymes.

Consider the breakdown of sugar to release energy. You can use a match to supply enough activation energy to set fire to cellulose, a polysaccharide, when you burn wood. However, the match flame is hot, and the reaction of glucose with oxygen gets even hotter because it is so fast. Living things also "burn" sugars, but they use enzymes to do so. The enzymes reduce the activation energy so much that only a little energy is needed to start the reaction. Then, a series of enzymes carries out the reaction in a slower, step-by-step manner so that the energy can be captured in the form of ATP molecules. In this process, very little heat is produced.

Reading Check *Why is the shape of an enzyme important?*

Section 4 Review

KEY IDEAS

1. **Explain** the importance of chemical reactions in living things.
2. **Describe** two conditions necessary for a chemical reaction to occur.
3. **Relate** enzymes and homeostasis.

CRITICAL THINKING

4. **Applying Information** Explain the difference between usable energy and the total amount of energy. How is this difference accounted for in living organisms?
5. **Recognizing Relationships** Your body breaks down starch into glucose molecules. In this reaction, which substance is the reactant, and which is the product?

WRITING FOR SCIENCE

6. **Predicting Outcomes** Research the enzyme carbonic anhydrase. Explain its role in maintaining homeostasis in the human body. How might a molecule that interferes with the action of carbonic anhydrase affect your body?

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interact online

Students can interact with the characteristics of "Enzyme Action" by going to go.hrw.com and typing in the keyword HX8BCMF17.

Demonstration

Pineapple Enzymes If fresh pineapple is added to a gelatin mixture, the protein will not gel. Prior to class, prepare gelatin in three separate cups. Cut 1 contains gelatin only. Cup 2 contains gelatin with fresh pineapple placed on the surface. Cup 3 contains gelatin with canned pineapple placed on the surface. Tell students that pineapple contains *bromelin,* an enzyme that breaks down gelatin. Ask students to explain the results. (The heating process in canned pineapple destroys bromelin. Gelatin stays gelled when canned pineapple is used.)

Answers to Caption Questions

Figure 17: The substrate would not fit the enzyme, so it would no longer be effective.

Close

Formative Assessment

1. The role of enzymes in chemical reactions is to ___.

A. increase activation energy (Incorrect. Enzymes reduce activation energy requirements.)

B. eliminate proteins (Incorrect. Enzymes are proteins.)

C. reduce the number of reactants (Incorrect. Enzymes do not affect the number of reactants.)

D. speed up the rate of reaction (Correct. Enzymes speed up the rate of a reaction.)

Answers to Section Review

1. Chemical reactions provide the energy and structural components needed for life processes.
2. Reactants need sufficient activation energy for a reaction to occur. The reactants must also be aligned properly during collisions to form products.
3. Enzymes enable biochemical reactions to occur at the temperature ranges and pH ranges needed for homeostasis.
4. Usable energy is what enables the organism to function. Usable energy always decreases within an organism because some of the total energy is given off to the surroundings as heat. The total amount of energy in a system never changes during the transfer of energy from one form to another.
5. Starch is the reactant, and glucose is the product.
6. Carbonic anhydrase catalyzes the production of carbonic acid from carbon dioxide and water. When carbonic acid in the blood is carried to the lung's alveoli, it reacts to form carbon dioxide and water. Carbon dioxide is then released from the body during exhalation. A molecule that interferes with the action of carbonic anhydrase would result in the accumulation of CO_2 in the blood, which can become toxic to the body.

Lab

Time Required

One 45-minute lab period for Day 1; 30 minutes for Day 2; and 15 minutes for Day 3

Ratings

EASY → HARD

Teacher Prep	2
Student Setup	3
Concept Level	3
Cleanup	2

Safety Caution

Make sure students wear safety goggles and a lab apron. Caution students to avoid burns by working carefully when heating and pouring boiling water.

Tips and Tricks

Review the Role of Enzymes Before starting the lab, ask students why enzymes are added to detergents. (to help break down proteins and other substances from foods that may stain clothing) Ask students why detergent enzymes are stable during the hot water cycle. (The enzymes found in commercial laundry soap have been engineered to withstand high temperatures.)

Gelatin Preparation The rate of hydrolysis is slower in instant gelatin, which contains sugar, than in sugar-free gelatin.

