North Carolina grade 8

HOLT SCIENCE & TECHNOLOGY

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Acknowledgments

Contributing Authors

Katy Z. Allen
Science Writer
Wayland, Massachusetts

Kathleen Meehan Berry
Science Chairman
Canon-McMillan School District
Canonsburg, Pennsylvania

Christie Borgford, Ph.D.
Assistant Professor of Chemistry
Department of Chemistry
The University of Alabama
Birmingham, Alabama

Andrew Champagne
Former Physics Teacher
Ashland, Massachusetts

Barbara Christopher
Science Writer and Editor
Austin, Texas

Mapi Cuevas, Ph.D.
Professor of Chemistry
Department of Natural Sciences
Santa Fe Community College
Gainesville, Florida

Jennie Dusheck
Science Writer
Santa Cruz, California

Robert H. Fronk, Ph.D.
Professor
Science and Mathematics Education Department
Florida Institute of Technology
Melbourne, Florida

Kathleen Kaska
Former Life and Earth Science Teacher and Science Department Chair

William G. Lamb, Ph.D.
Winningstad Chair in the Physical Sciences
Oregon Episcopal School
Portland, Oregon

Robert J. Sager, M.S., J.D., L.G.
Coordinator and Professor of Earth Science
Pierce College
Lakewood, Washington

Mark F. Taylor, Ph.D.
Associate Professor of Biology
Biology Department
Baylor University
Waco, Texas

Sally Ann Vonderbrink, Ph.D.
Chemistry Teacher (retired)
Cincinnati, Ohio

North Carolina Teacher Consultants

Pamela B. Heath
Director of Middle Grades Education
Lenoir County Public Schools
Kinston, North Carolina

James Thomas Heldreth III
Science Teacher
Eastern Guilford Middle School
Gibsonville, North Carolina

Brian Herndon
Instructional Specialist
Gaston County Schools
Gastonia, North Carolina

Dorothea Holley
Teacher
Southwest Middle School
Charlotte, North Carolina

Larry Hollis
Earth and Environmental Science Teacher
Southwest Middle School
Charlotte, North Carolina

Beverly Lyons
Science Teacher and Department Chair
Hanes Middle School
Winston-Salem, North Carolina

Donna Roberts
Science Teacher
Concord Middle School
Concord, North Carolina

Patricia Sherron-Underwood
K–8 Math and Science Curriculum Specialist
Curriculum and Instruction Department
Randolph County School District
Asheboro, North Carolina

Carolyn Woolsey
Science Teacher
Southwest Middle School
Charlotte, North Carolina

Inclusion Specialists

Karen Clay
Inclusion Specialist Consultant
Boston, Massachusetts

Ellen McPeek Glisan
Special Needs Consultant
San Antonio, Texas

Safety Reviewer

Jack Gerlovich, Ph.D.
Associate Professor
School of Education
Drake University
Des Moines, Iowa

Academic Reviewers

Kenneth H. Brink, Ph.D.
Senior Scientist and Physical Oceanography Director
Coastal Ocean Institute and Rinehart Coastal Research Center
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

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Contents in Brief

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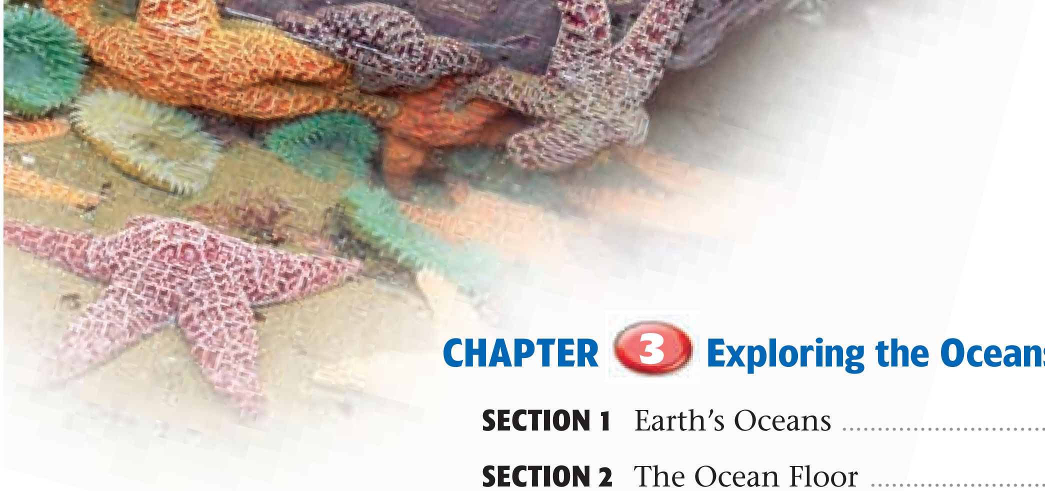

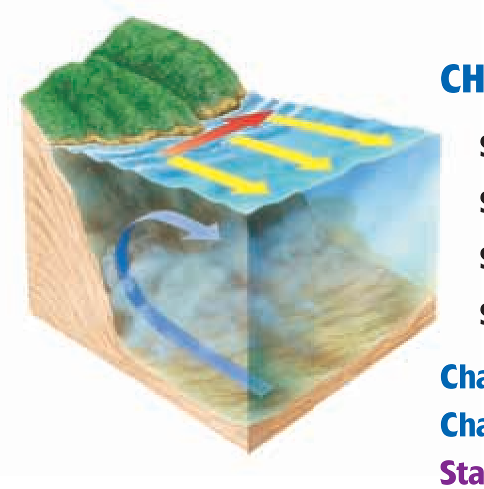

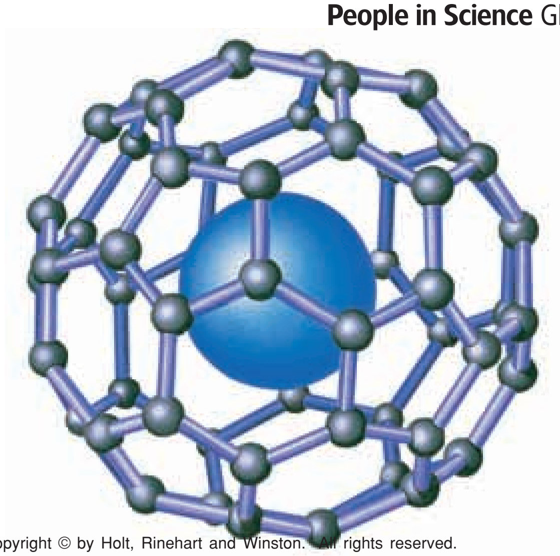

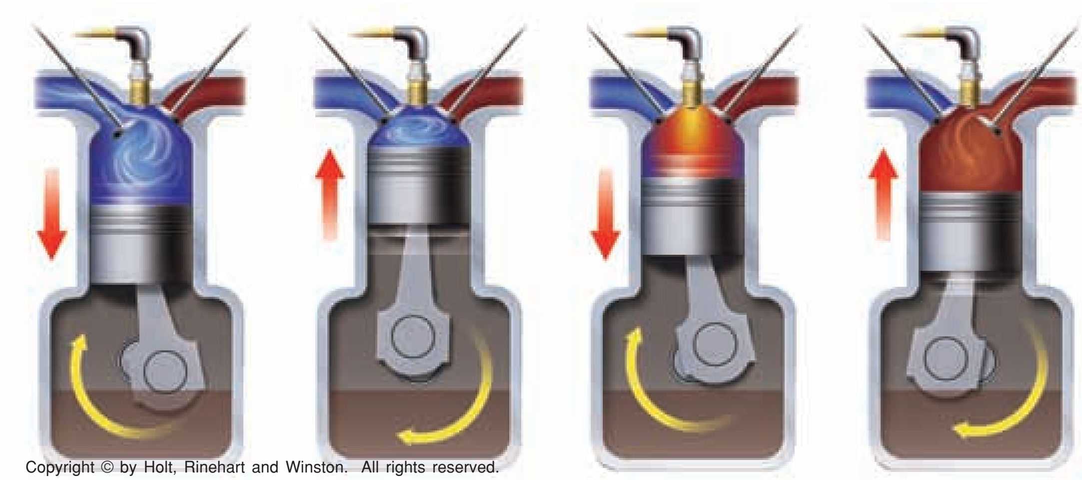

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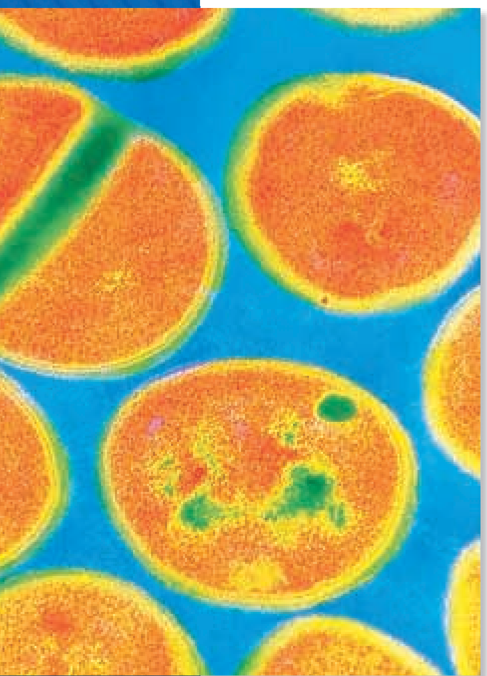
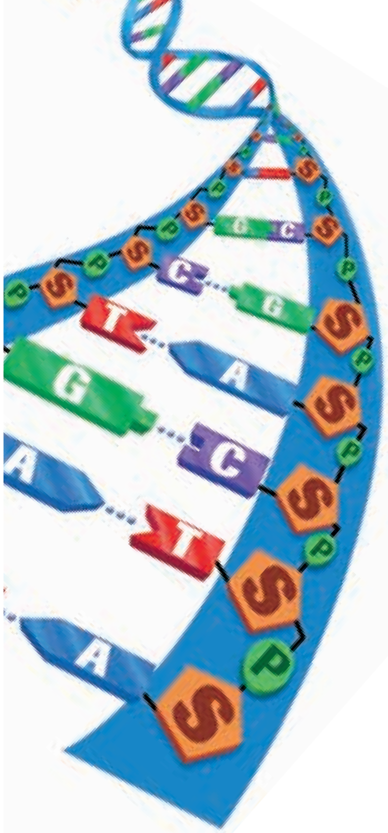
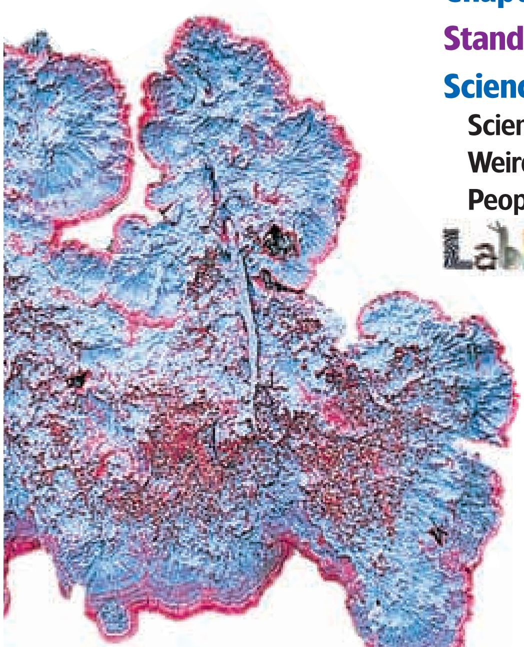
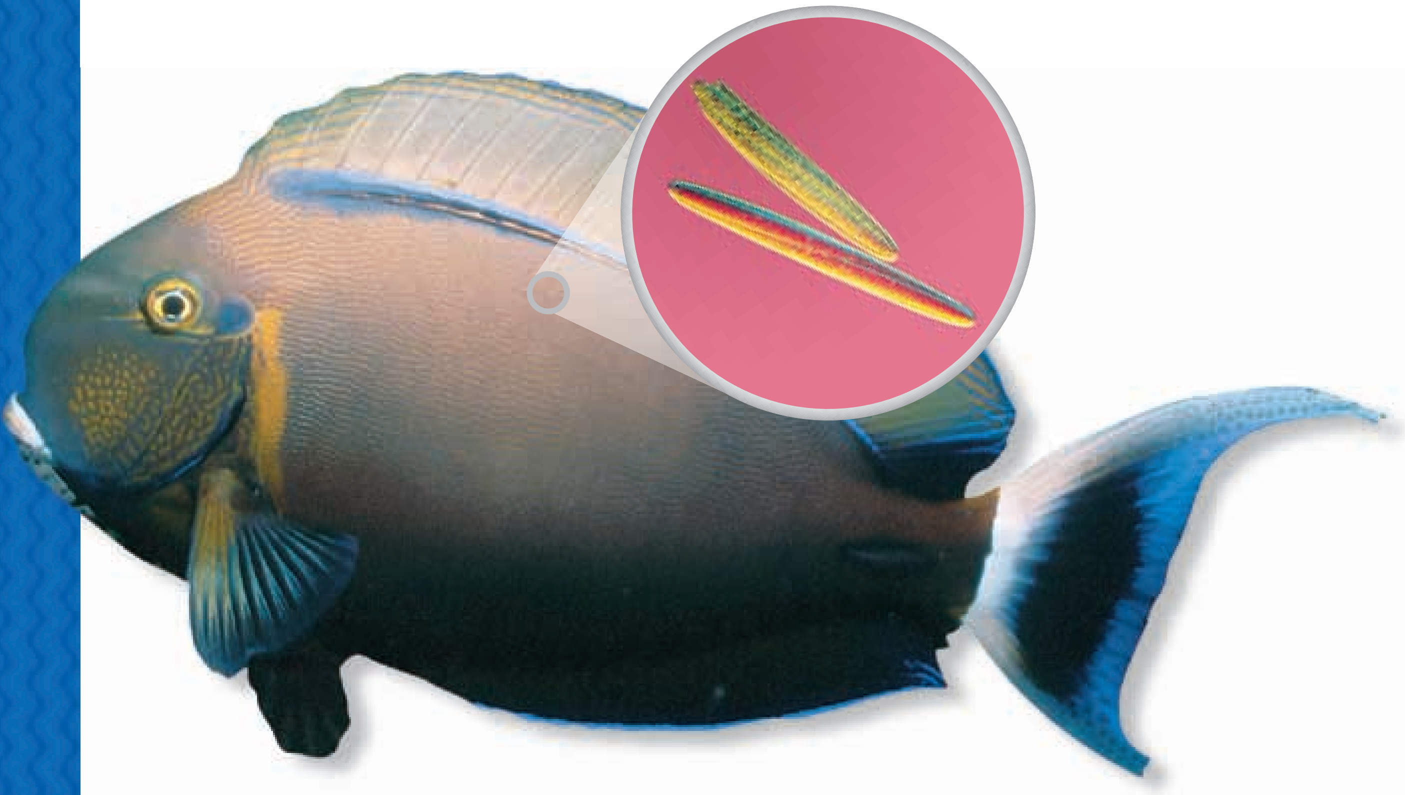




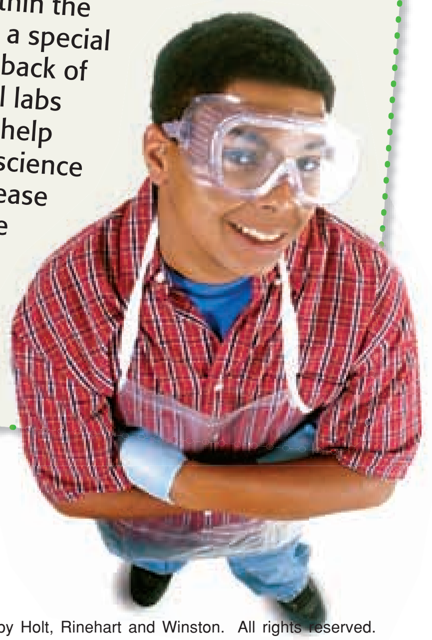




Chapter Labs and LabBook

The more labs, the better!

Take a minute to browse the variety of exciting **labs** in this textbook. Labs appear within the chapters and in a special LabBook in the back of the textbook. All labs are designed to help you experience science firsthand. But please don't forget to be safe. Read the Safety First! section before starting any of the labs.



Start your engines with an activity!

Get motivated to learn by doing the two activities at the beginning of each chapter. The **Pre-Reading Activity** helps you organize information as you read the chapter. The **Start-up Activity** helps you gain scientific understanding of the topic through hands-on experience.

PRE-READING ACTIVITY

FOLDNOTES

Graphic Organizer

START-UP ACTIVITY

READING STRATEGY

Remembering what you read doesn't have to be hard!

A **Reading Strategy** at the beginning of every section provides tips to help you remember and/or organize the information covered in the section.

Quick Lab

School to Home

Activity

Science brings you closer together!

Bring science into your home by doing **School-to-Home Activities** with a parent or another adult in your household.

INTERNET ACTIVITY

Get caught in the Web!

Go to **go.hrw.com** for **Internet Activities** related to each chapter. To find the Internet Activity for a particular chapter, just type in the keyword listed below.

MATH PRACTICE

MATH FOCUS

Science and math go hand in hand.

The **Math Focus** and **Math Practice** items show you many ways that math applies directly to science and vice versa.

Connection to...

One subject leads to another.

You may not realize it at first, but different subjects are related to each other in many ways. Each **Connection** explores a topic from the viewpoint of another discipline. In this way, all of the subjects you learn about in school merge to improve your understanding of the world around you.

Science in Action

Science moves beyond the classroom!

Read **Science in Action** articles to learn more about science in the real world. These articles will give you an idea of how interesting, strange, helpful, and action-packed science is. At the end of each chapter, you will find three short articles. And if your thirst is still not quenched, go to **go.hrw.com** for in-depth coverage.

How to Use Your Textbook

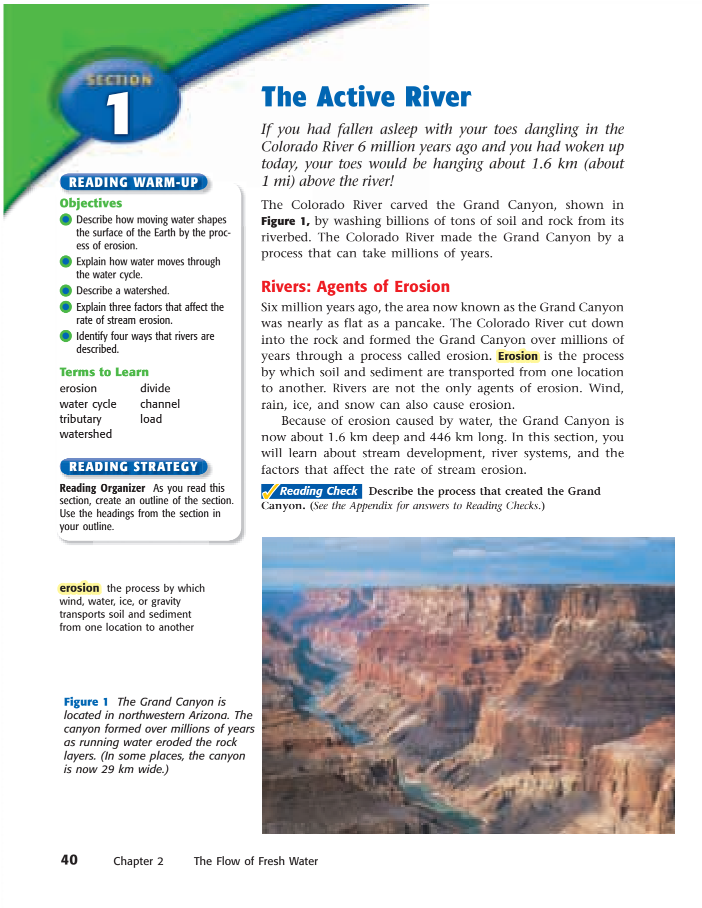
Your Roadmap for Success with Holt Science and Technology

Reading Warm-Up

A Reading Warm-Up at the beginning of every section provides you with the section's objectives and key terms. The objectives tell you what you'll need to know after you finish reading the section.

Key terms are listed for each section. Learn the definitions of these terms because you will most likely be tested on them. Each key term is highlighted in the text and is defined at point of use and in the margin. You can also use the glossary to locate definitions quickly.

STUDY TIP Reread the objectives and the definitions to the key terms when studying for a test to be sure you know the material.


SECTION 1

The Active River

READING WARM-UP

Objectives

- Describe how moving water shapes the surface of the Earth by the process of erosion.
- Explain how water moves through the water cycle.
- Describe a watershed.
- Explain three factors that affect the rate of stream erosion.
- Identify four ways that rivers are described.