Detergent Samples Each students should bring in a 1-cup sample of their home laundry detergent. Each sample should be labeled with the following: the name or brand, and the active ingredients listed on the container. Collect all of the samples and distribute 3–5 tablespoons of five different samples to each lab group for testing. Check that each group gets one sample of a nonenzyme detergent to use as a control.

Experimental Control Students should have a control test tube with 15 drops (1 mL) of water (no detergent) added to the gelatin surface. Require students to present a written procedure for their experiment and a list of all safety precautions before allowing them to gather materials for the lab. When students add the detergent solutions to the gelatin, the mixture will foam. During this reaction, carbon dioxide gas is released. The addition of baking soda ($NaHCO_3$) to the gelatin raises the pH of the gelatin from 4 to 8, which is the optimum pH for protease activation in the detergent samples.

Marking the Tubes Have students use a wax pencil to mark the test tubes at the uppermost level of the cooled gelatin in each tube. They will use this mark to measure the hydrolysis of the gelatin each day. Label the test tubes 1 through 6.

Preparing the Detergent Solution To prepare a 10 percent solution of laundry detergent, students should dissolve 1 g of detergent in 9 mL of distilled water. Have students record the pH for each numbered detergent sample. Students can measure protein hydrolysis after 24 hours by using a wax pencil to draw a second line at the top of the gelatin layer and then measuring the distance (in mm) between the first line and the second line. This measurement indicates

Inquiry

Chapter 3 Lab

Objectives

- Recognize the function of enzymes in laundry detergents.
- Relate temperature and pH to the activity of enzymes.

Materials

- lab apron, safety goggles, and disposable gloves
- balance
- graduated cylinder
- stirring rod, glass
- beaker, 150 mL
- gelatin, instant, regular (18 g) or sugar-free (1.8 g)
- $NaHCO_3$ (0.1 g)
- tongs or a hot mitt
- boiling water, 50 mL
- thermometer
- pH paper
- test tubes (6)
- test-tube rack
- pipet with bulb
- plastic wrap
- tape
- beakers, 50 mL (6)
- distilled water, 50 mL
- detergent, laundry, powdered, five brands (1 g of each)
- wax pencil
- metric ruler

Safety

Enzymes in Detergents

Some laundry detergents contain enzymes, substances that speed up chemical reactions. A protease is an enzyme that helps break down proteins. In this lab, you will investigate the effectiveness of laundry detergents that contain enzymes. To do so, you will use a protein mixture to simulate food stains.

Preparation

1. SCIENTIFIC METHODS **State the Problem** How can you determine if a detergent contains proteases?
2. SCIENTIFIC METHODS **Form a Hypothesis** Form a testable hypothesis that explains how a protein mixture might be affected by a detergent that contains protease.

Procedure

Make a Protein Substrate

1. Put on a lab apron, safety goggles, and gloves.
2. **CAUTION: Use tongs or a hot mitt to handle heated glassware.** Put 18 g of regular gelatin in a 150 mL beaker. Slowly add 50 mL of boiling water to the beaker, and stir the mixture with a stirring rod. Test and record the pH of this solution.

3. Very slowly add 0.1 g of $NaHCO_3$, baking soda, to the hot gelatin while stirring. Note any reaction. Test and record the pH of this solution.
4. Place six test tubes in a test-tube rack. Pour 5 mL of the gelatin-$NaHCO_3$ mixture into each tube. Use a pipet to remove any bubbles from the surface of the mixture in each tube. Cover the tubes tightly with plastic wrap and tape. Cool the tubes, and store them at room temperature until you begin your experiment.
5. Clean up your lab materials according to your teacher's instructions. Wash your hands before you leave the lab.

Design an Experiment

6. Design an experiment that tests your hypothesis and that uses the materials listed for this lab. Predict what will happen during your experiment if your hypothesis is supported.
7. Write a procedure for your experiment. Identify the variables that you will control, the experimental variables, and the responding variables. Construct any tables you will need to record your data. Make a list of all safety precautions you will take. Have your teacher approve your procedure before you begin the experiment.

Conduct Your Experiment

8. Put on a lab apron, safety goggles, and gloves.
9. Make a 10% solution of each laundry detergent by dissolving 1 g of detergent in 9 mL of distilled water.
10. Carry out your experiment. Observe the test tubes after 24 h. Record your data in a data table.
11. Clean up your lab materials according to your teacher's instructions. Wash your hands before you leave the lab.