Terms to Learn

erosion
water cycle
tributary
watershed
divide
channel
load

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

If you had fallen asleep with your toes dangling in the Colorado River 6 million years ago and you had woken up today, your toes would be hanging about 1.6 km (about 1 mi) above the river!

The Colorado River carved the Grand Canyon, shown in **Figure 1,** by washing billions of tons of soil and rock from its riverbed. The Colorado River made the Grand Canyon by a process that can take millions of years.

Rivers: Agents of Erosion

Six million years ago, the area now known as the Grand Canyon was nearly as flat as a pancake. The Colorado River cut down into the rock and formed the Grand Canyon over millions of years through a process called erosion. **Erosion** is the process by which soil and sediment are transported from one location to another. Rivers are not the only agents of erosion. Wind, rain, ice, and snow can also cause erosion.

Because of erosion caused by water, the Grand Canyon is now about 1.6 km deep and 446 km long. In this section, you will learn about stream development, river systems, and the factors that affect the rate of stream erosion.

Reading Check **Describe the process that created the Grand Canyon.** (*See the Appendix for answers to Reading Checks.*)

erosion the process by which wind, water, ice, or gravity transports soil and sediment from one location to another

Figure 1 *The Grand Canyon is located in northwestern Arizona. The canyon formed over millions of years as running water eroded the rock layers. (In some places, the canyon is now 29 km wide.)*

40 Chapter 2 The Flow of Fresh Water

Get Organized

A Reading Strategy at the beginning of every section provides tips to help you organize and remember the information covered in the section. Keep a science notebook so that you are ready to take notes when your teacher reviews the material in class. Keep your assignments in this notebook so that you can review them when studying for the chapter test.

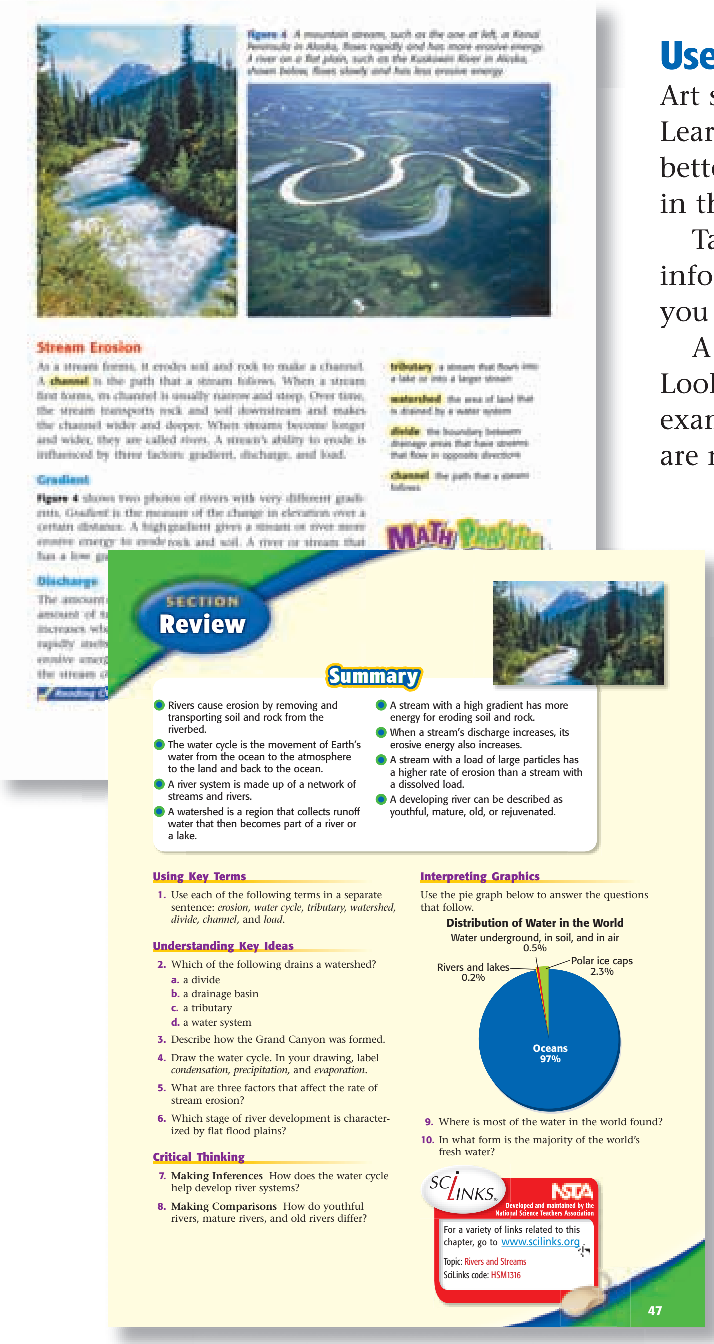
Be Resourceful — Use the Web

Internet Connect

boxes in your textbook take you to resources that you can use for science projects, reports, and research papers. Go to scilinks.org, and type in the SciLinks code to get information on a topic.

Visit go.hrw.com

Find worksheets, **Current Science®** magazine articles online, and other materials that go with your textbook at **go.hrw.com.** Click on the textbook icon and the table of contents to see all of the resources for each chapter.



Use the Illustrations and Photos

Art shows complex ideas and processes. Learn to analyze the art so that you better understand the material you read in the text.

Tables and graphs display important information in an organized way to help you see relationships.

A picture is worth a thousand words. Look at the photographs to see relevant examples of science concepts that you are reading about.

Answer the Section Reviews

Section Reviews test your knowledge of the main points of the section. Critical Thinking items challenge you to think about the material in greater depth and to find connections that you infer from the text.

STUDY TIP When you can't answer a question, reread the section. The answer is usually there.

Do Your Homework

Your teacher may assign worksheets to help you understand and remember the material in the chapter.

STUDY TIP Don't try to answer the questions without reading the text and reviewing your class notes. A little preparation up front will make your homework assignments a lot easier. Answering the items in the Chapter Review will help prepare you for the chapter test.

Holt Online Learning

Visit Holt Online Learning

If your teacher gives you a special password to log onto the Holt Online Learning site, you'll find your complete textbook on the Web. In addition, you'll find some great learning tools and practice quizzes. You'll be able to see how well you know the material from your textbook.

CNN Student News™

Visit CNN Student News

You'll find up-to-date events in science at **cnnstudentnews.com.**

Exploring, inventing, and investigating are essential to the study of science. However, these activities can also be dangerous. To make sure that your experiments and explorations are safe, you must be aware of a variety of safety guidelines. You have probably heard of the saying, "It is better to be safe than sorry." This is particularly true in a science classroom where experiments and explorations are being performed. Being uninformed and careless can result in serious injuries. Don't take chances with your own safety or with anyone else's.

The following pages describe important guidelines for staying safe in the science classroom. Your teacher may also have safety guidelines and tips that are specific to your classroom and laboratory. Take the time to be safe.

Safety Rules!

Start Out Right

Always get your teacher's permission before attempting any laboratory exploration. Read the procedures carefully, and pay particular attention to safety information and caution statements. If you are unsure about what a safety symbol means, look it up or ask your teacher. You cannot be too careful when it comes to safety. If an accident does occur, inform your teacher immediately regardless of how minor you think the accident is.

If you are instructed to note the odor of a substance, wave the fumes toward your nose with your hand. Never put your nose close to the source.

Safety Symbols

All of the experiments and investigations in this book and their related worksheets include important safety symbols to alert you to particular safety concerns. Become familiar with these symbols so that when you see them, you will know what they mean and what to do. It is important that you read this entire safety section to learn about specific dangers in the laboratory.

Eye Safety

Wear safety goggles when working around chemicals, acids, bases, or any type of flame or heating device. Wear safety goggles any time there is even the slightest chance that harm could come to your eyes. If any substance gets into your eyes, notify your teacher immediately and flush your eyes with running water for at least 15 minutes. Treat any unknown chemical as if it were a dangerous chemical. Never look directly into the sun. Doing so could cause permanent blindness.

Avoid wearing contact lenses in a laboratory situation. Even if you are wearing safety goggles, chemicals can get between the contact lenses and your eyes. If your doctor requires that you wear contact lenses instead of glasses, wear eye-cup safety goggles in the lab.

Safety Equipment

Know the locations of the nearest fire alarms and any other safety equipment, such as fire blankets and eyewash fountains, as identified by your teacher, and know the procedures for using the equipment.

Neatness

Keep your work area free of all unnecessary books and papers. Tie back long hair, and secure loose sleeves or other loose articles of clothing, such as ties and bows. Remove dangling jewelry. Don't wear open-toed shoes or sandals in the laboratory. Never eat, drink, or apply cosmetics in a laboratory setting. Food, drink, and cosmetics can easily become contaminated with dangerous materials.

Certain hair products (such as aerosol hair spray) are flammable and should not be worn while working near an open flame. Avoid wearing hair spray or hair gel on lab days.

Sharp/Pointed Objects

Use knives and other sharp instruments with extreme care. Never cut objects while holding them in your hands. Place objects on a suitable work surface for cutting.

Be extra careful when using any glassware. When adding a heavy object to a graduated cylinder, tilt the cylinder so that the object slides slowly to the bottom.

Chemicals

Wear safety goggles when handling any potentially dangerous chemicals, acids, or bases. If a chemical is unknown, handle it as you would a dangerous chemical. Wear an apron and protective gloves when you work with acids or bases or whenever you are told to do so. If a spill gets on your skin or clothing, rinse it off immediately with water for at least 5 minutes while calling to your teacher.

Never mix chemicals unless your teacher tells you to do so. Never taste, touch, or smell chemicals unless you are specifically directed to do so. Before working with a flammable liquid or gas, check for the presence of any source of flame, spark, or heat.

Heat

Wear safety goggles when using a heating device or a flame. Whenever possible, use an electric hot plate as a heat source instead of using an open flame. When heating materials in a test tube, always angle the test tube away from yourself and others. To avoid burns, wear heat-resistant gloves whenever instructed to do so.

Electricity

Be careful with electrical cords. When using a microscope with a lamp, do not place the cord where it could trip someone. Do not let cords hang over a table edge in a way that could cause equipment to fall if the cord is accidentally pulled. Do not use equipment with damaged cords. Be sure that your hands are dry and that the electrical equipment is in the "off" position before plugging it in. Turn off and unplug electrical equipment when you are finished.

Animal Safety

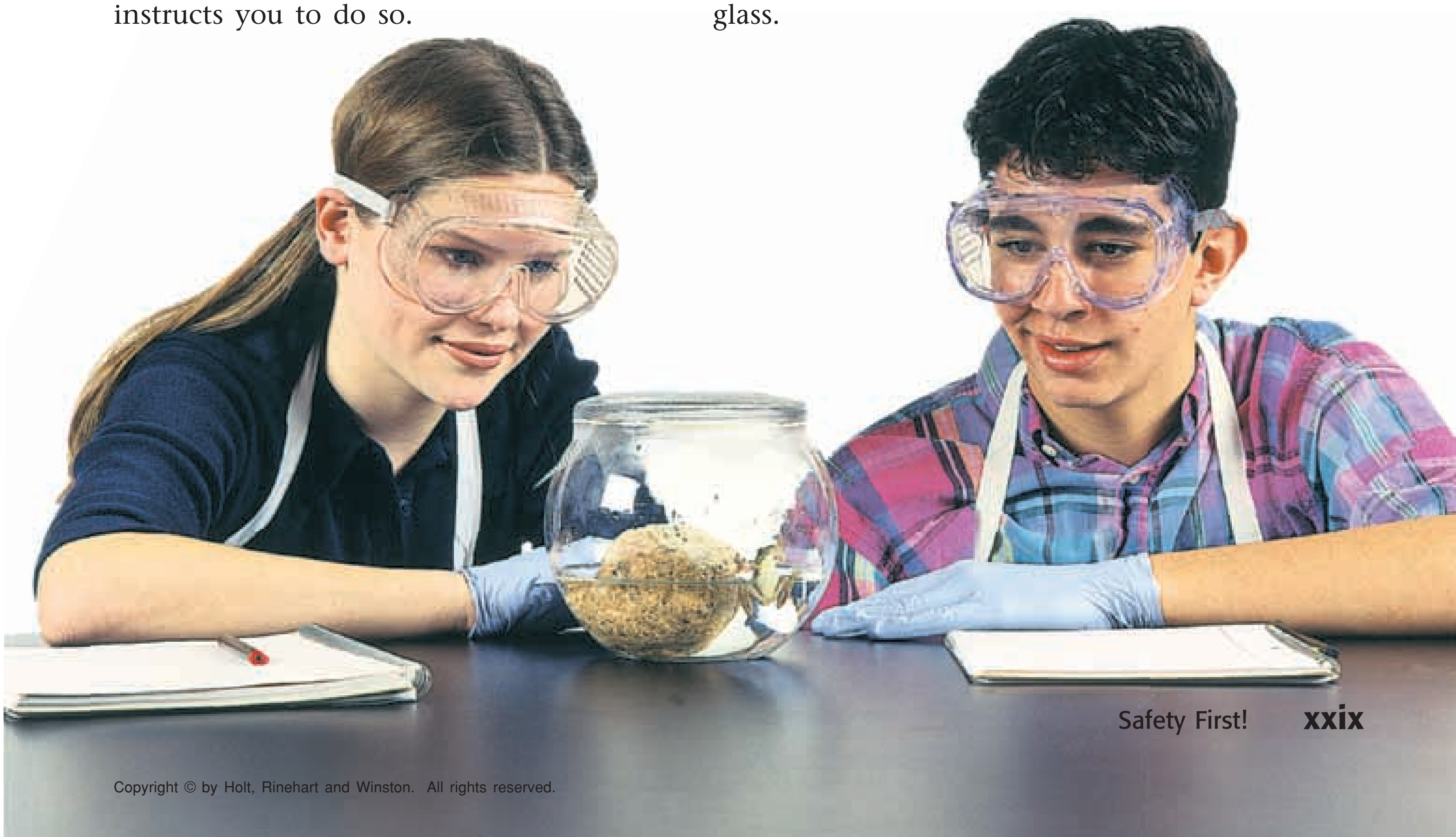
Always obtain your teacher's permission before bringing any animal into the school building. Handle animals only as your teacher directs. Always treat animals carefully and respectfully. Wash your hands thoroughly after handling any animal.

Plant Safety

Do not eat any part of a plant or plant seed used in the laboratory. Wash your hands thoroughly after handling any part of a plant. When in nature, do not pick any wild plants unless your teacher instructs you to do so.

Glassware

Examine all glassware before use. Be sure that glassware is clean and free of chips and cracks. Report damaged glassware to your teacher. Glass containers used for heating should be made of heat-resistant glass.



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Science in Our World

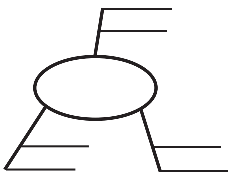
About the PHOTO

Flippers work great to help penguins move through the water. But could flippers help ships, too? Two scientists have been trying to find out. By using scientific methods, they are asking questions such as, "Would flippers use less energy than propellers do?" As a result of these investigations, ships may have flippers like those of penguins someday!

PRE-READING ACTIVITY

Graphic Organizer

Spider Map Before you read the chapter, create the graphic organizer entitled "Spider Map" described in the **Study Skills** section of the Appendix. Label the circle "Scientific Models." Create a leg for each type of scientific model. As you read the chapter, fill in the map with details about each type of scientific model.



START-UP ACTIVITY

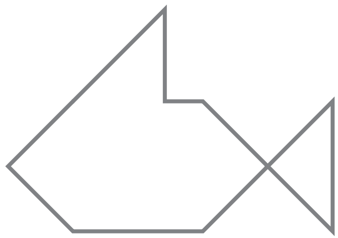
Figure It Out

In this activity, you will make observations and use them to solve a puzzle, just as scientists do.

Procedure

1. Get the **five shapes** shown here from your teacher.

2. Observe the drawing at right. Predict how the five shapes could be arranged to make the fish.



3. Test your idea. You may have to try several times. (Hint: Shapes can be turned over.)

Analysis

1. Did you solve the puzzle just by making observations? What observations helped the most?
2. How did testing your ideas help?

SECTION 1

Science and Scientists

You're eating breakfast. You look down and notice your reflection in your spoon is upside down! You wonder, Why is my reflection upside down even though I'm holding the spoon right side up?

Congratulations! You just completed the first steps of being a scientist. How did you do it? You observed the world around you. Then you asked questions about your observations. And that's part of what science is all about.

READING WARM-UP

Objectives

- Describe three methods of investigation.
- Identify benefits of science in the world around you.
- Describe jobs that use science.

Terms to Learn

science

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Science Starts with a Question

The process of gathering knowledge about the natural world is called **science**. Asking a question is often the first step in the process of gathering knowledge. The world around you is full of amazing things that can lead you to ask questions, such as those in **Figure 1.**

science the knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested

In Your Own Neighborhood

Take a look around your school and around your neighborhood. Most of the time, you take things that you use or see every day for granted. However, one day you might look at something in a new way. That's when a question hits you! The student in **Figure 1** didn't have to look very far to realize that she had some questions to ask.

Figure 1 *Part of science is asking questions about the world around you.*

The World and Beyond

Do you think you might get tired asking questions about things in your neighborhood? Then just remember that the world is made up of many different places. You could ask questions about deserts, forests, or sandy beaches. Many different plants and animals live in each of these places. And then there are the rocks, soil, and flowing water in the environment.

But Earth is not the final place to look for questions. You can look outward to the moon, sun, and planets in our solar system. And beyond that, you have the rest of the universe! There seem to be enough questions to keep scientists busy for a long time.

Investigation: The Search for Answers

Once you ask a question, it's time to find an answer. There are several different methods that you can use to start your investigation.

Figure 2 *A library is a good place to begin your search for answers.*

Research

You can find answers to some of your questions by doing research, as shown in **Figure 2.** You can ask someone who knows a lot about the subject of your question, or you can look up information in textbooks, encyclopedias, and magazines. You can also search on the Internet for information. You can find information by reading about an experiment that someone did. But be sure to think about where the information you find comes from. You want to use information only from reliable sources.

Observation

You can find answers to questions by making careful observations. For example, if you want to know if cloud type and weather are associated, you could make daily observations. By daily recording the types of clouds that you see and the day's weather, you may find associations between the two.

Experimentation

You can answer some of your questions by doing an experiment, as shown in **Figure 3.** Your research might help you plan your experiment. And, you'll need to make careful observations. What do you do if your experiment needs materials or conditions that are hard to get? For example, what do you do if you want to see how a rat runs through a maze in space? Don't give up! Do more research, and try to find the results from someone else's experiment!

Reading Check **What do you do if materials for your experiment are hard to find?** (*See the Appendix for answers to Reading Checks*)

Figure 3 *This student is doing an experiment to find out how her reflection changes in different mirrors.*

Figure 4 *The results of this test are used to improve air bags.*

Why Ask Why?

Although people cannot use science to answer every question, they do find some interesting answers. But do any of the answers really matter? Absolutely! As you study science, you will see how it affects you and everything around you.

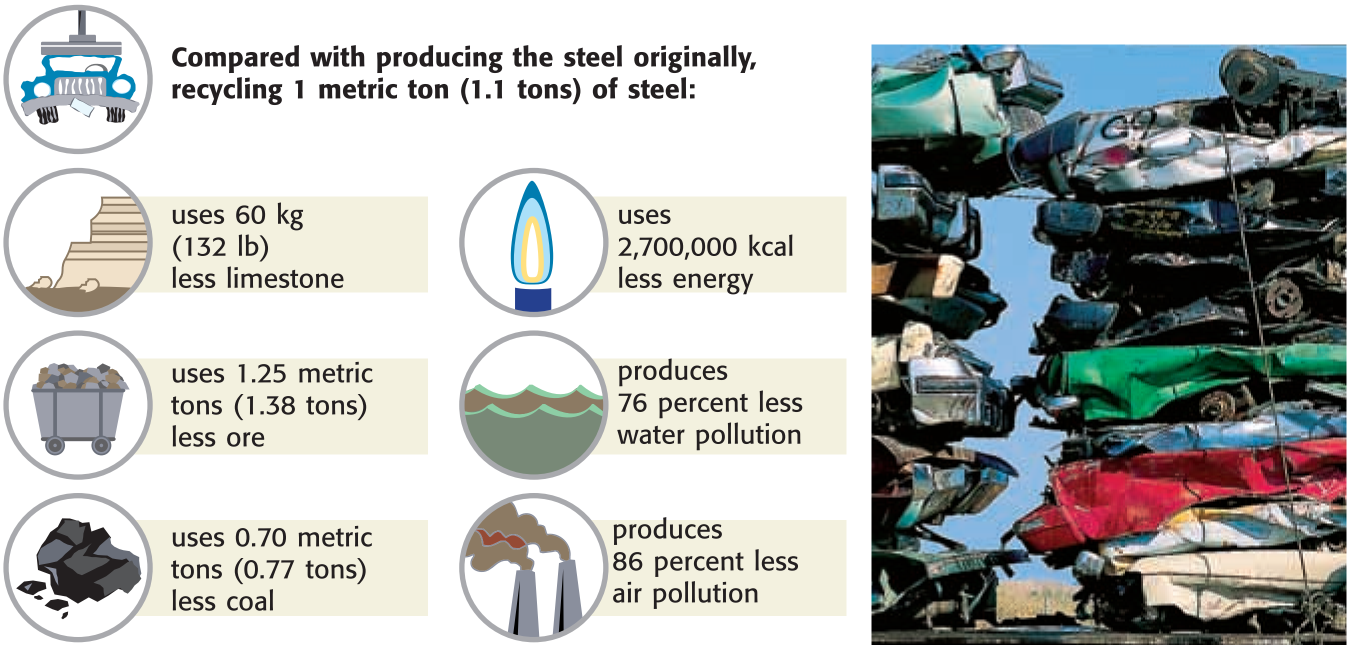
Saving Lives

Using science, people have come up with several answers to the question "How can people be protected during an automobile accident?" One answer is to require people to wear seat belts. Other answers include designing and building cars that are made of stronger materials and that have air bags. **Figure 4** shows how air bags are tested under scientific conditions. In this way, science helps make cars safer.