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Analyze and Conclude

1. SCIENTIFIC METHODS **Analyzing Methods** Suggest a reason for adding $NaHCO_3$ to the gelatin solution.
2. SCIENTIFIC METHODS **Summarizing Data** Make a bar graph of your data. Plot the amount of gelatin that has broken down (change in the depth of the gelatin) on the *y*-axis. Plot detergent on the *x*-axis.
3. SCIENTIFIC METHODS **Inferring Conclusions** What conclusions did your group infer from the results? Explain.
4. **Designing an Experiment** How can you test the effect of pH and temperature on action of enzymes in detergents?
5. **Further Inquiry** Write a new question about enzymes in detergents that could be explored in another investigation.

Extensions

6. **Relating Concepts** What other active ingredients are present in laundry detergents, and how do they help clean clothes?
7. **Applying Information** What other household products contain enzymes, and what types of enzymes do they contain?

the amount of protein hydrolysis in the gelatin by enzymes in the detergent. The level of the gelatin layer in the tube with the nonenzyme detergent should not change. This indicates that the detergent alone does not cause the protein hydrolysis reaction.

Answers to Analyze and Conclude

1. Baking soda increases the pH of the gelatin from 4 to 8, the optimum pH for enzyme activity in this reaction.
2. Graphs will vary.
3. Answers will vary. For example, enzymes are most effective at optimum temperature and pH.
4. Answers will vary. For example run the procedure again placing the tubes in a refrigerator or oven (250°F).
5. Answers will vary. For example: Are enzymes in detergent stable in the presence of bleach?

Sample Procedure

1. Prepare a 10 percent solution of each of five different detergents. (mark the one known to be nonenzyme)
2. Test the pH of each detergent solution with pH paper. Record the pH for each sample in a data table similar to the one below.
3. Add about 15 drops (1 mL) of the first detergent solution to the gelatin surface of the first test tube. Repeat for each of the other samples. Reseal the test tubes and place them in a test-tube rack for observation.
4. Add 15 drops of water to the gelatin surface of the sixth test tube.
5. Put the tubes aside for 24 hours at room temperature.
6. Draw another wax-pencil line at the top of the gelatin layer. Measure the distance in mm between the first line and the second line. Record the data in a data table.

Sample Data

Detergent	pH	Amount of Protein Broken Down
1	8	7 mm
2	8	0 mm
3	8	9 mm
4	8	0 mm
5	8	6 mm

Answers to Extensions

6. Answers will vary. Ingredients that breakdown the components of specific stains, such as blood, urine, and grass pigments.
7. Answers will vary. For example, digestive supplements for dairy products contain lactase. Contact-lens cleaning solutions contain enzymes to break down the protein build-up on lenses.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 3

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the keyword **HX8BCMS** to access the Super Summary for this chapter.

Reteaching Key Ideas

Interpreting Food Labels/Math Skills Have students bring to class several Nutrition Facts labels from food containers and determine the following using the information on the labels:

1. Calories per gram $\left(\frac{\text{Calories per serving}}{\text{serving size}}\right)$
2. percentage of fat $\left(\frac{\text{mass of fat per serving}}{\text{total mass of serving}}\right) \times 100$
3. percentage of carbohydrate $\left(\frac{\text{mass of carbohydrate per serving}}{\text{total mass of serving}}\right) \times 100$
4. percentage of sugar $\left(\frac{\text{mass of sugar per serving}}{\text{total mass of serving}}\right) \times 100$
5. percentage of protein $\left(\frac{\text{mass of protein per serving}}{\text{total mass of serving}}\right) \times 100$

Have students compare the nutritional contents of the labels they've analyzed. Summarize the class data to determine which foods have the most fat, carbohydrate, and protein per serving. **LS Visual/Logical**

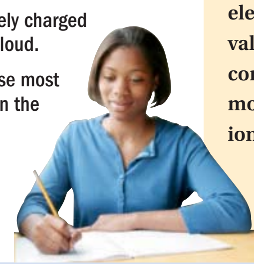
Chapter 3 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8BCMS

Key Ideas | **Key Terms**

1 Matter and Substances

- All matter is made up of atoms. An atom has a positively charged nucleus surrounded by a negatively charged electron cloud.
- Chemical bonds form between groups of atoms because most atoms become stable when they have eight electrons in the valence shell.
- Polar attractions and hydrogen bonds are forces that play an important role in many of the molecules that make up living things.



Key Terms: **atom** (51), **element** (51), **valence electron** (52), **compound** (52), **molecule** (52), **ion** (53)

2 Water and Solutions

- The hydrogen bonding between water molecules explains many of the unique properties that make water an important substance for life.
- Acids and bases change the concentration of hydronium ions in aqueous solutions. The pH of solutions in living things must be stable.

Key Terms: **cohesion** (55), **adhesion** (55), **solution** (56), **acid** (56), **base** (56), **pH** (57), **buffer** (57)

3 Carbon Compounds

- Large, complex biomolecules are built from a few smaller, simpler, repeating units arranged in an extremely precise way.
- Cells use carbohydrates for sources of energy, structural materials, and cellular identification.
- The main functions of lipids include storing energy and controlling water movement.
- Proteins are chains of amino acids that twist and fold into shapes that determine what the protein does.
- Nucleic acids store and transmit hereditary information.

Key Terms: **carbohydrate** (60), **lipid** (61), **protein** (62), **amino acid** (62), **nucleic acid** (63), **nucleotide** (63), **DNA** (63), **RNA** (63), **ATP** (63)

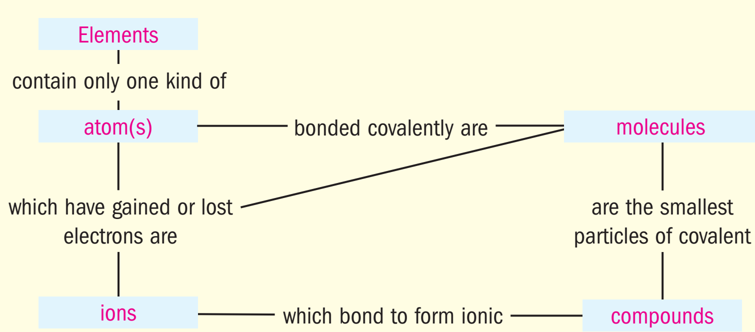
4 Energy and Metabolism

- Living things use different chemical reactions to get the energy needed for life processes.
- An activation energy is needed to start a chemical reaction. The reactants must also be aligned to form the product.
- By assisting in necessary biochemical reactions, enzymes help organisms maintain homeostasis.

Key Terms: **energy** (64), **reactant** (65), **product** (65), **activation energy** (65), **enzyme** (66), **active site** (66), **substrate** (66)

Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 3 Review

READING TOOLBOX

1. **Comparison Table** Make a comparison table to compare proteins and nucleic acids.
2. **Concept Map** Make a concept map that illustrates the structure of matter. Include the following terms in your map: *atom, element, compound, molecule,* and *ion.*

Using Key Terms

3. Explain the relationship between *reactant, product,* and *substrate.*

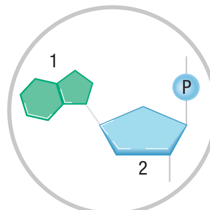
For each pair of terms, explain how the meanings of the terms differ.

4. *cohesion* and *adhesion*
5. *nucleic acid* and *nucleotide*

Understanding Key Ideas

6. What are the three components of atoms?
   - **a.** matter, electrons, and ions
   - **b.** matter, compounds, and ions
   - **c.** nucleus, electrons, and isotopes
   - **d.** protons, electrons, and neutrons
7. Water dissolves ionic compounds because water molecules
   - **a.** are nonpolar.
   - **b.** do not contain atoms.
   - **c.** have a pH of 14 or greater.
   - **d.** have partially charged ends.
8. An aqueous solution that contains extra hydroxide ions is a(n)
   - **a.** gas
   - **b.** base
   - **c.** acid
   - **d.** solid
9. How many electrons are in the valence shell of a carbon atom?
   - **a.** 1
   - **b.** 2
   - **c.** 4
   - **d.** 6
10. The order of amino acids is a protein's
    - **a.** primary structure.
    - **b.** secondary structure.
    - **c.** tertiary structure.
    - **d.** quaternary structure.
11. A new substance that forms as the result of a chemical reaction is a(n)
    - **a.** gas.
    - **b.** product.
    - **c.** reactant.
    - **d.** element.
12. Why do living things depend on enzymes?
    - **a.** Enzymes produce energy.
    - **b.** Enzymes change the temperature.
    - **c.** Enzymes speed up chemical reactions.
    - **d.** Enzymes prevent the formation of wastes.