Saving Resources

Science has also helped answer the question, How can resources be made to last longer? Recycling is one answer. Science has helped people invent ways to recycle a variety of materials. For example, when a car becomes worn out or is wrecked, its steel can be recycled and used to make new products. And recycling steel saves more than just the steel, as shown in **Figure 5.** Using science, people develop more-efficient methods and better equipment for recycling steel, aluminum, paper, glass, and even some plastics. In this way, science helps make resources last longer.

Figure 5 Resources Saved Through Recycling



Saving the Environment

Science has helped answer the question, How can the ozone layer be protected? Substances called chlorofluorocarbons (KLAWR oh FLUR uh KAHR buhnz) (CFCs), which can be found in aerosols, have had a role in damaging the ozone layer. But using science, people have made other substances that can take the place of CFCs. These substances do not harm the ozone layer.

Why does the loss of this layer matter? The ozone that makes up this layer protects everything on the planet from a harmful type of light called ultraviolet (UV) light. Without the protection of the ozone layer, higher levels of UV light will reach the ground. Higher rates of skin cancer could result. By finding ways to reduce the use of these chemicals, we can help protect the environment and make the world a healthier place.

SCHOOL to HOME

Challenging Topics

Although science can be used to explain or answer many questions about the world around us, there are some topics that cannot be examined usefully in a scientific way. With a parent, discuss two or three possible topics that may not be explained by science.

ACTIVITY

Scientists Are All Around You

Believe it or not, scientists work in many different places. If you think about it, any person who asks questions and looks for answers could be called a scientist! Keep reading to learn about just a few jobs that use science.

Meteorologist

A *meteorologist* (MEET ee uhr AHL uh jist) is a person who studies the atmosphere. One of the most common careers that meteorologists have is that of weather forecaster. But some meteorologists specialize in—and even chase—tornadoes! These meteorologists predict where a tornado is likely to form. Then, they drive very near the site to gather data, as shown in **Figure 6.** These data help meteorologists and other scientists understand tornadoes better. A better understanding of tornadoes enables scientists to more accurately predict the behavior of these violent storms. The ability to make more-accurate predictions allows scientists to give earlier warnings of storms, which helps reduce injuries and deaths caused by storms.

Reading Check **What is a meteorologist?**

Figure 6 *These meteorologists are risking their lives to gather data about tornadoes.*

Figure 7 *This geochemist takes rock samples from the field. Then she studies them in her laboratory.*

Geochemist

Look at **Figure 7.** A *geochemist* (JEE oh KEM ist) is a person who specializes in the chemistry of rocks, minerals, and soil. Geochemists determine the economic value of these materials. They also try to find out what the environment was like when these materials formed and what has happened to the materials since they first formed.

Ecologist

To understand the behavior of living things, you also need to know about the surroundings. An *ecologist* (ee KAHL uh jist) is a person who studies a community of organisms and their nonliving environment. Ecologists work in many fields, such as wildlife management, agriculture, forestry, and conservation.

Figure 8 *Volcanologists study volcanoes. Many volcanologists study volcanic patterns in order to predict when a volcano will erupt.*

Volcanologist

Imagine that your workplace was at the edge of 1,000°C pool of lava, as seen in **Figure 8**. That's where you might work if you were a volcanologist! A *volcanologist* (VAHL kuh NAHL uh jist) is a scientist who studies volcanoes. Volcanologists must know the structure and the chemistry of Earth and its rocks. They must also understand how volcanic materials interact with air and water. This knowledge helps volcanologists learn how and why volcanoes erupt. If volcanologists can predict when a volcano will erupt, they can help save lives.

Science Illustrator

You may be surprised to learn that there is a career that uses both art and science skills. *Science illustrators* draw scientific diagrams, such as the one in **Figure 9.**

Science illustrators often have a background in art and a variety of sciences. However, some science illustrators focus on one area of science. For example, some science illustrators draw only medical diagrams. These diagrams are used in medical textbooks, or in brochures that patients receive from their doctors.

Reading Check What is a science illustrator?

Figure 9 *A science illustrator drew this diagram so students can learn about the digestive system in birds.*

SECTION Review

Summary

- Science is the process of gathering knowledge about the natural world.
- Science begins by asking a question.
- Three methods of investigation are research, observation, and experimentation.
- Science affects people's daily lives. Science can help save lives, save resources, and improve the environment.
- There are several types of scientists and many jobs that use science.

Using Key Terms

1. In your own words, write a definition for the term *science*.

Understanding Key Ideas

2. Which of the following items describes what volcanologists must know in order to help them predict the eruption of a volcano?
   a. the structure of Earth
   b. the chemistry of Earth's rocks
   c. the interaction between volcanic material and air
   d. All of the above.
3. Describe three jobs that use science.
4. What are three methods of investigation?
5. Describe how science can help people save resources such as coal.

Math Skills

6. A slow flow of lava is travelling at a rate of 3 m per day. How far will the lava have travelled at the end of 30 days?

Critical Thinking

7. **Applying Concepts** Your friend wants to know the average amount of salt added to her favorite fast-food French fries. What would you recommend that she do to find out the amount of salt?
8. **Making Inferences** The slogan for a package delivery service is "For the fastest shipping from port to port, call Holt Speedy Transport!" What inferences about the service can you make from this slogan? Describe how science could help you figure out whether this service really ships packages faster than other services do.

SECTION 2

Scientific Methods

READING WARM-UP

Objectives

- Identify the steps used in scientific methods.
- Formulate testable hypotheses.
- Explain how scientific methods are used to answer questions and solve problems.

Terms to Learn

scientific methods
observation
technology
hypothesis
data

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember scientific methods.

Imagine that you are trying to improve ships. Would you study the history of shipbuilding? Would you investigate different types of fuel? Would you observe creatures that move easily through the water, such as dolphins and penguins?

Two scientists from the Massachusetts Institute of Technology (MIT) thought that studying penguins was a great way to improve ships! In the next few pages, you'll learn about James Czarnowski (zahr NOW SKEE) and Michael Triantafyllou (tree AHN ti FEE loo). These two scientists from MIT used scientific methods to develop *Proteus* (PROH tee uhs), the penguin boat.

What Are Scientific Methods?

The ways in which scientists answer questions and solve problems are called **scientific methods**. As scientists look for answers, they often use the same steps. But there is more than one way to use the steps. Look at **Figure 1.** Scientists may use all of the steps or just some of the steps during an investigation. They may even repeat some of the steps or do them in a different order. It all depends on what works best to answer their question.

Figure 1 **Scientific Methods**

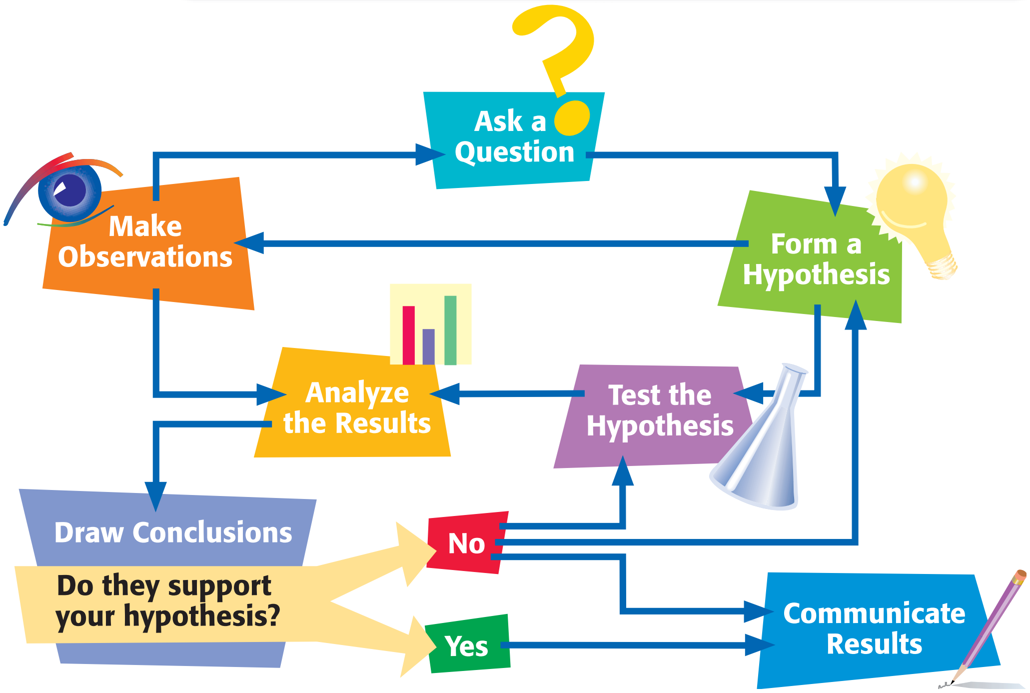


Figure 2 *James Czarnowski (left) and Michael Triantafyllou (right) made observations about how boats work in order to develop Proteus.*

Ask a Question

Asking a question helps focus the purpose of an investigation. Scientists often ask a question after making observations. An **observation** is any use of the senses to gather information. Noting that the sky is blue or that a cotton ball feels soft is an observation. Measurements are observations that are made with tools such as metersticks and stopwatches.

Observations should be accurately recorded so that scientists can use the information in future investigations. In an investigation, if information is not gathered from a large enough number of samples, the study's results may be misleading.

scientific methods a series of steps followed to solve problems, including collecting data, formulating a hypothesis, testing the hypothesis, and stating conclusions

observation the process of obtaining information by using the senses

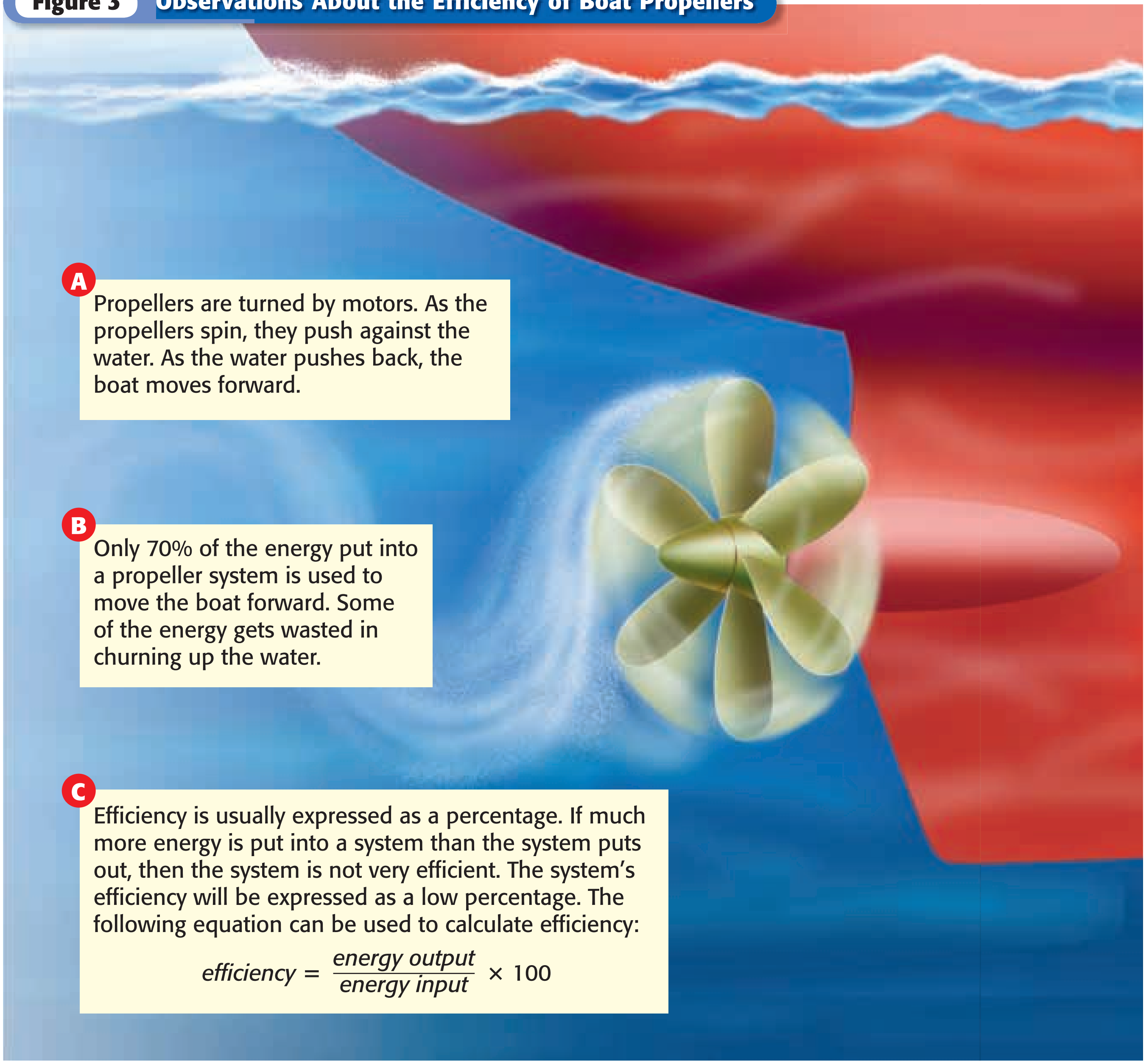
technology the application of science for practical purposes; the use of tools, machines, materials, and processes to meet human needs

A Real-World Question

Czarnowski and Triantafyllou, shown in **Figure 2,** are engineers (EN juh NIRZ), scientists who put scientific knowledge to practical human use. Engineers create **technology** or use science to make tools for practical purposes. Czarnowski and Triantafyllou observed boat propulsion (proh PUHL shuhn) systems, which are what make boats move. Then, they studied ways to improve these systems. Most boats move by using propellers. These engineers studied the efficiency (e FISH uhn see) of boat propulsion systems. *Efficiency* compares energy output (the energy used to move the boat) with energy input (the energy supplied by the engine). The engineers learned from their observations that boat propellers are not very efficient.

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

Figure 3 Observations About the Efficiency of Boat Propellers



A Propellers are turned by motors. As the propellers spin, they push against the water. As the water pushes back, the boat moves forward.

B Only 70% of the energy put into a propeller system is used to move the boat forward. Some of the energy gets wasted in churning up the water.

C Efficiency is usually expressed as a percentage. If much more energy is put into a system than the system puts out, then the system is not very efficient. The system's efficiency will be expressed as a low percentage. The following equation can be used to calculate efficiency:

$$\textit{efficiency} = \frac{\textit{energy output}}{\textit{energy input}} \times 100$$

The Importance of Boat Efficiency

Look at **Figure 3.** Czarnowski and Triantafyllou found that only 70% of the energy put into a propeller system is used to move the boat forward. Why is boat efficiency important? Making only a small fraction of the United States' boats and ships just 10% more efficient would save millions of liters of fuel per year. Saving fuel means saving money. It also means using less of Earth's supply of fossil fuels. Based on their observations and all of this information, Czarnowski and Triantafyllou were ready to ask the following question: How can boat propulsion systems be made more efficient?

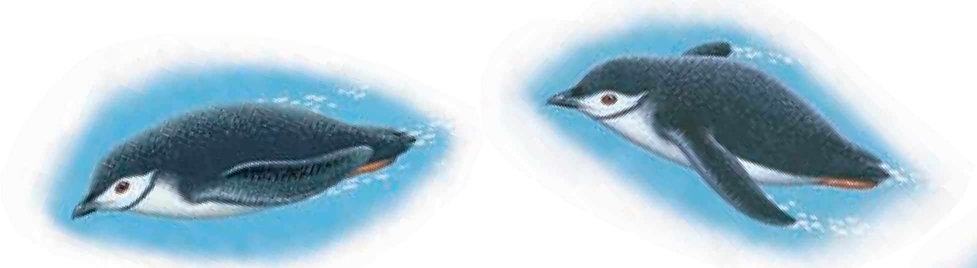


Figure 4 *Penguins use their flippers to "fly" underwater. As they pull their flippers toward their body, they push against the water, which propels them forward.*

Form a Hypothesis

Once you've asked your question and made observations, you are ready to form a *hypothesis*. A **hypothesis** is a possible explanation or answer to a question. You can use what you already know and what you have observed in order to form a hypothesis. A good hypothesis is testable. This means that information can be gathered or an experiment can be designed to test it. A hypothesis that is not testable is not necessarily wrong. But there is no way to support the hypothesis or to show that it is wrong.

hypothesis an explanation that is based on prior scientific research or observations and that can be tested

Nature Provides a Possible Answer

Czarnowski observed how quickly and easily penguins at the New England Aquarium moved through the water. **Figure 4** shows how penguins propel themselves. Czarnowski also observed that penguins have a rigid body, similar to a boat. These observations led to a hypothesis: A propulsion system that mimics the way a penguin swims will be more efficient than a propulsion system that uses propellers.

Make Predictions

Before scientists test a hypothesis, they often make predictions that state what they think will happen during the actual test of the hypothesis. Scientists usually state predictions in an if-then format. The engineers at MIT might have made the following prediction: *If* two flippers are attached to a boat, *then* the boat will be more efficient than a boat powered by propellers.

Reading Check **What is a prediction?**

CONNECTION TO Biology

Not Tested on Humans? Did you know that scientists use people as subjects for certain investigations? Of course, these humans first have to agree to participate! Research and describe the types of investigations that use people. Why is it important to inform each person about the risks and benefits of an investigation?

Quick Lab

That's Swingin'!

1. Make a pendulum. Tie a **piece of string** to a **ring stand.** Hang a **small weight** from the string.
2. Form a testable hypothesis about one factor (such as the mass of the weight) that may affect the rate at which the pendulum swings.
3. Predict the results as you change this factor (the variable).
4. Test your hypothesis. Record the number of swings made in 10 seconds for each trial.
5. Was your hypothesis supported? Analyze your results.

Test the Hypothesis

After you form a hypothesis, you must test it. You must find out whether it is a reasonable answer to your question. Testing helps you find out if your hypothesis is pointing you in the right direction or if it is way off the mark. Often, a scientist will test a prediction that is based on the hypothesis.

Keep It Under Control

One way to test a hypothesis is to do a controlled experiment. A *controlled experiment* compares the results from a control group with the results from one or more experimental groups. The control group and the experimental groups are the same except for one factor. This factor is called a *variable*. The experiment will then show the effect of the variable. If your experiment has more than one variable, determining which variable is responsible for the experiment's results will be difficult or impossible.

Sometimes, such as in a study of the stars, doing a controlled experiment is not possible. In such cases, you can make more observations or do research. Or you may have to build technology that you want to test as a model or model system. That's just what Czarnowski and Triantafyllou did. They built *Proteus*, the penguin boat, shown in **Figure 5.** *Proteus* is 3.4 m long and 50 cm wide, too narrow for even a single passenger.

Math Practice

Number of Observations

Making several observations during an experiment is important because if you based your conclusions on a small number of observations, you may reach the wrong conclusion. Imagine you flipped a coin 3 times, and each time the coin landed heads-up. You might make the generalization, "Every time I flip a quarter, it will land heads-up." But this generalization is dangerous, because if the coin lands tails up even once, your generalization is incorrect. Now, flip a coin 30 times. Can you make a more accurate generalization now? Why?

Figure 5 **Proteus**

Proteus has two flipperlike paddles, called *foils*. Both foils move out and then in, much as a penguin uses its flippers underwater.

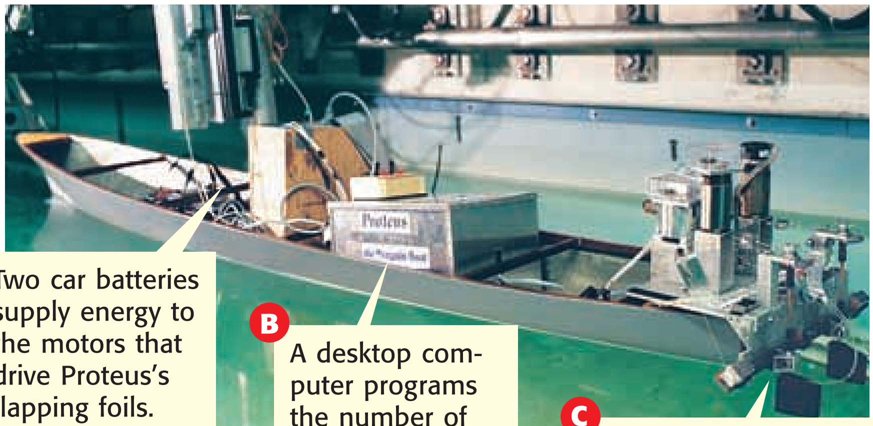
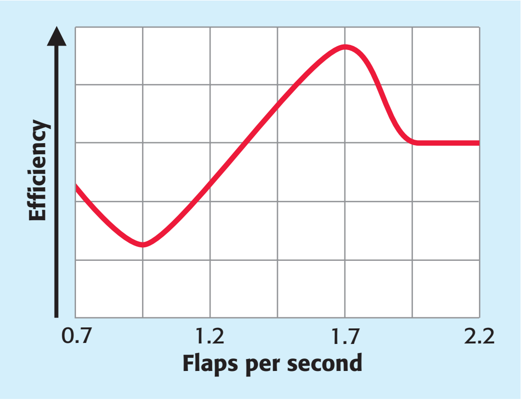
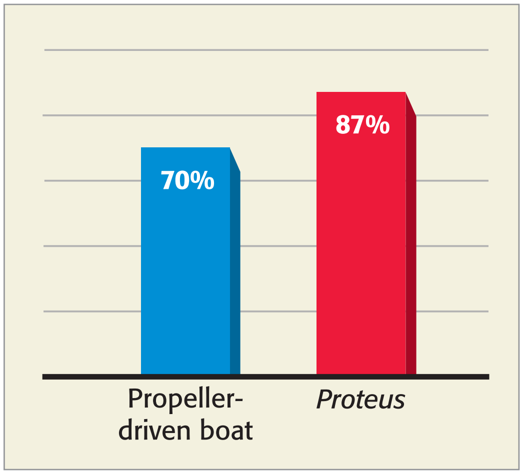


Figure 6 **Graphs of the Test Results**

This line graph shows that *Proteus* was most efficient when its foils were flapping about 1.7 times per second.



This bar graph shows that *Proteus* is 17 percent more efficient than a propeller-driven boat.



Testing *Proteus*

The engineers took *Proteus* into open water when they were ready to collect data. **Data** are pieces of information acquired through experimentation. The number of data samples in an experiment is important. The sample number must be large enough for scientists to be sure that the experiment's results are due to the variable and not to normal variation between samples. The engineers did several tests. Only the flapping rate varied between tests. Data such as the flapping rate, the energy used by the motor, and the boat's speed were recorded for each test. Input energy was determined by how much energy was used. Output energy was determined from *Proteus*'s speed.

data any pieces of information acquired through observation or experimentation

Analyze the Results

Once you have your data, you must analyze them. You must find out whether the results of your test support the hypothesis. You can analyze your results by doing calculations, or by organizing data into tables and graphs.

Reading Check **What must you do after you have your data?**

Analyzing *Proteus*

Czarnowski and Triantafyllou used the data for input energy and output energy to calculate *Proteus*'s efficiency for different flapping rates. These data are graphed in **Figure 6.** The scientists compared *Proteus*'s highest level of efficiency with the average efficiency of a propeller-driven boat. Look at the bar graph in **Figure 6.** Do the data support the original hypothesis?

Figure 7 *Could a penguin propulsion system be used on large ships, such as oil tankers? The research continues!*

CONNECTION TO Social Studies

Biased Samples Sometimes, the samples of data collected during an investigation may be biased. Information shows bias when it is not objective. For example, in the presidential election of 1936, a polling publication determined that Franklin Roosevelt's opponent, Alf Landon, would win the election by a landslide. The pollsters did not realize that their sample had a greater percentage of supporters of Alf Landon than were in the general population. Their information was biased. When President Roosevelt won the election, the pollsters were very surprised. Research the dangers of biased samples and make a poster about what you have learned.

ACTIVITY

Draw Conclusions

At the end of an investigation, you must draw a conclusion. You could conclude that your results support your hypothesis. Or you could conclude that your results do *not* support your hypothesis. Or you might even conclude that you need more information. Your conclusion can help guide what you do next. You could ask new questions or gather more information. You could change the procedure or check your calculations for errors. Or you could do another investigation.

The *Proteus* Conclusion

After analyzing their data, Czarnowski and Triantafyllou did many more trials. Each time they found that the penguin propulsion system was more efficient than a propeller propulsion system. So they concluded that their hypothesis was supported. But this conclusion led to more questions, as you can see in **Figure 7.**

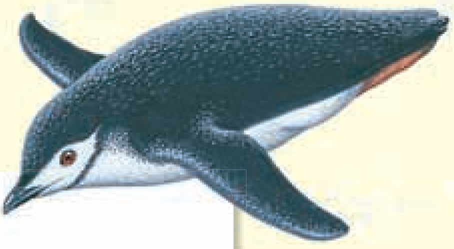
Communicate Results

One of the most important steps in any investigation is to communicate your results accurately and honestly. Accurate reporting ensures the credibility of a scientist. You can communicate your results in a report or on a Web site. People who read your report can reproduce your experiment and verify your data.

Communicating About *Proteus*

Czarnowski and Triantafyllou published their results in academic papers. They also displayed their project and its results on the Internet. In addition, science magazines and newspapers have reported their work. These reports allow you to conduct some research of your own about *Proteus*.

SECTION Review



Summary

- Scientific methods are the ways in which scientists answer questions and solve problems.
- Asking a question helps you focus the purpose of an investigation.
- A hypothesis is a possible answer to a question. A good hypothesis is testable.
- Testing a hypothesis helps you find out if the hypothesis is a reasonable answer to your question.
- Analyzing the data collected during an investigation will help you find out whether the results of your test support your hypothesis.
- Conclusions that you draw from your results will show you if your test supported your hypothesis.
- Communicating your results will allow other scientists to use your investigation for research or conduct an investigation of their own.

Using Key Terms

In each of the following sentences, replace the incorrect term with the correct term from the word bank.

scientific methods	observations
hypotheses	data

1. Hypotheses are any use of the senses to gather information.
2. Data are possible explanations or answers to a question.

Understanding Key Ideas

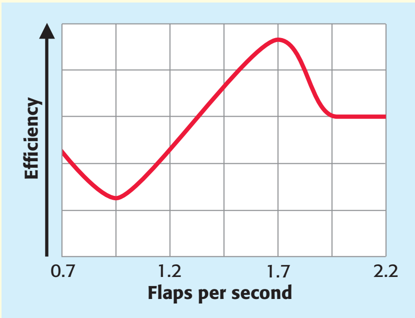
3. The statement, "If I don't study for this test, then I will not get a good grade," is an example of a(n)
   a. law.
   b. theory.
   c. observation.
   d. prediction.
4. How do scientists and engineers use scientific methods?
5. Name the steps that can be used in scientific methods.

Critical Thinking

6. **Analyzing Methods** Explain how a small amount of data cannot prove that a prediction is always correct but can prove that a prediction is NOT always correct.
7. **Applying Concepts** You want to test different shapes of kites to see which shape produces the strongest lift. What are some factors that need to be the same for each trial so that the only variable is the shape of the kite?

Interpreting Graphics

Use the graph below to answer the question that follows.



8. What is the flapping rate at the point of lowest efficiency?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Scientific Methods
SciLinks code: HSM1359

SECTION 3

Scientific Models

How much like a penguin was Proteus? Well, Proteus didn't have feathers and wasn't a living thing. But its "flippers" were designed to create the same kind of motion as a penguin's flippers.

READING WARM-UP

Objectives

- Describe how models are used to represent the natural world.
- Identify three types of scientific models.
- Describe theories and laws.

Terms to Learn

model
theory
law

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

The MIT engineers built *Proteus* to mimic the way a penguin swims. They wanted to get a greater understanding about boat propulsion. In other words, they made a *model*.

Types of Scientific Models

A representation of an object or system is called a **model**. Models often use familiar objects or ideas that stand for other things. That's how a model can be a tool for understanding the natural world. A model uses something familiar to help you understand something that is not familiar. Models can be used to explain the past and the present. They can even be used to predict future events. However, keep in mind that models have limitations. Three major kinds of scientific models are physical, mathematical, and conceptual models.

model a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept

Physical Models

Model airplanes, dolls, and even many drawings are all physical models. Some physical models, such as the model flower in **Figure 1,** look like the thing they model. However, a limitation of the model flower is that it does not grow like a real flower. Other physical models, such as *Proteus*, act somewhat like the thing they model. *Proteus* was a model of how penguins swim. Of course, *Proteus* doesn't eat fish like penguins do!

Figure 1 *The model flower makes learning the different parts of a flower much easier. But the model does not smell as sweet!*

Mathematical Models

Every day, people try to predict the weather. One way that they predict the weather is to use mathematical models. **Figure 2** shows a mathematical model that is expressed as a weather map. A mathematical model is made up of mathematical equations and data. Some mathematical models are simple. These models allow you to calculate things such as forces and acceleration. Others are so complex that only computers can handle them. Some of these very complex models have many variables. Using the most correct data does not make the prediction correct. A change in a variable that was not thought of could cause the model to fail.

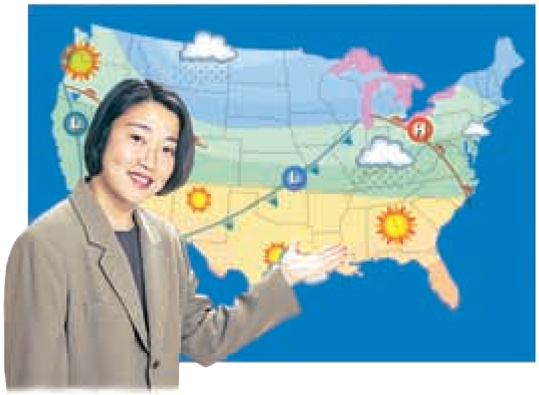


Figure 2 *Weather maps that you see on the evening news are mathematical models.*

Conceptual Models

The third kind of model is a conceptual model. Some conceptual models are systems of ideas. Others are based on making comparisons with familiar things to help illustrate or explain an idea. The big bang theory, illustrated in **Figure 3,** is a conceptual model. This model says that the universe was once a small, hot, and dense volume of matter. Although the big bang theory is widely accepted by astronomers, some data do not quite fit the model. For example, scientists have calculated the ages of some old, nearby stars. If the calculations are right, then some of these stars are older than the universe itself.

Reading Check **What is a conceptual model?** (*See Appendix for answers to Reading Checks.*)

SCHOOL to HOME

Models and Scale

Models are often built to scale. This means that the size of the parts of the model are proportional to the parts of the real object. Make a scale drawing of a room in your home, including some of the objects in the room. Then, exchange drawings with a classmate. Can you determine the actual size of the room and its objects from your classmate's drawing?

ACTIVITY

Figure 3 *The big bang theory says that 12 billion to 15 billion years ago, an event called the big bang sent matter in all directions to eventually form the galaxies and planets.*

Figure 4 *Looking at a model of a cell can show you what is inside an actual cell.*

Models Are Just the Right Size

Models are often used to represent things that are very small or very large. Particles of matter are too small to see. The Earth or the solar system is too large to see completely. In these cases, a model can help you picture the thing in your mind. How can you learn about the parts of a cell? That's not an easy thing to do because you can't see inside a cell with just your eyes. But you can look at a model, such as the one being used by the student in **Figure 4.**

Models Build Scientific Knowledge

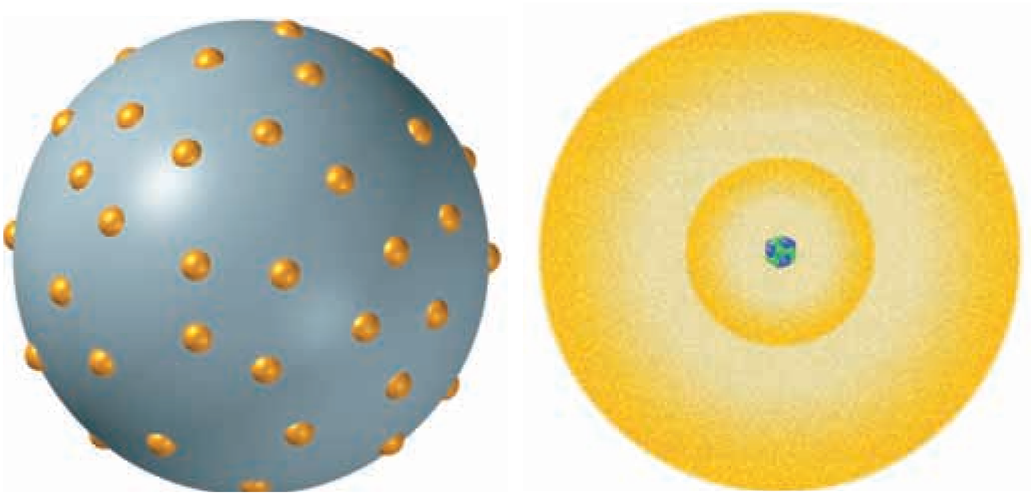
Models are often used to help illustrate and explain scientific theories. In science, a **theory** is a unifying explanation for a broad range of hypotheses and observations that have been supported by testing. A theory not only can explain an observation you've made but also can predict what might happen in the future.

Scientists use models to help guide their search for new information. This information can help support a theory or show it to be wrong. Keep in mind that models can be changed or replaced. These changes happen because new observations that cause scientists to change their theories are made. You can compare an old model with a current one in **Figure 5.**

Reading Check What is a theory?

theory an explanation for some phenomenon that is based on observation, experimentation, and reasoning

law a summary of many experimental results and observations; a law tells how things work.



1897 atomic model

Current atomic model

Figure 5 *These models show the way scientists' idea of the atom has changed over time as new information was gathered.*

Scientific Laws

What happens when a theory and its models correctly predict the results of many different experiments? A scientific law could be formed. In science, a **law** is a summary of many experimental results and observations. A law tells you how things work. Laws are not the same as theories. Laws tell you only what happens, not why it happens.

A law tells you to expect the same thing to happen every time. Look at **Figure 6.** A chemical change took place when the flask was turned over. A light-blue solid and a dark-blue solution formed. Notice that the mass did not change. This is a demonstration of the *law of conservation of mass*. This law says that during a chemical change, the total mass of the materials formed is the same as the total mass of the starting materials. The law describes every single chemical change! However, the law doesn't explain why this happens. It says only that you can be sure that it will happen.

Figure 6 *The total mass before the change is always the same as the total mass after the change.*

SECTION Review

Summary

- A model uses familiar things to describe unfamiliar things.
- Physical, mathematical, and conceptual models are commonly used in science.
- A scientific theory is an explanation for many hypotheses and observations.
- A scientific law summarizes experimental results and observations. It describes what happens, but not why.

Using Key Terms

1. In your own words, write a definition for the term *model*.

Understanding Key Ideas

2. Which kind of model would you use to represent a human heart?
   - **a.** a mathematical model
   - **b.** a physical model
   - **c.** a conceptual model
   - **d.** a natural model
3. Explain the difference between a theory and a law.

Critical Thinking

4. **Analyzing Methods** Both a globe and a flat world map can model features of Earth. Give an example of when you would use each of these models.
5. **Applying Concepts** Identify two limitations of physical models.

Math Skills

6. For a science fair, you want to make a model of the moon orbiting Earth by using a ball. The diameter of the ball that will represent Earth will be about 62 cm. You want your model to be scale. If the moon is about 4 times smaller than Earth, what should the diameter of the ball that represents the moon be?

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Using Models
SciLinks code: HSM1588

SECTION 4

Tools, Measurement, and Safety

READING WARM-UP

Objectives

- Identify tools used to collect and analyze data.
- Explain the importance of the International System of Units.
- Identify the appropriate units to use for particular measurements.
- Identify safety symbols.

Terms to Learn

meter	volume
area	density
mass	temperature

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Would you use a spoon to dig a hole to plant a tree? You wouldn't if you had a shovel!

To dig a hole, you need the correct tools. Scientists use many different tools to help them in their experiments. A *tool* is anything that helps you do a task.

Tools for Measuring

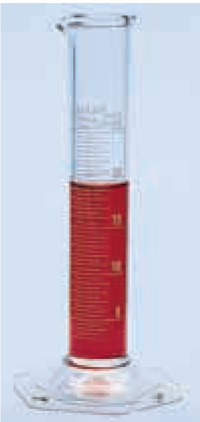
You might remember that one way to collect data is to take measurements. To get the best measurements, you need the proper tools. Stopwatches, metersticks, and balances are some of the tools you can use to make measurements. Thermometers, spring scales, and graduated cylinders are also helpful tools. Some of the uses of these tools are shown in **Figure 1.**

Reading Check **What kinds of tools are used to make measurements?** (*See the Appendix for answers to Reading Checks.*)

Tools for Analyzing

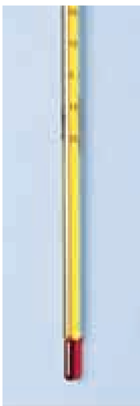
After you collect data, you need to analyze them. Perhaps you need to find the average of your data. Calculators are handy tools to help you do calculations quickly. Or you might show your data in a graph or a figure. You may use a pencil and graph paper or even a computer to graph your data.

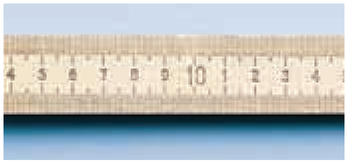
Figure 1 **Measurement Tools**



You can use a **graduated cylinder** to measure volume.

You can use a **thermometer** to measure temperature.





You can use a **meterstick** to measure length.

You can use a **spring scale** to measure force.

You can use a **balance** to measure mass.

You can use a **stopwatch** to measure time.

Measurement

Hundreds of years ago, different countries used different systems of measurement. In England, the standard for an inch used to be three grains of barley placed end to end. Other modern standardized units were originally based on parts of the body, such as the foot. Such systems were not very reliable. Their units were based on objects that had different sizes.

The International System of Units

In time, people saw that they needed a simple and reliable measurement system. In the late 1700s, the French Academy of Sciences set out to make that system. Over the next 200 years, the metric system was formed. This system is now called the International System of Units (SI).

Today, most scientists and almost all countries use the International System of Units. One advantage of using SI measurements is that they help all scientists share and compare their observations and results. Another advantage of SI is that all units are based on the number 10. This makes changing from one unit to another easier. **Table 1** shows SI units for length, volume, mass, and temperature.

MATH PRACTICE

Units of Measure

Pick an object to use as a unit of measure. You can pick a pencil, your hand, or anything else. Find out how many units wide your desk is, and compare your measurement with those of your classmates. What were some of the units used? Now, choose two of the units that were used in your class, and make a conversion factor. For example, 1.5 pencils equal 1 board eraser.

Table 1 **Common SI Units and Conversions**

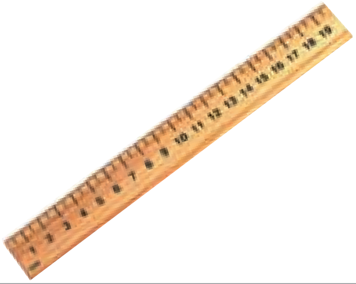
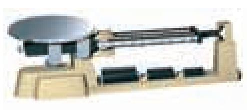
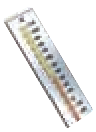
Length 	**meter (m)** kilometer (km) decimeter (dm) centimeter (cm) millimeter (mm) micrometer (µm) nanometer (nm)	1 km = 1,000 m 1 dm = 0.1 m 1 cm = 0.01 m 1 mm = 0.001 m 1 µm = 0.000001 m 1 nm = 0.000000001 m
Volume 	**cubic meter (m^3)** cubic centimeter (cm^3) liter (L) milliliter (mL)	1 cm^3 = 0.000001 m^3 1 L = 1 dm^3 = 0.001 m^3 1 mL = 0.001 L = 1 cm^3
Mass 	**kilogram (kg)** gram (g) milligram (mg)	1 g = 0.001 kg 1 mg = 0.000001 kg
Temperature 	**Kelvin (K)** **Celsius (°C)**	0°C = 273 K 100°C = 373 K

Figure 2 *This scientist is measuring the thickness of an ice sheet.*

Length

How thick is the ice sheet in **Figure 2**? To describe this length, a scientist would probably use meters (m). A **meter** is the basic SI unit of length. Other SI units of length are larger or smaller than the meter by multiples of 10. For example, if you divide 1 m into 1,000 parts, each part equals 1 mm. This means that 1 mm is one-thousandth of a meter. To describe the length of a grain of salt, scientists use micrometers (µm) or nanometers (nm).

meter the basic unit of length in the SI (symbol, m)

area a measure of the size of a surface or a region

mass a measure of the amount of matter in an object; a fundamental property of an object that is not affected by the forces that act on the object, such as the gravitational force

Area

How much wallpaper would you need to cover the walls of your classroom? To answer this question, you must find the area of the walls. **Area** is a measure of how much surface an object has. Area is based on two measurements. To calculate the area of a square or a rectangle, first measure the length and width. Then, use the following equation:

$$area = length \times width$$

The units for area are square units, such as square kilometers (km^2), square meters (m^2), and square centimeters (cm^2).