This diagram is a model of a nucleotide. Use the diagram to answer the following question(s).



13. What does Structure 1 represent?
    - **a.** a base
    - **b.** a sugar
    - **c.** a steroid
    - **d.** a phosphate
14. What does Structure 2 represent?
    - **a.** a base
    - **b.** a sugar
    - **c.** a steroid
    - **d.** a phosphate

Explaining Key Ideas

15. **Describe** how forming compounds affects the stability of atoms.
16. **Identify** an example of adhesion and an example of cohesion.
17. **Compare** the structure of a simple carbohydrate with that of a complex carbohydrate.
18. **Identify** an important characteristic of waxes in living things.
19. **Differentiate** between a physical change and a chemical change.
20. **Explain** why a product might not form even if the activation energy is available.

Assignment Guide

Section	Questions
1	2, 6, 7, 15, 23, 24, 25, 26
2	4, 8, 16, 21, 22, 26, 31, 32, 34
3	1, 5, 9, 10, 13, 14, 17, 18, 27, 28, 29, 33
4	3, 11, 12, 19, 20, 21, 22, 30, 31, 35

Review

Reading Toolbox

1. Students' comparison tables should include similarities and differences between proteins and nucleic acids in terms of structure and function.
2. See previous page for answer to concept map.

Using Key Terms

3. A *reactant* is a substance that changes in a chemical reaction to form a *product.* A *substrate* is a reactant that binds to an enzyme in an enzyme-catalyzed chemical reaction.
4. *Cohesion* is the attraction among particles of the same substance. *Adhesion* is attraction between particles of different substances.
5. A *nucleic acid* is a molecule made up of one or two chains of nucleotides. A *nucleotide* is a subunit of a nucleic acid chain that consists of a sugar, a phosphate, and a nitrogenous base.

Understanding Key Ideas

6. d **7.** d **8.** b **9.** c
10. a **11.** b **12.** c **13.** a
14. b

Explaining Key Ideas

15. Most atoms are not naturally stable because their outermost energy levels are not filled. Atoms react by gaining, losing, or sharing electrons to fill their outer levels and become more stable.
16. The formation of dew shows cohesion. Water can move up a stem due to its adhesion to the cells of the plant and cohesion with its neighboring water molecules.
17. A simple carbohydrate may be made up of one sugar unit (monosaccharide) or two sugar units linked together (disaccharide). A complex carbohydrate is made up of several sugar units linked as chains or branches. The basic unit of both simple and complex carbohydrates is made up of carbon, hydrogen, and oxygen in a 1:2:1 ratio.
18. Waxes are waterproof and form protective coatings.

19. In a physical change, the identity of the substance does not change shape. In a chemical change, the substance becomes a different substance.

20. Reacting atoms of the reactants must also align properly so that the new chemical bonds can form.

Using Science Graphics

21. pH 3.0

22. The stomach is more acidic than the small intestine.

Critical Thinking

23. All atoms in an element are of the same type.

24. H_2 and O_2 are more stable than H and O because atoms within H_2 and O_2 share electrons in covalent bonds and have full energy levels. H_2 and O_2 are not compounds; but they are molecules.

25. The covalent bond occurs when atoms share electrons to complete their outer energy levels. An ionic bond is the force of attraction between ions of opposite charge that occurs when atoms lose or gain electrons.

26. When salt is added to water, it dissolves. The dissolved ions disrupt the hydrogen bonds that form among water molecules as water solidifies. Thus, it is more difficult for ice to form after salt has been added to the water. Lowering the temperature below the freezing point of the solution will eventually cause it to freeze.

27. If you eat an unbalanced diet, you may lack one or more of these three nutrients, and your cells will lack the components to store energy and make proteins.