Mass

How many cars can a bridge support? The answer depends on the strength of the bridge and the mass of the cars. **Mass** is the amount of matter that something is made of. The kilogram (kg) is the basic SI unit for mass. The kilogram is used to describe the mass of a car. The gram is used to describe the mass of small objects. One thousand grams equals 1 kg. A medium-sized apple has a mass of about 100 g. Masses of very large objects are given in metric tons. A metric ton equals 1,000 kg.

Volume

Look at **Figure 3.** Think about moving some bones to a museum. How big would your box need to be? To answer that question, you need to understand volume. **Volume** is the amount of space that something occupies or, as in the case of the box, the amount of space that something contains.

The volume of a liquid is often given in liters (L). Liters are based on the meter. A cubic meter (1 m^3) is equal to 1,000 L. So 1,000 L will fit into a box measuring 1 m on each side. A milliliter (mL) will fit into a box measuring 1 cm on each side. So 1 mL = 1 cm^3. Graduated cylinders are used to measure the volume of liquids.

The volume of a large, solid object is given in cubic meters (m^3). The volumes of smaller objects can be given in cubic centimeters (cm^3) or cubic millimeters (mm^3). To calculate the volume of a box-shaped object, multiply the object's length by its width and then by its height. To find the volume of an irregularly shaped object, measure the volume of liquid that the object displaces. **Figure 4** shows how this method works.

Figure 3 *The box has a volume, so it can hold only a limited number of bones.*

Density

If you measure the mass and the volume of an object, you have the information that you need in order to find the density of the object. **Density** is the amount of matter in a given volume. You cannot measure the density directly. But you can calculate density using the following equation:

$$density = \frac{mass}{volume}$$

Because mass is expressed in grams and volume is expressed in milliliters or cubic centimeters, density can be expressed in grams per milliliter or grams per cubic centimeter.

volume a measure of the size of a body or region in three-dimensional space

density the ratio of the mass of a substance to the volume of the substance; often expressed as grams per cubic centimeter for solids and liquids and as grams per liter for gases

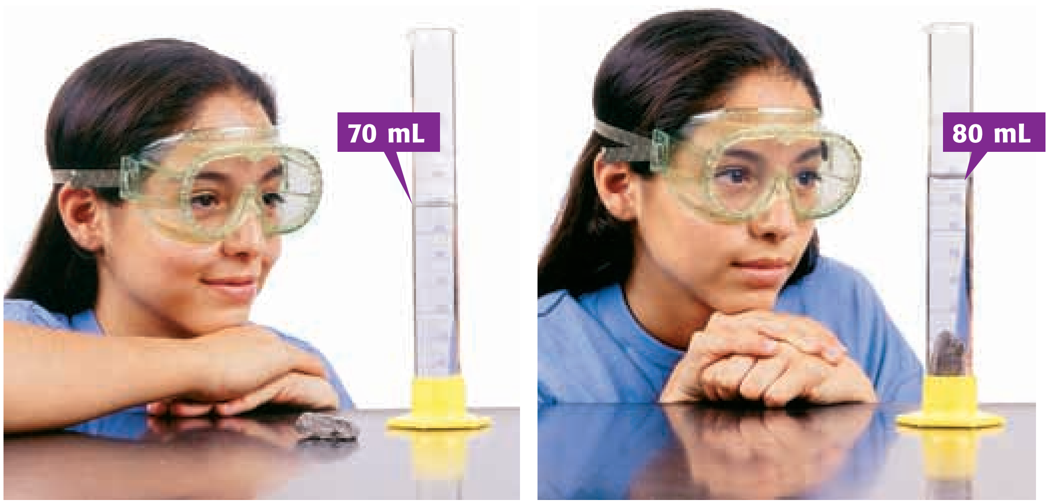


Figure 4 *Adding the rock changes the water level from 70 mL to 80 mL. So, the rock displaces 10 mL of water. Because 1 mL = 1 cm^3, the volume of the rock is 10 cm^3.*

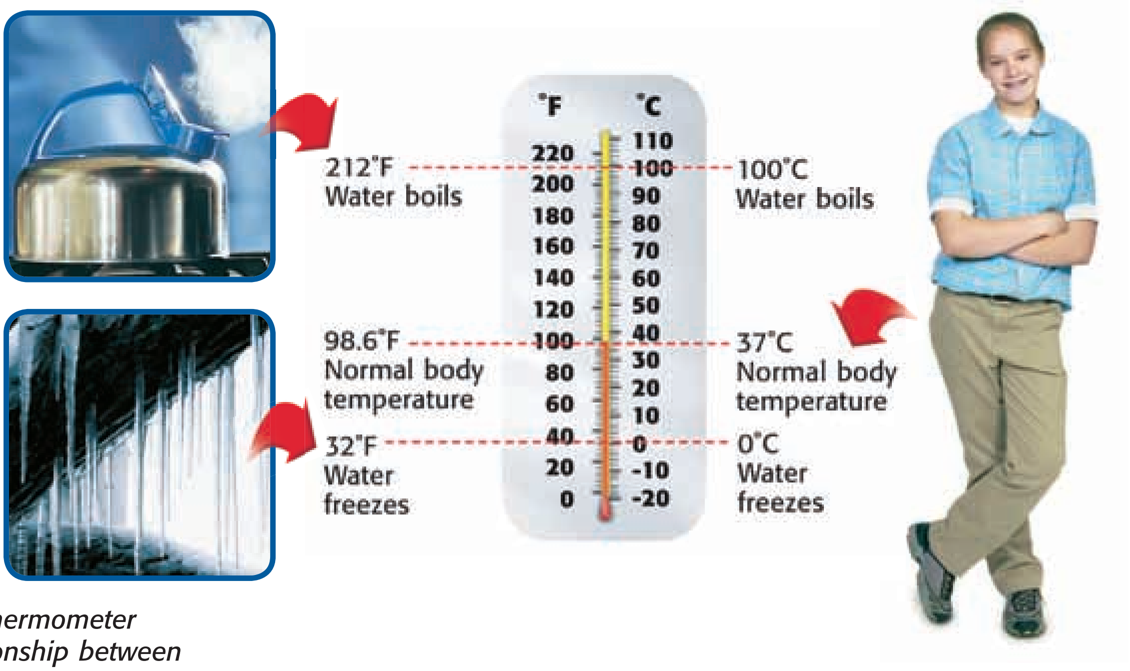


Figure 5 *This thermometer shows the relationship between degrees Fahrenheit and degrees Celsius.*

Temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

Temperature

How hot does it need to be to kill bacteria? How cold does it have to be before mercury freezes? To answer these questions, a scientist would measure the temperature at which bacteria die, or the temperature of the air at which mercury freezes. **Temperature** is a measure of how hot (or cold) something is. You are probably used to describing temperature with degrees Fahrenheit (°F). Scientists often use degrees Celsius (°C). However, kelvins (K), the SI base unit for temperature, is also used. The thermometer in **Figure 5** shows how the Fahrenheit scale compares with the Celsius scale. Degrees Celsius is the unit you will see most often in this book.

Reading Check **What is the SI base unit for temperature?**

CONNECTION TO Social Studies

Thermal Pollution Factories are often built along the banks of rivers. The factories use the river water to cool the engines of their machinery. Then, the hot water is poured back into the river. Energy, in the form of heat, is transferred from this water to the river water. The increase in temperature results in the death of many living things. Research how thermal pollution causes fish to die. Also, find out what many factories are doing to prevent thermal pollution. Make a brochure that explains what thermal pollution is and what is being done to prevent it.

Safety Rules!

Science is exciting and fun, but it can also be dangerous. Always follow your teacher's instructions. Don't take shortcuts, even when you think that there is no danger. Read lab procedures carefully and thoroughly. Pay special attention to safety information and caution statements. **Figure 6** shows the safety symbols used in this book. Learn these symbols and their meanings by reading the safety information at the start of the book. **Knowing the safety information is important!** If you are still not sure about what a safety symbol means, ask your teacher.

Figure 6 **Safety Symbols**

SECTION Review

Summary

- Tools are used to make observations, take measurements, and analyze data.
- The International System of Units (SI) is the standard system of measurement.
- Length, volume, mass, and temperature are quantities of measurement.
- Density is the amount of matter in a given volume.
- Safety symbols are for your protection.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. The length multiplied by the width of an object is the <u>density</u> of the object.
2. The measure of the amount of matter in an object is the <u>area</u>.

Understanding Key Ideas

3. Which SI unit would you use to express the height of your desk?
   a. kilogram
   b. gram
   c. meter
   d. inch
4. Explain the relationship between mass and density.
5. What is normal body temperature in degrees Fahrenheit and degrees Celsius?
6. What tools would you select to find the force needed to move a 1 kg object 1 m in 30 seconds?
7. Explain the importance of having a standard method of measurement such as the SI system.

Math Skills

8. A certain bacterial cell has a diameter of 0.50 µm. The tip of a pin is about 1,100 µm in diameter. How many of these bacterial cells would fit on the tip of the pin?
9. What is the density of lead if a cube measuring 2 cm per side has a mass of 90.8 g?

Critical Thinking

10. **Analyzing Ideas** What safety icons would you see on a lab that asks you to pour acid into a beaker?
11. **Applying Concepts** To find the area of a rectangle, multiply the length by the width. Why is area called a *derived quantity*?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: SI Units
SciLinks code: HSM1390

Skills Practice Lab

Measuring Liquid Volume

OBJECTIVES

Measure accurately different volumes of liquids with a graduated cylinder.

Transfer exact amounts of liquids from a graduated cylinder to a test tube.

MATERIALS

- beakers, filled with colored liquid (3)
- funnel, small
- graduated cylinder, 10 mL
- marker
- tape, masking
- test-tube rack
- test tubes, large (6)

SAFETY

In this lab, you will use a graduated cylinder to measure and transfer precise amounts of liquids. Remember that, to accurately measure liquids in a graduated cylinder, you should first place the graduated cylinder flat on the lab table. Then, at eye level, read the volume of the liquid at the bottom of the meniscus, which is the curved surface of the liquid.

Procedure

1. Using the masking tape and marker, label the test tubes A, B, C, D, E, and F. Place them in the test-tube rack.
2. Make a data table as shown on the next page.
3. Using the graduated cylinder and the funnel, pour 14 mL of the red liquid into test tube A. (To do this, first measure out 10 mL of the liquid in the graduated cylinder, and pour it into the test tube. Then, measure an additional 4 mL of liquid in the graduated cylinder, and add this liquid to the test tube.)
4. Rinse the graduated cylinder and funnel with water each time you measure a different liquid.
5. Measure 13 mL of the yellow liquid, and pour it into test tube C.
6. Measure 13 mL of the blue liquid, and pour it into test tube E. Record the initial color and the volume of the liquid in each test tube.

Data Table

Test tube	Initial color	Initial volume	Final color	Final volume
A				
B				
C				
D				
E				
F				

7. Transfer 4 mL of liquid from test tube C into test tube D. Transfer 7 mL of liquid from test tube E into test tube D.

8. Measure 4 mL of blue liquid from the beaker, and pour it into test tube F. Measure 7 mL of red liquid from the beaker, and pour it into test tube F.

9. Transfer 8 mL of liquid from test tube A into test tube B. Transfer 3 mL of liquid from test tube C into test tube B.

Analyze the Results

1. **Analyzing Data** Record your final color observations in your data table.

2. **Examining Data** What is the final volume of all of the liquids? Use the graduated cylinder to measure the volume of liquid in each test tube. Record the volumes in your data table.

3. **Organizing Data** Record your final color observations and final volumes in a table of class data prepared by your teacher.

Draw Conclusions

4. **Interpreting Information** Did all of your classmates report the same colors? Form a hypothesis that could explain why the colors were the same or different after the liquids were combined.

5. **Evaluating Methods** Why should you not fill the graduated cylinder to the top?

Chapter Review

USING KEY TERMS

1. In your own words, write a definition for each of the following terms: *meter, temperature,* and *density*.

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

2. *science* and *scientific methods*
3. *observation* and *hypothesis*
4. *theory* and *law*
5. *model* and *theory*
6. *volume* and *mass*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Which of the following are methods of investigation?
   - **a.** research
   - **b.** observation
   - **c.** experimentation
   - **d.** All of the above

8. The statement "Sheila has a stain on her shirt" is an example of a(n)
   - **a.** law.
   - **b.** hypothesis.
   - **c.** observation.
   - **d.** prediction.

9. A hypothesis
   - **a.** may or may not be testable.
   - **b.** is supported by evidence.
   - **c.** is a possible answer to a question.
   - **d.** All of the above

10. A variable
    - **a.** is found in an uncontrolled experiment.
    - **b.** is the factor that changes in an experiment.
    - **c.** cannot change.
    - **d.** is rarely included in experiments.

11. Organizing data into a graph is an example of
    - **a.** collecting data.
    - **b.** forming a hypothesis.
    - **c.** asking a question.
    - **d.** analyzing data.

12. How many milliliters are in 3.5 kL?
    - **a.** 0.0035
    - **b.** 3,500
    - **c.** 35,000
    - **d.** 3,500,000

13. A map of Seattle is an example of a
    - **a.** physical model.
    - **b.** mathematical model.
    - **c.** conceptual model.
    - **d.** All of the above

14. Ten meters is equal to
    - **a.** 100 cm.
    - **b.** 1,000 cm.
    - **c.** 100,000 mm.
    - **d.** 1,000 μm.

Short Answer

15. Describe three kinds of models used in science. Give an example and explain one limitation of each model.

16 Name two SI units that can be used to describe the volume of an object and two SI units that can be used to describe the mass of an object.

17 What are the steps used in scientific methods?

18 If a hypothesis is not testable, is the hypothesis wrong? Explain.

Math Skills

19 The cereal box on the right has a mass of 340 g. Its dimensions are 27 cm × 19 cm × 6 cm. What is the volume of the box? What is its density?

CRITICAL THINKING

20 **Concept Mapping** Use the following terms to create a concept map: *science, scientific methods, hypothesis, problems, questions, experiments,* and *observations*.

21 **Applying Concepts** A tailor is someone who makes or alters items of clothing. Why might a standard system of measurement be helpful to a tailor?

22 **Analyzing Ideas** Imagine that you are conducting an experiment. You are testing the effects of the height of a ramp on the speed at which a toy car goes down the ramp. What is the variable in this experiment? What factors must be controlled?

23 **Evaluating Assumptions** Suppose a classmate says, "I don't need to study science because I'm not going to be a scientist, and scientists are the only people who use science." How would you respond? In your answer, give examples of careers that use science.

24 **Making Inferences** You build a model boat that you predict will float. However, your tests show that the boat sinks. What conclusion would you draw? Suggest some logical next steps.

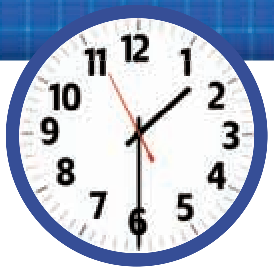
INTERPRETING GRAPHICS

Use the picture below to answer the questions that follow.

25 How similar is this model to a real object?

26 What are some of the limitations of this model?

27 How might this model be useful?



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The white light we see every day is actually composed of all of the colors of the visible spectrum. A laser emits a very small portion of this spectrum, so there can be blue lasers, red lasers, and so on. High-voltage sources called laser "pumps" cause laser materials to emit certain wavelengths of light depending on the material used. A laser material, such as a helium-neon (HeNe) gas mixture, emits radiation (light) as a result of electrons in high energy levels moving to lower energy levels. This process gives lasers their name: **l**ight **a**mplification of the **s**timulated **e**mission of **r**adiation.

1. Why are there blue lasers and red lasers?

A White light is composed of all of the colors of the visible spectrum.

B A laser emits a small portion of the visible spectrum.

C A laser material emits radiation.

D High-voltage sources are called laser "pumps."

2. In this passage, what is the meaning of the word *emit*?

F to brighten

G to compose

H to change

I to give off

3. Why does a laser produce radiation?

A Only a small amount of light is used.

B A laser is a high-voltage pump.

C Light is made up of all of the colors in the visible spectrum.

D Electrons in atoms change energy levels.

Passage 2 Researchers have created a new class of molecules. These molecules are called texaphyrins because of their large size and the five-pointed starlike shape at their center. Texaphyrins are similar to molecules that already exist in most living things. But texaphyrins are different because of their shape and their large size. The shape and large size of the molecules let scientists attach other elements to the molecules. Depending on what element is attached, texaphyrins can be used to locate tumors in the body or to help in treatments for some kinds of cancer.

1. Which of the following statements is true about texaphyrins, according to the passage?

A They were just recently discovered.

B They have the same shape that most natural molecules do.

C They are used to treat certain cancers.

D They are extremely small molecules.

2. In this passage, what is the meaning of the word *class*?

F room

G standing

H rank

I group

3. What is the main advantage of texaphyrin in treating tumors?

A the small size of texaphyrin

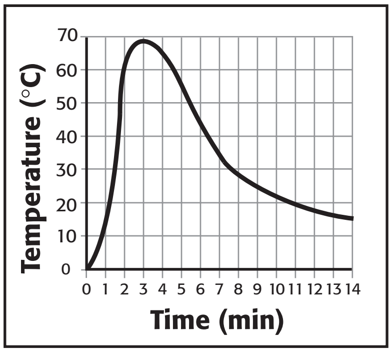
B the star shape of texaphyrin

C the ability to attach to other substances

D the man-made nature of the molecule

INTERPRETING GRAPHICS

The graph below shows the changes in temperature during a chemical reaction. Use the graph below to answer the questions that follow.



1. What was the highest temperature reached during the reaction?
   - **A** 20°C
   - **B** 40°C
   - **C** 50°C
   - **D** 70°C

2. During what period of time was the temperature increasing?
   - **F** between 3 min and 14 min
   - **G** between 0 min and 3 min
   - **H** between 1 min and 13 min
   - **I** between 0 min and 4 min

3. How many minutes did it take the temperature to increase from 10°C to 60°C?
   - **A** less than 1 min
   - **B** 1 min
   - **C** 2 min
   - **D** 3 min

4. About how many minutes passed from the time the highest temperature was reached until the time the temperature decreased to 20°C?
   - **F** 7 min
   - **G** 8 min
   - **H** 11 min
   - **I** 12 min

MATH

Read each question below, and choose the best answer.

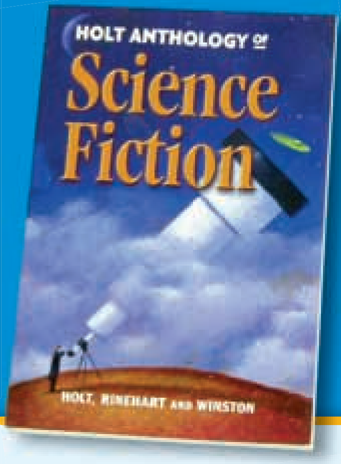
1. What is the volume of a room that is 3.125 m high, 4.25 m wide, and 5.75 m long?
   - **A** 13.1 m
   - **B** 13.1 m^3
   - **C** 76.4 m
   - **D** 76.4 m^3

2. Yukiko has a storage box that measures 12 cm wide, 16.5 cm long, and 10 cm high. It has a mass of 850 g. What is the density of the box?
   - **F** 1,980 cm^3
   - **G** 38.5 cm^3
   - **H** 2.3 g/cm^3
   - **I** .43 g/cm^3

3. Remy traveled to Osaka, Japan, where the unit of currency is the yen. He spent 4,900 yen on train tickets. If the exchange rate was 113 yen to 1 U.S. dollar, approximately how much did the train tickets cost in U.S. dollars?
   - **A** $25
   - **B** $43
   - **C** $49
   - **D** $80

4. Lucia is measuring how fast bacteria grow in a Petri dish by measuring the area that the bacteria cover. On day 1, the bacteria cover 0.25 cm^2. On day 2, they cover 0.50 cm^2. On day 3, they cover 1.00 cm^2. What is the best prediction for the area covered on day 4?
   - **F** 1.25 cm^2
   - **G** 1.50 cm^2
   - **H** 1.75 cm^2
   - **I** 2.00 cm^2

Science in Action



Science Fiction

"Inspiration" by Ben Bova

What if you were able to leap back and forth through time? Novelist H. G. Wells imagined such a possibility in his 1895 novelette *The Time Machine*. Most physicists said that time travel was against all the laws of physics. But what if Albert Einstein, then 16 and not a very good student, had met Wells and had an inspiration? Ben Bova's story "Inspiration" describes such a possibility. Young Einstein meets Wells and the great physicist of the time, Lord Kelvin. But was the meeting just a lucky coincidence or something else entirely? Escape to the *Holt Anthology of Science Fiction,* and read "Inspiration."

Social Studies ACTIVITY

Research the life of Albert Einstein from high school through college. Make a poster that describes some of his experiences during this time. Include information about how he matured as a student.

Weird Science

A Palace of Ice

An ice palace is just a fancy kind of igloo, but it takes a lot of ice and snow to make an ice palace. One ice palace was made from 27,215.5 metric tons of snow and 9,071.85 metric tons of ice! Making an ice palace takes time, patience, and temperatures below freezing. Sometimes, blocks of ice are cut with chain saws from a frozen river or lake and then transported in huge trucks. On location, the huge ice cubes are stacked on each other. Slush is used as mortar between the "bricks." The slush freezes and cements the blocks of ice together. Then, sculptors with chain saws, picks, and axes fashion elegant details in the ice.

Math ACTIVITY

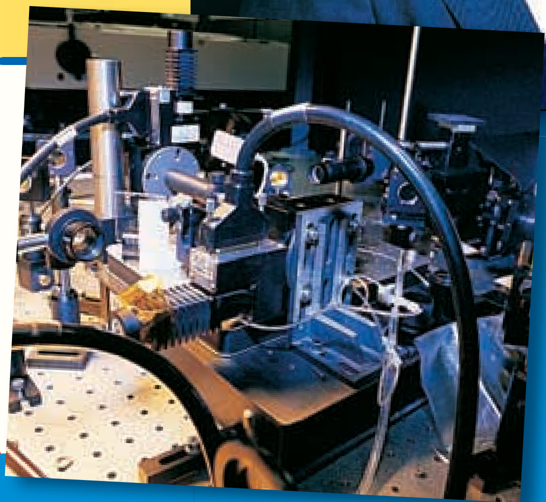
One block of ice used to make the ice palace in the story above has a mass of 181.44 kg. How many blocks of ice were needed to make the ice palace if 9071.85 metric tons of ice was used?

Careers

Julie Williams-Byrd

Electronics Engineer Julie Williams-Byrd uses her knowledge of physics to develop better lasers. She started working with lasers when she was a graduate student at Hampton University in Virginia. Today, Williams-Byrd works as an electronics engineer in the Laser Systems Branch (LSB) of NASA. She designs and builds lasers that are used to study wind and ozone in the atmosphere. Williams-Byrd uses scientific models to predict the nature of different aspects of laser design. For example, laser models are used to predict output energy, wavelength, and efficiency of the laser system.

Her most challenging project has been building a laser transmitter that will be used to measure winds in the atmosphere. This system, called *Lidar,* is very much like radar except that it uses light waves instead of sound waves to bounce off objects. Although Williams-Byrd works with high-tech lasers, she points out that lasers are a part of daily life for many people. For example, lasers are used in scanners at many retail stores. Ophthalmologists use lasers to correct vision problems. Some metal workers use them to cut metal. And lasers are even used to create spectacular light shows!



Language Arts ACTIVITY

WRITING SKILL Research lasers and how they can be used in everyday life. Then, write a one-page essay on how lasers have made life easier for people.

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UNIT 1

TIMELINE

Earth's Water

In this unit, you will learn about Earth's water. There is a limited amount of fresh water available on Earth. In fact, only 3% of Earth's water is drinkable. Most of Earth's water is contained in the oceans. Together, the oceans form the largest single feature on the Earth. Earth's oceans cover approximately 70% of the Earth's surface. The oceans not only serve as home for countless living organisms but also affect life on land. This timeline presents some milestones in the exploration of Earth's oceans. Take a deep breath, and dive in!

1851

Herman Melville's novel *Moby Dick* is published.

1938

A coelacanth is discovered in the Indian Ocean near South Africa. Called a fossil fish, the coelacanth was thought to have been extinct for 60 million years.

1978

Louise Brown, the first "test-tube baby," is born in England.

1986

Commercial whaling is temporarily stopped by the International Whaling Commission, but some whaling continues.

1872

The *HMS Challenger* begins its four-year voyage. Its discoveries lay the foundation for the science of oceanography.

1914

The Panama Canal, which links the Atlantic Ocean with the Pacific Ocean, is completed.

1927

Charles Lindbergh completes the first nonstop solo airplane flight over the Atlantic Ocean.

1943

Jacques Cousteau and Émile Gagnan invent the aqualung, a breathing device that allows divers to freely explore the silent world of the oceans.

1960

Jacques Piccard and Don Walsh dive to a record 10,916 m below sea level in their bathyscaph *Trieste*.

1977

Thermal vent communities of organisms that exist without sunlight are discovered on the ocean floor.

1994

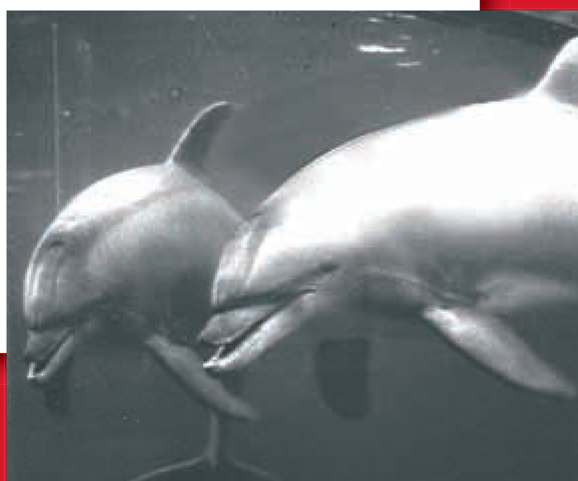
The completion of the tunnel under the English Channel makes train and auto travel between Great Britain and France possible.

1998

Ben Lecomte of Austin, Texas, successfully swims across the Atlantic Ocean from Massachusetts to France, a distance of 5,980 km. His record-breaking feat takes 73 days.

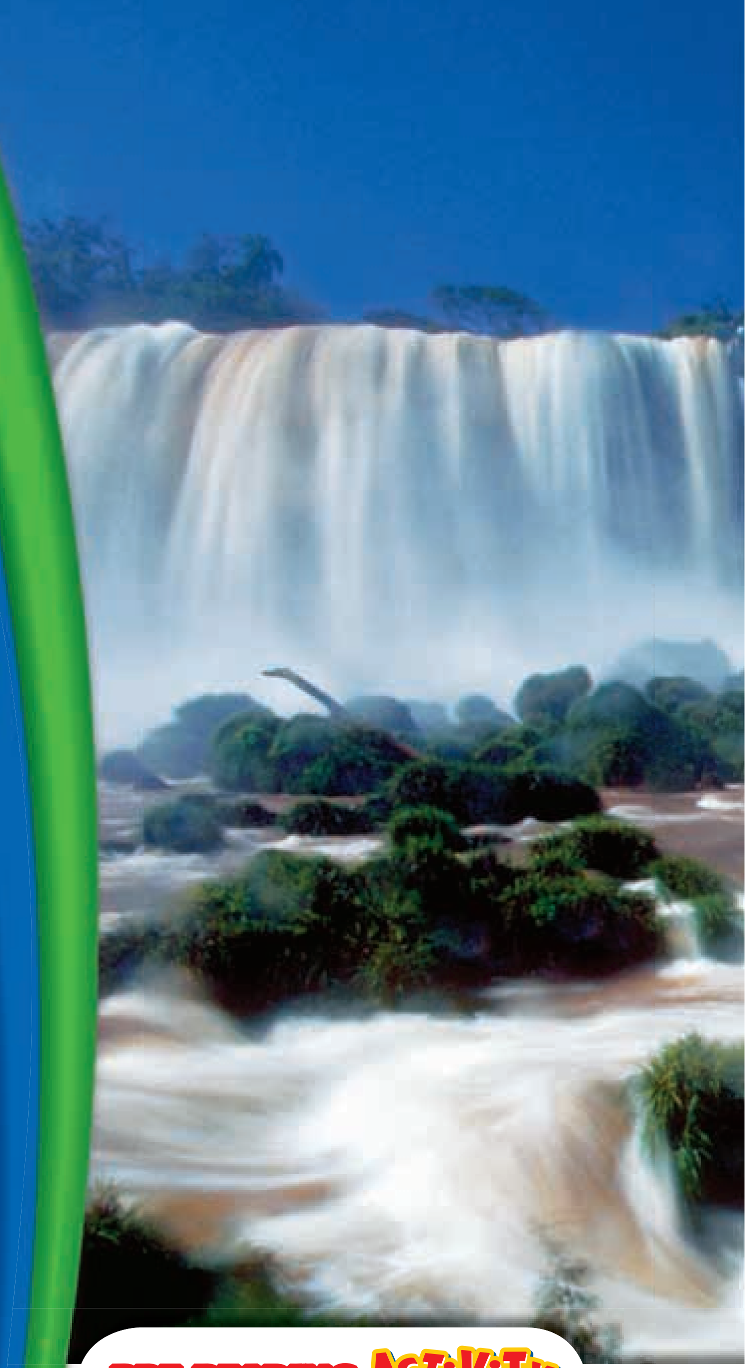
2001

Researchers find that dolphins, like humans and the great apes, can recognize themselves in mirrors.



2

The Flow of Fresh Water



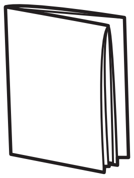
About the PHOTO

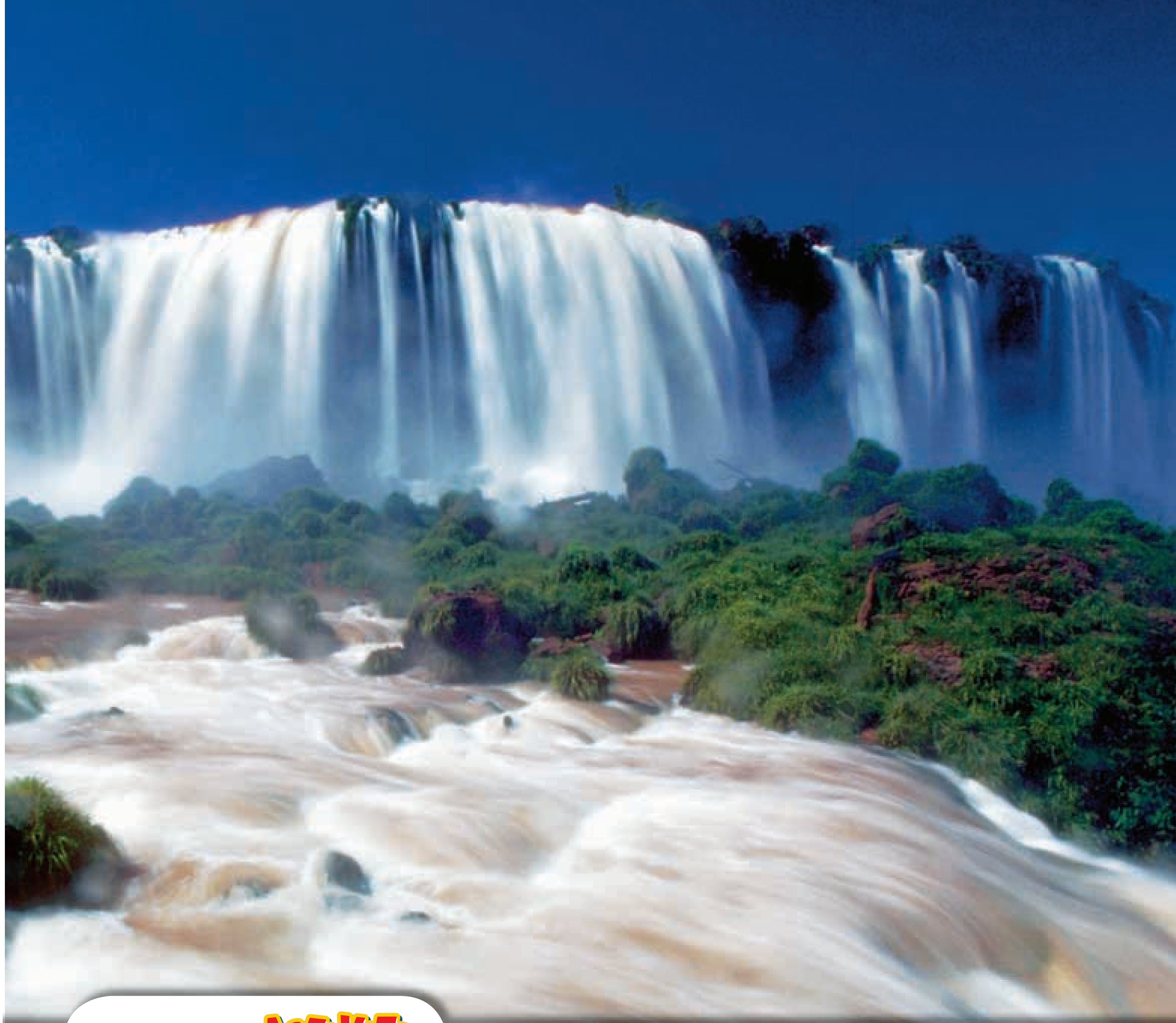
You can hear the roar of Iguaçu (EE gwah SOO) Falls for miles. The Iguaçu River travels more than 500 km across Brazil before it tumbles off the edge of a volcanic plateau in a series of 275 individual waterfalls. Over the past 20,000 years, erosion has caused the falls to move 28 km upstream.

PRE-READING ACTIVITY

FOLDNOTES

Booklet Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.





START-UP ACTIVITY

Stream Weavers

Do the following activity to learn how streams and river systems develop.

Procedure

1. Begin with enough **sand** and **gravel** to fill the bottom of a **rectangular plastic washtub.**
2. Spread the gravel in a layer at the bottom of the washtub. On top of the gravel, place a layer of sand that is 4 cm to 6 cm deep. Add more sand to one end of the washtub to form a slope.
3. Make a small hole in the bottom of a **paper cup.** Attach the cup to the inside wall of the tub with a **clothespin.** The cup should be placed at the end that has more sand.
4. Fill the cup with **water,** and observe the water as it moves over the sand. Use a **magnifying lens** to observe features of the stream more closely.
5. Record your observations.

Analysis

1. At the start of your experiment, how did the moving water affect the sand?
2. As time passed, how did the moving water affect the sand?
3. Explain how this activity modeled the development of streams. In what ways was the model accurate? How was it inaccurate?

SECTION 1

The Active River

If you had fallen asleep with your toes dangling in the Colorado River 6 million years ago and you had woken up today, your toes would be hanging about 1.6 km (about 1 mi) above the river!

READING WARM-UP

Objectives

- Describe how moving water shapes the surface of the Earth by the process of erosion.
- Explain how water moves through the water cycle.
- Describe a watershed.
- Explain three factors that affect the rate of stream erosion.
- Identify four ways that rivers are described.

Terms to Learn

erosion	divide
water cycle	channel
tributary	load
watershed	

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

The Colorado River carved the Grand Canyon, shown in **Figure 1,** by washing billions of tons of soil and rock from its riverbed. The Colorado River made the Grand Canyon by a process that can take millions of years.

Rivers: Agents of Erosion

Six million years ago, the area now known as the Grand Canyon was nearly as flat as a pancake. The Colorado River cut down into the rock and formed the Grand Canyon over millions of years through a process called erosion. **Erosion** is the process by which soil and sediment are transported from one location to another. Rivers are not the only agents of erosion. Wind, rain, ice, and snow can also cause erosion.

Because of erosion caused by water, the Grand Canyon is now about 1.6 km deep and 446 km long. In this section, you will learn about stream development, river systems, and the factors that affect the rate of stream erosion.

Reading Check **Describe the process that created the Grand Canyon.** (*See the Appendix for answers to Reading Checks.*)

erosion the process by which wind, water, ice, or gravity transports soil and sediment from one location to another

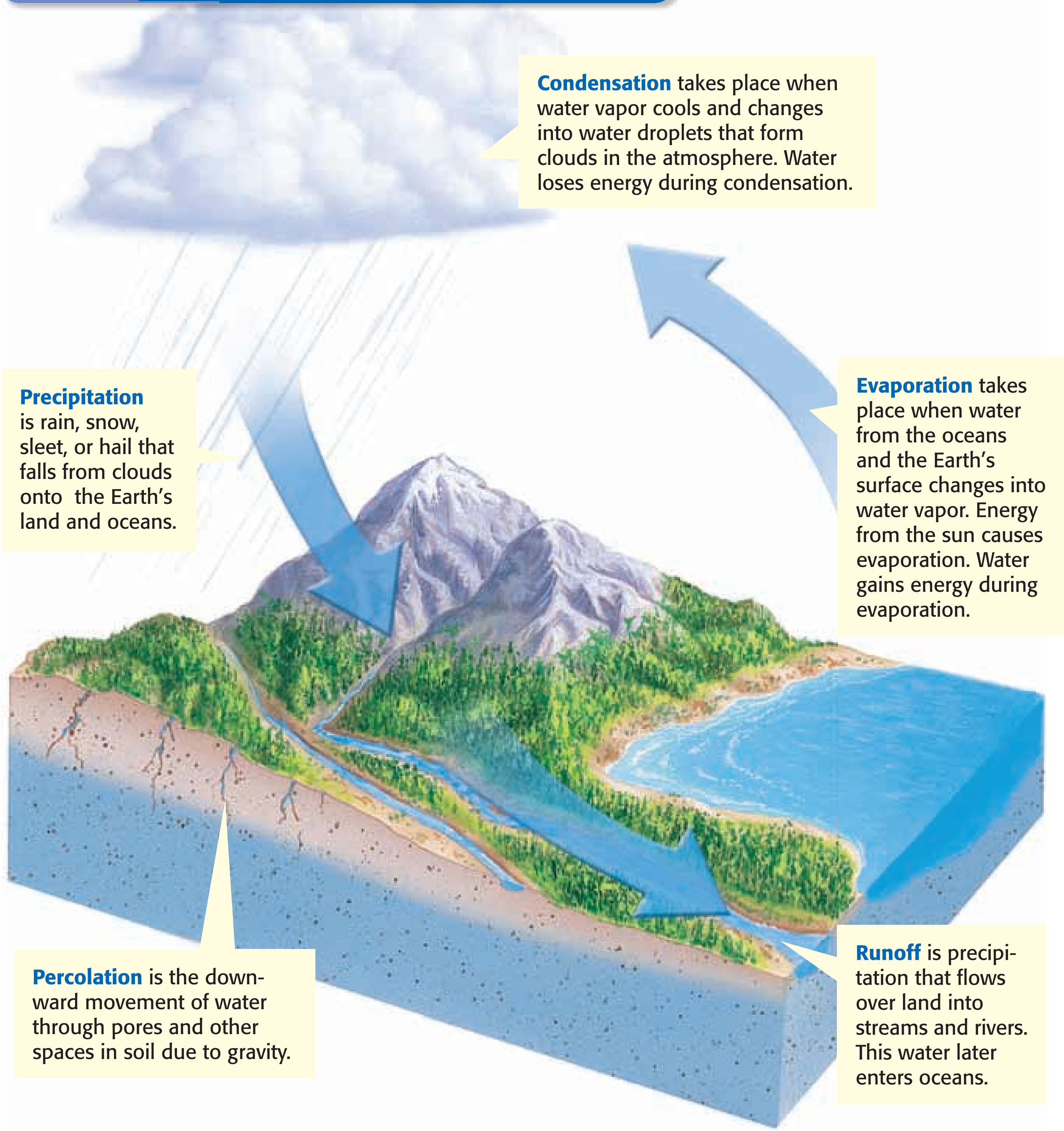
Figure 1 *The Grand Canyon is located in northwestern Arizona. The canyon formed over millions of years as running water eroded the rock layers. (In some places, the canyon is now 29 km wide.)*

The Water Cycle

Have you ever wondered how rivers keep flowing? Where do rivers get their water? Learning about the water cycle, shown in **Figure 2,** will help you answer these questions. The **water cycle** is the continuous movement of Earth's water from the ocean to the atmosphere to the land and back to the ocean. The water cycle is driven by energy from the sun.

water cycle the continuous movement of water from the ocean to the atmosphere to the land and back to the ocean

Figure 2 The Water Cycle



River Systems

The next time you take a shower, notice that individual drops of water join together to become small streams. These streams join other small streams and form larger ones. Eventually, all of the water flows down the drain. Every time you shower, you create a model river system—a network of streams and rivers that drains an area of its runoff. Just as the shower forms a network of flowing water, streams and rivers form a network of flowing water on land. A stream that flows into a lake or into a larger stream is called a **tributary.**

SCHOOL to HOME

Floating down the River

Study a map of the United States at home with a parent. Find the Mississippi River. Imagine that you are planning a rafting trip down the river. On the map, trace the route of your trip from Lake Itasca, Minnesota to the mouth of the river in Louisiana. If you were floating on a raft down the Mississippi River, what major tributaries would you pass? What cities would you pass? Mark them on the map. How many kilometers would you travel on this trip?