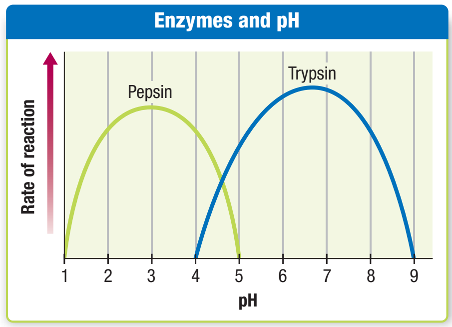
28. Oils have lower freezing points, so they are less likely to freeze in cold temperatures.

29. Hair is made up of proteins. Heat from the curling iron weakens the bonds between the amino acid chains. New bonds form to curl the hair around the barrel of the curling iron, changing the proteins' shape.

30. Maintaining the organization within a living system requires energy. Metabolism requires energy. Activation energy is needed for metabolic reactions to occur.

Using Science Graphics

This graph shows the relationship between pH and the activity of two digestive enzymes, pepsin and trypsin. Use the graph to answer the following question(s).



21. At what pH does pepsin work best?

22. Pepsin works in the stomach, while trypsin works in the small intestine. What does the graph indicate about the relative acidity of the stomach and small intestine?

Critical Thinking

23. Applying Information Given that elements are pure substances, how many types of atoms make up the structure of a single element? Explain your answer.

24. Analyzing Concepts In nature, the elements oxygen and hydrogen are usually found as gases with the formulas O_2 and H_2. Why? Are they compounds? Are they molecules?

25. Recognizing Differences What are two differences between ionic bonds and covalent bonds?

26. Inferring Relationships When salt is added to water, the freezing point of the water decreases. Explain why.

27. Applying Concepts Based on what you know about carbohydrates, lipids, and proteins, why is a balanced diet important?

28. Making Inferences Animals that live in freezing climates often store body fat as oil. What would be the adaptive advantage of storing body fat as oil instead of as a solid?

29. Recognizing Relationships High temperatures can weaken bonds within a protein molecule. How might this fact explain the effects of using a hot curling iron or rollers in one's hair?

30. Analyzing Concepts Living things need a constant supply of energy. Explain why.

31. Inferring Conclusions Outline a reason why a slight change in the pH of solutions in living things could result in the death of the organism.

Why It Matters

32. Surface Tension Using what you have learned about the properties of water, explain how some insects, such as water striders, can stand on the surface of water.

Alternative Assessment

33. Evaluating Promotional Claims Analyze the ingredients of various packaged foods. For each food, record the percentage of the food that carbohydrates, fats, and proteins make up. List any additives that the products contain. Research whether the additives are natural or artificial, and find out why they are added to particular foods. Compare these data to advertising claims about the products that you analyzed.

Writing for Science

34. Extended Response Pure water contains equal numbers of hydronium ions and hydroxide ions and is therefore neutral. What is the initial cause of the dissociation of water molecules into hydrogen and hydroxide ions? Explain the process. After water dissociates, hydronium ions form. Explain this process.

35. Short Response In an experiment that a student conducted, the rate of an enzyme-catalyzed reaction did not increase, even though the student increased the substrate concentration. Deduce why the reaction rate does not change even though more of the reactant is available.

31. Enzymes that catalyze chemical reactions function within a narrow pH range.

Why It Matters

32. The attraction between individual water molecules at the surface forms a kind of "film" over the surface. The weight of the water strider is well-distributed over water-resistant legs. Thus, it can stand on the water's surface.

Alternative Assessment

33. Some examples of natural additives are carrageen and agar, derived from algae and used as thickening agents. Salt, sugar, and vinegar are some natural preservatives. Recent concerns over advertising claims have caused the FDA to create guidelines for determining whether a food can be labeled as all natural or not.

Writing Skills

34. Polar attractions coupled with the proper orientation between colliding water molecules split a molecule to form a hydrogen ion and a hydroxide ion. The hydrogen ion reacts with water to form a hydronium ion.

35. When the amount of substrate exceeds the amount of enzyme, there are no additional enzyme molecules to bind the substrate. The enzyme becomes available when the other reactions have been completed.

Chapter 3 Standardized Test Prep

TEST TIP Choose your answer to a question based on both information that you already know and any information presented in the question.