ACTIVITY

Watersheds

River systems are divided into regions called watersheds. A **watershed,** or *drainage basin,* is the area of land that is drained by a water system. The largest watershed in the United States is the Mississippi River watershed. The Mississippi River watershed has hundreds of tributaries that extend from the Rocky Mountains, in the West, to the Appalachian Mountains, in the East.

The satellite image in **Figure 3** shows that the Mississippi River watershed covers more than one-third of the United States. Other major watersheds in the United States are the Columbia River, Rio Grande, and Colorado River watersheds. Watersheds are separated from each other by an area of higher ground called a **divide.**

Reading Check **Describe the difference between a watershed and a divide.**

Figure 3 *The Continental Divide runs through the Rocky Mountains. It separates the watersheds that flow into the Atlantic Ocean and the Gulf of Mexico from those that flow into the Pacific Ocean.*

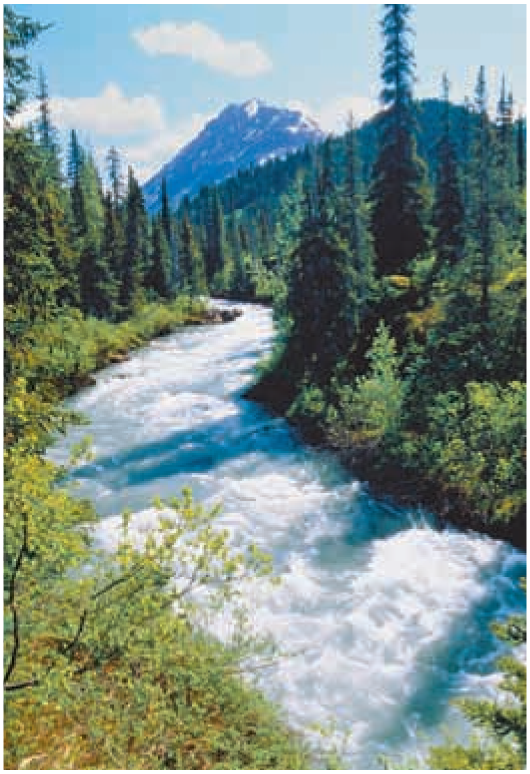


Figure 4 *A mountain stream, such as the one at left, at Kenai Peninsula in Alaska, flows rapidly and has more erosive energy. A river on a flat plain, such as the Kuskowin River in Alaska, shown below, flows slowly and has less erosive energy.*

Stream Erosion

As a stream forms, it erodes soil and rock to make a channel. A **channel** is the path that a stream follows. When a stream first forms, its channel is usually narrow and steep. Over time, the stream transports rock and soil downstream and makes the channel wider and deeper. When streams become longer and wider, they are called *rivers*. A stream's ability to erode is influenced by three factors: gradient, discharge, and load.

tributary a stream that flows into a lake or into a larger stream

watershed the area of land that is drained by a water system

divide the boundary between drainage areas that have streams that flow in opposite directions

channel the path that a stream follows

Gradient

Figure 4 shows two photos of rivers with very different gradients. *Gradient* is the measure of the change in elevation over a certain distance. A high gradient gives a stream or river more erosive energy to erode rock and soil. A river or stream that has a low gradient has less energy for erosion.

Discharge

The amount of water that a stream or river carries in a given amount of time is called *discharge*. The discharge of a stream increases when a major storm occurs or when warm weather rapidly melts snow. As the stream's discharge increases, its erosive energy and speed and the amount of materials that the stream can carry also increase.

Reading Check **What factors cause a stream to flow faster?**

MATH PRACTICE

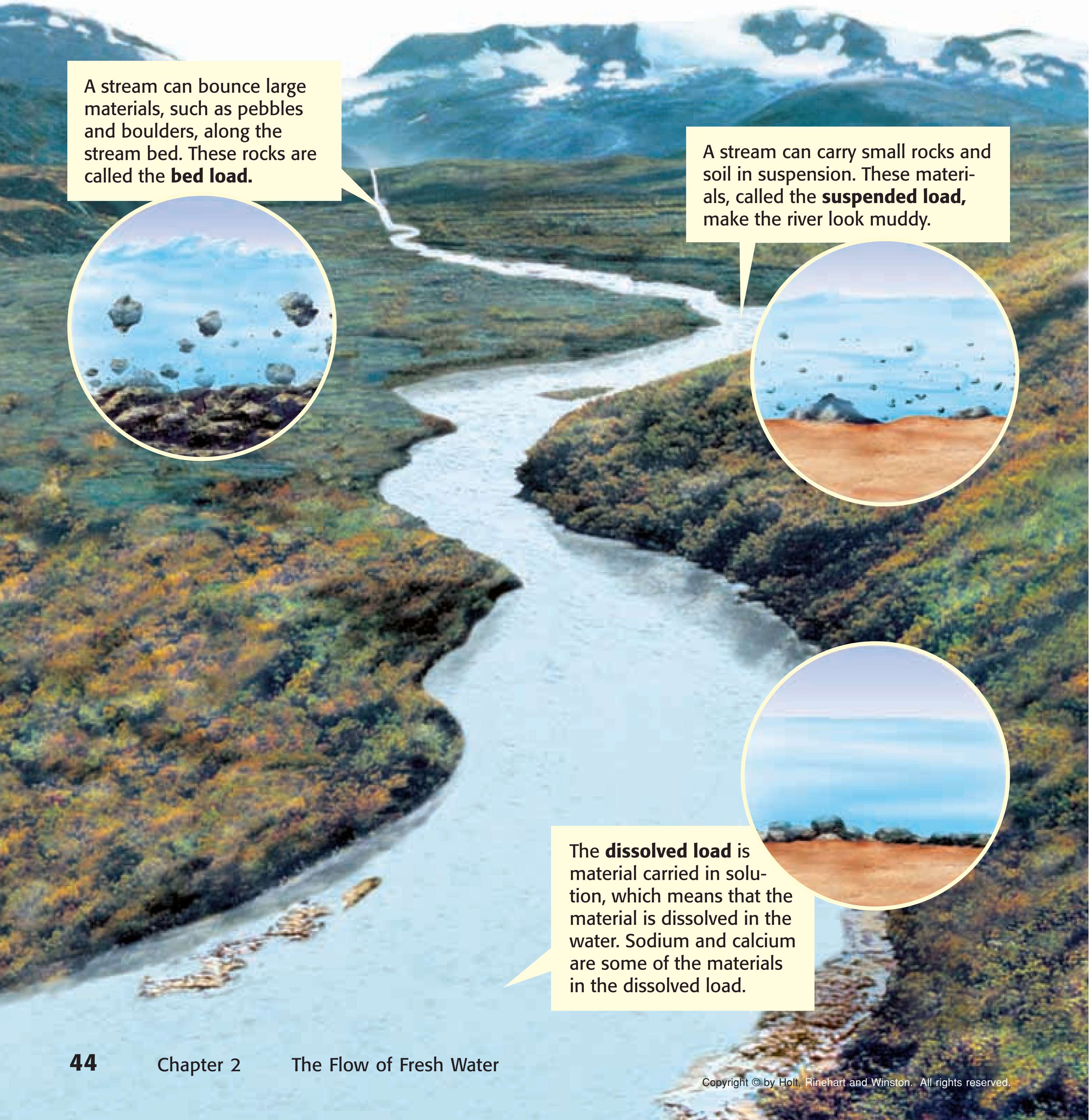
Calculating a Stream's Gradient

If a stream starts at an elevation of 4,900 m and travels 450 km downstream to a lake that is at an elevation of 400 m, what is the stream's gradient? (Hint: Subtract the final elevation from the starting elevation, and divide by 450. Don't forget to keep track of the units.)

load the materials carried by a stream

Load

The materials carried by a stream are called the stream's **load.** The size of a stream's load is affected by the stream's speed. Fast-moving streams can carry large particles. Rocks and pebbles bounce and scrape along the bottom and sides of the stream bed. Thus, the size of a stream's load also affects its rate of erosion. The illustration below shows the three ways that a stream can carry its load.



The Stages of a River

In the early 1900s, William Morris Davis developed a model for the stages of river development. According to his model, rivers evolve from a youthful stage to an old-age stage. He thought that all rivers erode in the same way and at the same rate.

Today, scientists support a different model that considers factors of stream development that differ from those considered in Davis's model. For example, because different materials erode at different rates, one river may develop more quickly than another river. Many factors, including climate, gradient, and load, influence the development of a river. Scientists no longer use Davis's model to explain river development, but they still use many of his terms to describe a river. These terms describe a river's general features, not a river's actual age.

CONNECTION TO Language Arts

Huckleberry Finn Mark Twain's famous book, *The Adventures of Huckleberry Finn,* describes the life of a boy who lived on the Mississippi River. Mark Twain's real name was Samuel Clemens. Do research to find out why Clemens chose to use the name Mark Twain and how the name relates to the Mississippi River.

Youthful Rivers

A youthful river, such as the one shown in **Figure 5,** erodes its channel deeper rather than wider. The river flows quickly because of its steep gradient. Its channel is narrow and straight. The river tumbles over rocks in rapids and waterfalls. Youthful rivers have very few tributaries.

Figure 5 *This youthful river is located in Yellowstone National Park in Wyoming. Rapids and falls are found where the river flows over hard, resistant rock.*

Mature Rivers

A mature river, as shown in **Figure 6,** erodes its channel wider rather than deeper. The gradient of a mature river is not as steep as that of a youthful river. Also, a mature river has fewer falls and rapids. A mature river is fed by many tributaries. Because of its good drainage, a mature river has more discharge than a youthful river.

Reading Check **What are the characteristics of a mature river?**

Figure 6 *A mature river, such as this one in the Amazon basin of Peru, curves back and forth. The bends in the river's channel are called* meanders.

Figure 7 *This old river is located in New Zealand.*

Old Rivers

An old river has a low gradient and little erosive energy. Instead of widening and deepening its banks, the river deposits rock and soil in and along its channel. Old rivers, such as the one in **Figure 7,** are characterized by wide, flat *flood plains*, or valleys, and many bends. Also, an old river has fewer tributaries than a mature river because the smaller tributaries have joined together.

Rejuvenated Rivers

Rejuvenated (ri JOO vuh NAYT ed) rivers are found where the land is raised by tectonic activity. When land rises, the river's gradient becomes steeper, and the river flows more quickly. The increased gradient of a rejuvenated river allows the river to cut more deeply into the valley floor. Steplike formations called *terraces* often form on both sides of a stream valley as a result of rejuvenation. Can you find the terraces in **Figure 8**?

Reading Check **How do rejuvenated rivers form?**

Figure 8 *This rejuvenated river is located in Canyonlands National Park in Utah.*

SECTION Review

Summary

- Rivers cause erosion by removing and transporting soil and rock from the riverbed.
- The water cycle is the movement of Earth's water from the ocean to the atmosphere to the land and back to the ocean.
- A river system is made up of a network of streams and rivers.
- A watershed is a region that collects runoff water that then becomes part of a river or a lake.
- A stream with a high gradient has more energy for eroding soil and rock.
- When a stream's discharge increases, its erosive energy also increases.
- A stream with a load of large particles has a higher rate of erosion than a stream with a dissolved load.
- A developing river can be described as youthful, mature, old, or rejuvenated.

Using Key Terms

1. Use each of the following terms in a separate sentence: *erosion, water cycle, tributary, watershed, divide, channel,* and *load.*

Understanding Key Ideas

2. Which of the following drains a watershed?
   a. a divide
   b. a drainage basin
   c. a tributary
   d. a water system
3. Describe how the Grand Canyon was formed.
4. Draw the water cycle. In your drawing, label *condensation, precipitation,* and *evaporation.*
5. What are three factors that affect the rate of stream erosion?
6. Which stage of river development is characterized by flat flood plains?

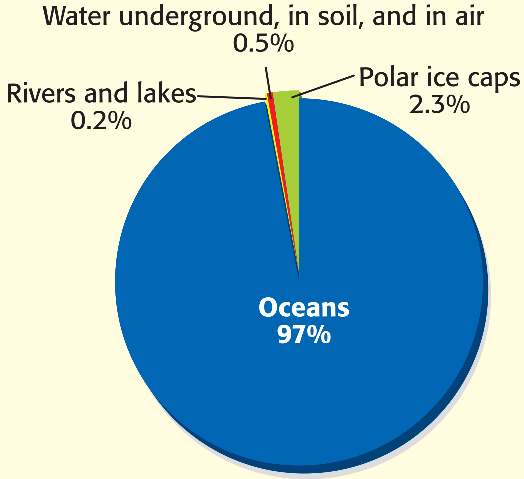
Critical Thinking

7. **Making Inferences** How does the water cycle help develop river systems?
8. **Making Comparisons** How do youthful rivers, mature rivers, and old rivers differ?

Interpreting Graphics

Use the pie graph below to answer the questions that follow.

Distribution of Water in the World



9. Where is most of the water in the world found?
10. In what form is the majority of the world's fresh water?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Rivers and Streams
SciLinks code: HSM1316

SECTION 2

Stream and River Deposits

If your job were to carry millions of tons of soil across the United States, how would you do it? You might use a bulldozer or a dump truck, but it would still take you a long time. Did you know that rivers do this job every day?

READING WARM-UP

Objectives

- Describe the four different types of stream deposits.
- Describe how the deposition of sediment affects the land.

Terms to Learn

deposition
delta
alluvial fan
floodplain

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Rivers erode and move enormous amounts of material, such as soil and rock. Acting as liquid conveyor belts, rivers often carry fertile soil to farmland and wetlands. Although erosion is a serious problem, rivers also renew soils and form new land. As you will see in this section, rivers create some of the most impressive landforms on Earth.

Deposition in Water

You have learned how flowing water erodes the Earth's surface. After rivers erode rock and soil, they drop, or *deposit,* their load downstream. **Deposition** is the process in which material is laid down or dropped. Rock and soil deposited by streams are called *sediment*. Rivers and streams deposit sediment where the speed of the water current decreases. **Figure 1** shows this type of deposition.

Figure 1 *This photo shows erosion and deposition at a bend, or meander, of a river in Alaska.*

Placer Deposits

Heavy minerals are sometimes deposited at places in a river where the current slows down. This kind of sediment is called a *placer deposit* (PLAS uhr dee PAHZ it). Some placer deposits contain gold. During the California gold rush, which began in 1849, many miners panned for gold in the placer deposits of rivers, as shown in **Figure 2.**

Figure 2 *Miners rushed to California in the 1850s to find gold. They often found it in the bends of rivers in placer deposits.*

Delta

A river's current slows when a river empties into a large body of water, such as a lake or an ocean. As its current slows, a river often deposits its load in a fan-shaped pattern called a **delta.** In **Figure 3,** you can see an astronaut's view of the Nile Delta. A delta usually forms on a flat surface and is made mostly of mud. These mud deposits form new land and cause the coastline to grow. The world's deltas are home to a rich diversity of plant and animal life.

If you look back at the map of the Mississippi River watershed, you can see where the Mississippi Delta has formed. It has formed where the Mississippi River flows into the Gulf of Mexico. Each of the fine mud particles in the delta began its journey far upstream. Parts of Louisiana are made up of particles that were transported from places as far away as Montana, Minnesota, Ohio, and Illinois!

Reading Check **What are deltas made of?** (*See the Appendix for answers to Reading Checks*.)

deposition the process in which material is laid down

delta a fan-shaped mass of material deposited at the mouth of a stream

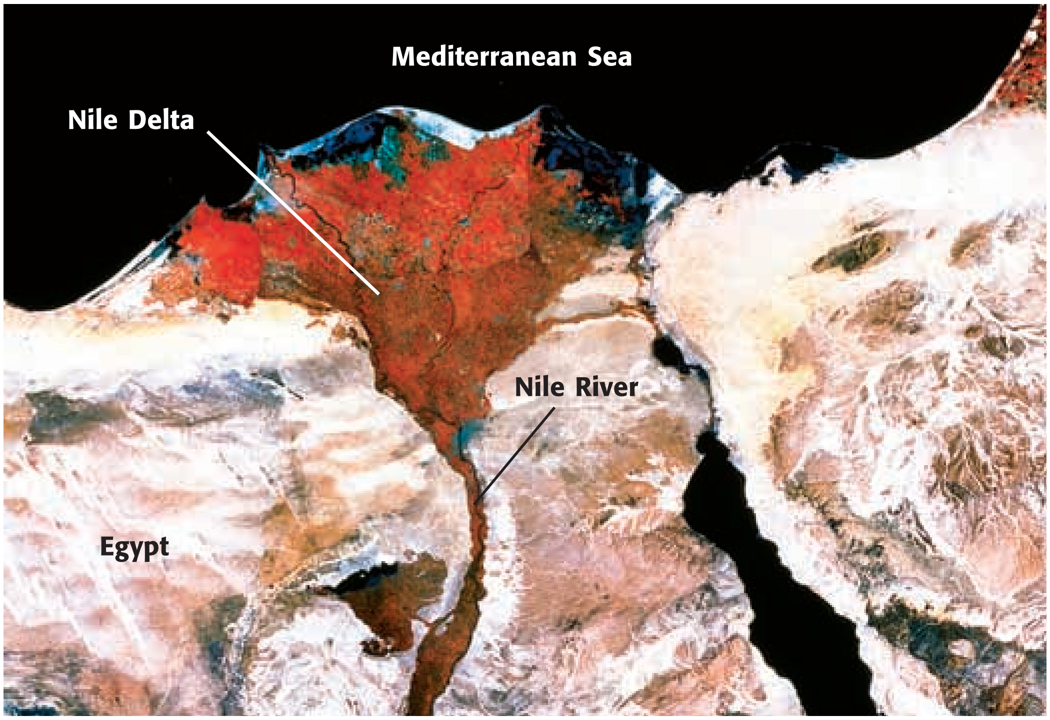

Figure 3 *As sediment is dropped at the mouth of the Nile River, in Egypt, a delta forms.*

Figure 4 *An alluvial fan, like this one at Death Valley in California, forms when an eroding stream changes rapidly into a depositing stream.*

Deposition on Land

When a fast-moving mountain stream flows onto a flat plain, the stream slows down very quickly. As the stream slows down, it deposits sediment. The sediment forms an alluvial fan, such as the one shown in **Figure 4. Alluvial fans** are fan-shaped deposits that, unlike deltas, form on dry land.

alluvial fan a fan-shaped mass of material deposited by a stream when the slope of the land decreases sharply

floodplain an area along a river that forms from sediments deposited when the river overflows its banks

Floodplains

During periods of high rainfall or rapid snow melt, a sudden increase in the volume of water flowing into a stream can cause the stream to overflow its banks. The area along a river that forms from sediment deposited when a river overflows its banks is called a **floodplain.** When a stream floods, a layer of sediment is deposited across the flood plain. Each flood adds another layer of sediment.

Flood plains are rich farming areas because periodic flooding brings new soil to the land. However, flooding can cause damage, too. When the Mississippi River flooded in 1993, farms were destroyed, and entire towns were evacuated. **Figure 5** shows an area north of St. Louis, Missouri, that was flooded.