Science Concepts

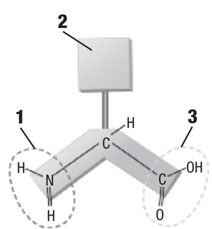
1. The way in which elements bond to form compounds depends on which of the following?
- **A** the size of the electrons
- **B** the shape of the nucleus
- **C** the number of neutrons in each atom
- **D** the electrons in the atoms of the elements

2. In what type of bond are electrons shared?
- **F** ionic
- **G** nuclear
- **H** covalent
- **J** hydrogen

3. What weak bond holds together the two strands of nucleotides in a DNA molecule?
- **A** ionic
- **B** nuclear
- **C** covalent
- **D** hydrogen

4. When an unknown substance is dissolved in water, hydronium ions form. What can you conclude about the substance?
- **F** The substance is a gas.
- **G** The substance is a base.
- **H** The substance is an acid.
- **J** The substance is a carbohydrate.

This diagram shows a type of biomolecule. Use the diagram to answer the following question(s).

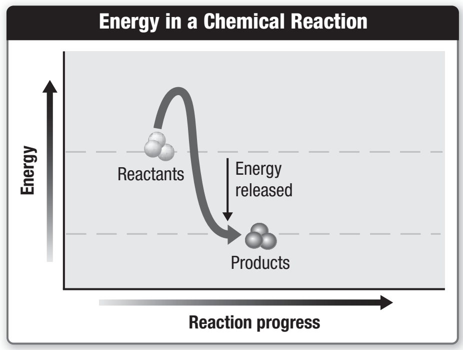


5. A bond can form between Group 1 of this type of molecule and Group 3 of another type of this molecule. What is this bond called?
- **A** ionic bond
- **B** peptide bond
- **C** double bond
- **D** triple bond

6. Carboxypeptidase is an enzyme that catalyzes reactions in the small intestine. The products of these reactions are amino acids. What are the substrates of carboxypeptidase?
- **F** lipids
- **G** proteins
- **H** nucleic acids
- **J** carbohydrates.

Using Science Graphics

This graph shows the energy in a catalyzed chemical reaction as the reaction progresses. Use the graph to answer the following question(s).



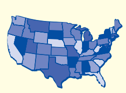
7. The amount of energy needed for this chemical reaction to begin is shown by the line rising from the reactants. What is this energy called?
- **A** chemical energy
- **B** electrical energy
- **C** activation energy
- **D** mechanical energy

8. Suppose that this reaction needs a catalyst to proceed. In the absence of a catalyst, the activation energy would be which of the following?
- **F** larger than what is shown
- **G** the same as what is shown
- **H** smaller than what is shown
- **J** very similar to what is shown

Math Skills

9. Protein A is a chain of 660 amino acids. Protein B is a chain of 11 amino acids. How many times as many amino acids as Protein B does Protein A have?
- **A** 6
- **B** 16
- **C** 60
- **D** 66

State Resources



For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development

Answers

1. D **2.** H **3.** D
4. H **5.** B **6.** G
7. C **8.** F **9.** C

TEST DOCTOR

Question 1 Students must recognize that electrons are a factor in bonding. Choice **A** is incorrect, because all electrons are the same size. Choices **B** and **C** are incorrect, because neutrons do not affect the bonding properties of atoms. Choice **D** is correct.

Question 6 Students must recognize that the building blocks of proteins are amino acids. Choices **F, H,** and **J** would not produce amino acids in a reaction with enzymes. Choice **G** is correct.

Question 7 Students must know that activation energy is represented by the energy rise on the graph. Choices **A, B,** and **D** are incorrect, because these are considered forms of energy. Choice **C** is correct.

Question 8 Students must understand that catalysts lower the activation energy of a reaction. Students must also read the directions, which explain that the graph shows the energy diagram of a catalyzed reaction. Choice **G** and **H** are incorrect, because the activation energy of the uncatalyzed reaction is much larger than that of the catalyzed reaction. Choice **J** is incorrect because, if the reaction needs a catalyst to proceed, the activation energy would be significantly larger. Choice **F** is correct.

Question 9 Students must know to divide the number of amino acids in Protein A by that in Protein B. Choice **A** is incorrect because an answer of 6 would mean that Protein A has 66 amino acids. Choice **B** is incorrect, because an answer of 16 would mean that Protein A has 176 amino acids. Choice **C** is correct. Protein A has 60 times as many amino acids as Protein B. Choice **D** is incorrect, because an answer of 66 would mean that Protein A has 726 amino acids.