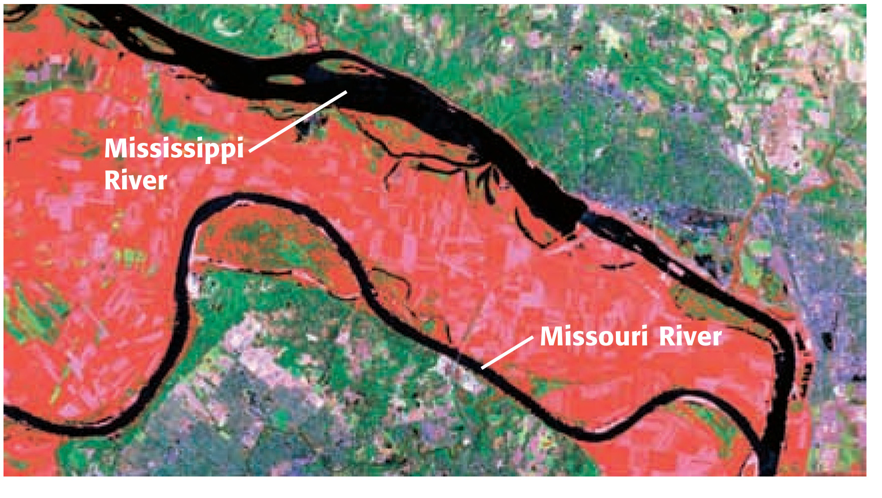

Figure 5 *The normal flow of the Mississippi River and Missouri River is shown in black. The area that was flooded when both rivers spilled over their banks in 1993 is shaded red.*

Flooding Dangers

The flooding of the Mississippi River in 1993 caused damage in nine states. But floods can damage more than property. Many people have lost their lives to powerful floods. As shown in **Figure 6,** flash flooding can take a driver by surprise. However, there are ways that floods can be controlled.

One type of barrier that can be built to help control flooding is called a *dam*. A dam is a barrier that can redirect the flow of water. A dam can prevent flooding in one area and create an artificial lake in another area. The water stored in the artificial lake can be used to irrigate farmland during droughts and provide drinking water to local towns and cities. The stored water can also be used to generate electricity.

Overflow from a river can also be controlled by a barrier called a *levee*. A levee is the buildup of sediment deposited along the channel of a river. This buildup helps keep the river inside its banks. People often use sandbags to build artificial levees to control water during serious flooding.

Figure 6 *Cars driven on flooded roads can easily be carried down to deeper, more dangerous water.*

Reading Check **List two ways that the flow of water can be controlled.**

SECTION Review

Summary

- Sediment forms several types of deposits.
- Sediments deposited where a river's current slows are called *placer deposits.*
- A delta is a fan-shaped deposit of sediment where a river meets a large body of water.
- Alluvial fans can form when a river deposits sediment on land.
- Flooding brings rich soil to farmland but can also lead to property damage and death.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *deposition* and *flood plain.*

Understanding Key Ideas

2. Which of the following forms at places in a river where the current slows?
   a. a placer deposit
   b. a delta
   c. a flood plain
   d. a levee
3. Which of the following can help to prevent a flood?
   a. a placer deposit
   b. a delta
   c. a flood plain
   d. a levee
4. Where do alluvial fans form?
5. Explain why flood plains are both good and bad areas for farming.

Math Skills

6. A river flows at a speed of 8 km/h. If you floated on a raft in this river, how far would you have traveled after 5 h?

Critical Thinking

7. **Identifying Relationships** What factors increase the likelihood that sediment will be deposited?
8. **Making Comparisons** How are alluvial fans and deltas similar?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Stream Deposits
SciLinks code: HSM1458

SECTION 3

Water Underground

Imagine that instead of turning on a faucet to get a glass of water, you pour water from a chunk of solid rock! This idea may sound crazy, but millions of people get their water from within rock that is deep underground.

READING WARM-UP

Objectives

- Identify and describe the location of the water table.
- Describe an aquifer.
- Explain the difference between a spring and a well.
- Explain how caves and sinkholes form as a result of erosion and deposition.

Terms to Learn

water table
aquifer
porosity
permeability
recharge zone
artesian spring

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Although you can see some of Earth's water in streams and lakes, you cannot see the large amount of water that flows underground. The water located within the rocks below the Earth's surface is called *groundwater*. Groundwater not only is an important resource but also plays an important role in erosion and deposition.

The Location of Groundwater

Surface water seeps underground into the soil and rock. This underground area is divided into two zones. Rainwater passes through the upper zone, called the *zone of aeration*. Farther down, the water collects in an area called the *zone of saturation*. In this zone, the spaces between the rock particles are filled with water.

These two zones meet at a boundary known as the **water table,** shown in **Figure 1.** The water table rises during wet seasons and falls during dry seasons. In wet regions, the water table can be at or just beneath the soil's surface. In dry regions, such as deserts, the water table may be hundreds of meters beneath the ground.

water table the upper surface of underground water; the upper boundary of the zone of saturation

Reading Check **Describe where the zone of aeration is located.** *(See the Appendix for answers to Reading Checks.)*

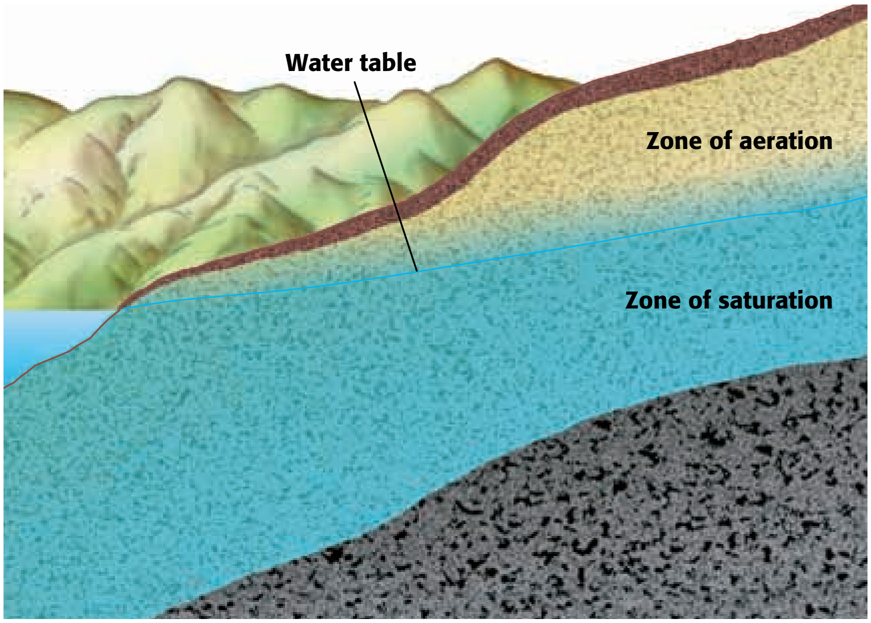


Figure 1 *The water table is the upper surface of the zone of saturation.*

Aquifers

A rock layer that stores groundwater and allows the flow of groundwater is called an **aquifer.** An aquifer can be described by its ability to hold water and its ability to allow water to pass freely through it.

aquifer a body of rock or sediment that stores groundwater and allows the flow of groundwater

porosity the percentage of the total volume of a rock or sediment that consists of open spaces

permeability the ability of a rock or sediment to let fluids pass through its open spaces, or pores

Porosity

The more open spaces, or pores, between particles in an aquifer, the more water the aquifer can hold. The percentage of open space between individual rock particles in a rock layer is called **porosity.**

Porosity is influenced by the differences in sizes of the particles in the rock layer. If a rock layer contains many particles of different sizes, it is likely that small particles will fill up the different-sized empty spaces between large particles. Therefore, a rock layer with particles of different sizes has a low percentage of open space between particles and has low porosity. On the other hand, a rock layer containing same-sized particles has high porosity. This rock layer has high porosity because smaller particles are not present to fill the empty space between particles. So, there is more open space between particles.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5DEPW.**

Permeability

If the pores of a rock layer are connected, groundwater can flow through the rock layer. A rock's ability to let water pass through is called **permeability.** A rock that stops the flow of water is *impermeable*.

The larger the particles are, the more permeable the rock layer is. Because large particles have less surface area relative to their volume than small particles do, large particles cause less friction. *Friction* is a force that causes moving objects to slow down. Less friction allows water to flow more easily through the rock layer, as shown in **Figure 2.**

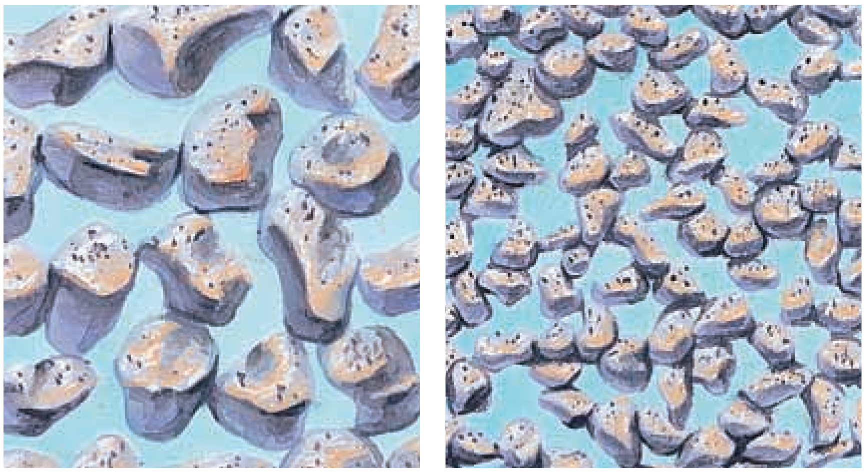


Figure 2 *Large particles, shown at left, have less total surface area—and so cause less friction—than small particles, shown at right, do.*

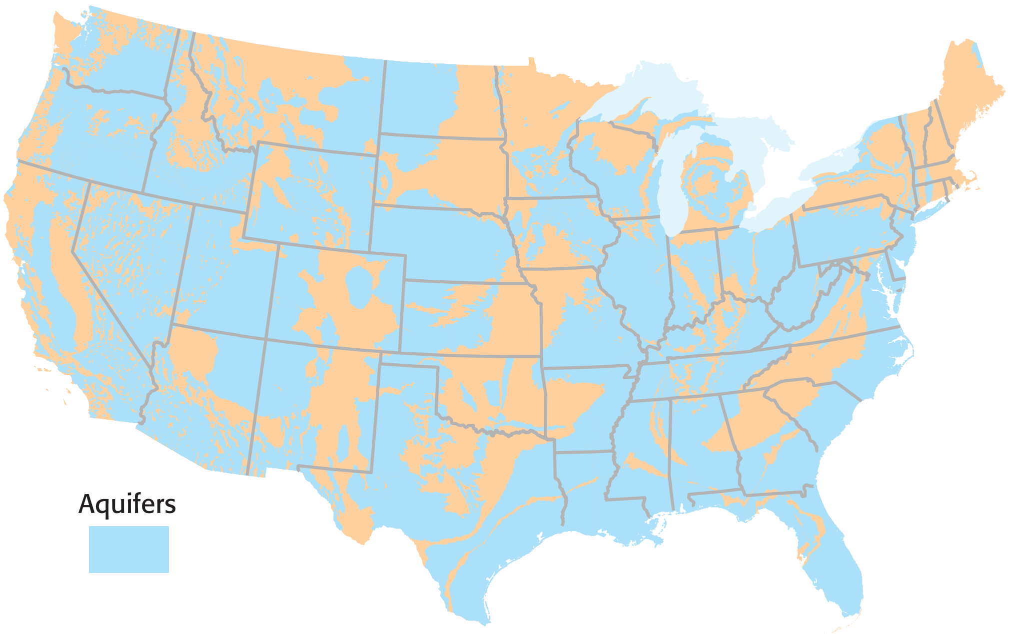


Figure 3 *This map shows aquifers in the United States (excluding Alaska and Hawaii).*

Aquifer Geology and Geography

recharge zone an area in which water travels downward to become part of an aquifer

The best aquifers usually form in permeable materials, such as sandstone, limestone, or layers of sand and gravel. Some aquifers cover large underground areas and are an important source of water for cities and agriculture. The map in **Figure 3** shows the location of the major aquifers in the United States.

Recharge Zones

Like rivers, aquifers depend on the water cycle to maintain a constant flow of water. The ground surface where water enters an aquifer is called the **recharge zone.** The size of the recharge zone depends on how permeable rock is at the surface. If the surface rock is permeable, water can seep down into the aquifer. If the aquifer is covered by an impermeable rock layer, water cannot reach the aquifer. Construction of buildings on top of the recharge zone can also limit the amount of water that enters an aquifer.

Reading Check **What factors affect the size of the recharge zone?**

SCHOOL to HOME

Water Conservation

Did you know that water use in the United States has been reduced by 15% in the last 20 years? This decrease is due in part to the conservation efforts of people like you. Work with a parent to create a water budget for your household. Figure out how much water your family uses every day. Identify ways to reduce your water use, and then set a goal to limit your water use over the course of a week.

ACTIVITY

Springs and Wells

Groundwater movement is determined by the slope of the water table. Like surface water, groundwater tends to move downslope, toward lower elevations. If the water table reaches the Earth's surface, water will flow out from the ground and will form a *spring*. Springs are an important source of drinking water. In areas where the water table is higher than the Earth's surface, lakes will form.

Artesian Springs

A sloping layer of permeable rock sandwiched between two layers of impermeable rock is called an *artesian formation*. The permeable rock is an aquifer, and the top layer of impermeable rock is called a *cap rock,* as shown in **Figure 4.** Artesian formations are the source of water for artesian springs. An **artesian spring** is a spring whose water flows from a crack in the cap rock of the aquifer. Artesian springs are sometimes found in deserts, where they are often the only source of water.

Most springs have cool water. However, some springs have hot water. The water becomes hot when it flows deep in the Earth, because Earth's temperature increases with depth. The temperature of some hot springs can reach 50°C!

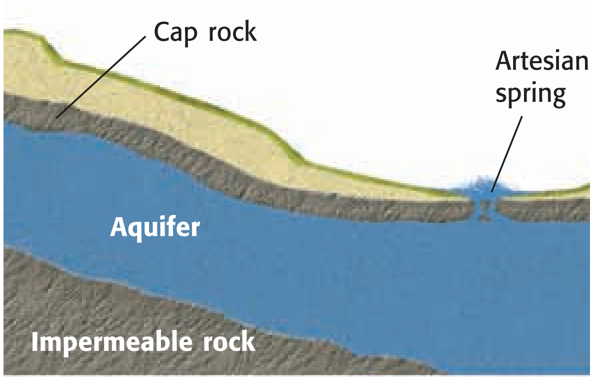


Figure 4 *Artesian springs form when water from an aquifer flows through cracks in the cap rock of an artesian formation.*

Wells

A human-made hole that is deeper than the level of the water table is called a *well*. If a well is not deep enough, as shown in **Figure 5,** it will dry up when the water table falls below the bottom of the well. Also, if an area has too many wells, groundwater can be removed too rapidly. If groundwater is removed too rapidly, the water table will drop, and all of the wells will run dry.

artesian spring a spring whose water flows from a crack in the cap rock over the aquifer

Reading Check **How deep must a well be to reach water?**

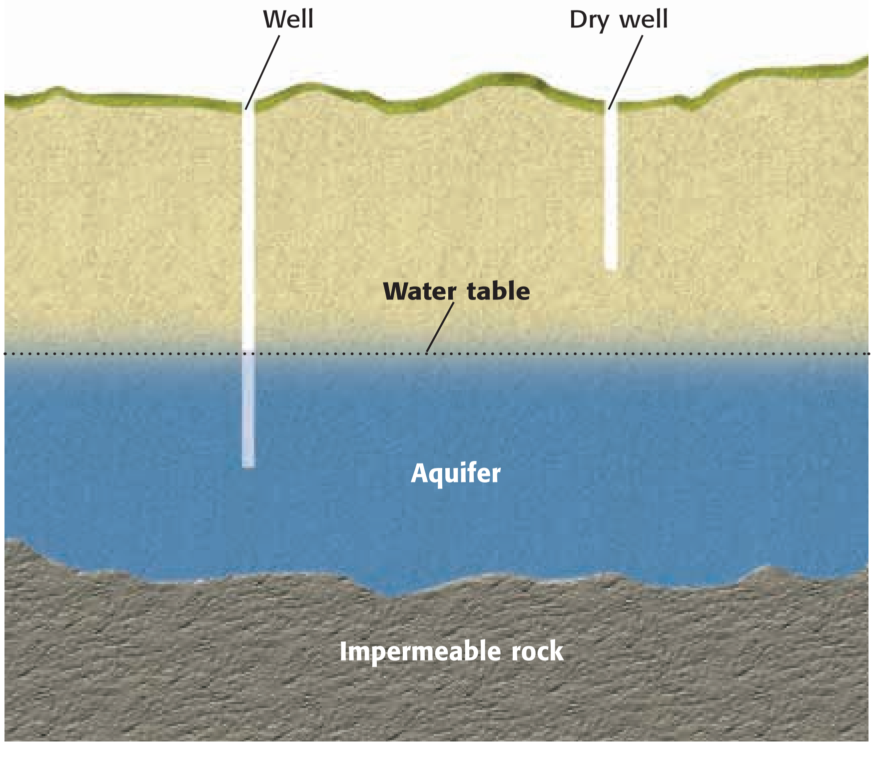


Figure 5 *A well must be drilled deep enough so that when the water table drops, the well still contains water.*

Underground Erosion and Deposition

As you have learned, rivers cause erosion when water removes and transports rock and soil from its banks. Groundwater can also cause erosion. However, groundwater causes erosion by dissolving rock. Some groundwater contains weak acids, such as carbonic acid, that dissolve the rock. Also, some types of rock, such as limestone, dissolve in groundwater more easily than other types do.

When underground erosion happens, caves can form. Most of the world's caves formed over thousands of years as groundwater dissolved the limestone of the cave sites. Some caves, such as the one shown in **Figure 6,** reach spectacular proportions.

CONNECTION TO
Environmental Science

Bat Environmentalists
Most bat species live in caves. Bats are night-flying mammals that play an important role in the environment. Bats eat vast quantities of insects. Many bat species also pollinate plants and distribute seeds. Can you think of other animals that eat insects, pollinate plants, and distribute seeds? Create a poster that includes pictures of these other animals.

ACTIVITY

Cave Formations

Although caves are formed by erosion, they also show signs of deposition. Water that drips from a crack in a cave's ceiling leaves behind deposits of calcium carbonate. Sharp, icicle-shaped features that form on cave ceilings are known as *stalactites* (stuh LAK tiets). Water that falls to the cave's floor adds to cone-shaped features known as *stalagmites* (stuh LAG MIETS). If water drips long enough, the stalactites and stalagmites join to form a *dripstone column*.

Reading Check **What process causes the formation of stalactites and stalagmites?**

Figure 6 *At Carlsbad Caverns in New Mexico, underground passages and enormous "rooms" have been eroded below the surface of the Earth.*

Sinkholes

When the water table is lower than the level of a cave, the cave is no longer supported by the water underneath. The roof of the cave can then collapse, which leaves a circular depression called a *sinkhole*. Surface streams can "disappear" into sinkholes and then flow through underground caves. Sinkholes often form lakes in areas where the water table is high. Central Florida is covered with hundreds of round sinkhole lakes. **Figure 7** shows how the collapse of an underground cave can affect a landscape.

Figure 7 *The damage to this city block shows the effects of a sinkhole in Winter Park, Florida.*

SECTION Review

Summary

- The water table is the boundary between the zone of aeration and the zone of saturation.
- Porosity and permeability describe an aquifer's ability to hold water and ability to allow water to flow through.
- Springs are a natural way that water reaches the surface. Wells are made by humans.
- Caves and sinkholes form from the erosion of limestone by groundwater.

Using Key Terms

1. Use the following terms in the same sentence: *water table, aquifer, porosity,* and *artesian spring*.

Understanding Key Ideas

2. Which of the following describes an aquifer's ability to allow water to flow through?
   a. porosity
   b. permeability
   c. geology
   d. recharge zone
3. What is the water table?
4. Describe how particles affect the porosity of an aquifer.
5. Explain the difference between an artesian spring and other springs.
6. Name a feature that is formed by underground erosion.
7. Name two features that are formed by underground deposition.
8. What type of weathering process causes underground erosion?

Math Skills

9. Groundwater in an area flows at a speed of 4 km/h. How long would it take the water to flow 10 km to its spring?

Critical Thinking

10. **Predicting Consequences** Explain how urban growth might affect the recharge zone of an aquifer.
11. **Making Comparisons** Explain the difference between a spring and a well.
12. **Analyzing Relationships** What is the relationship between the zone of aeration, the zone of saturation, and the water table?

SECTION 4

Using Water Wisely

READING WARM-UP

Objectives

- Identify two forms of water pollution.
- Explain how the properties of water influence the health of a water system.
- List four water-monitoring methods that can indicate poor water quality in a water system.
- Describe two ways that wastewater can be treated.
- Describe how water is used and how water can be conserved in industry, in agriculture, and at home.

Terms to Learn

point-source pollution
nonpoint-source pollution
sewage treatment plant

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Did you know that you are almost 65% water? You depend on clean, fresh drinking water to maintain that 65% of you. But there is a limited amount of fresh water available on Earth. Only 3% of Earth's water is drinkable.

And of the 3% of Earth's water that is drinkable, 75% is frozen in the polar icecaps. This frozen water is not readily available for our use. Practicing good stewardship of Earth's water supply helps preserve clean water for future generations.

Water Pollution

Surface water, such as the water in rivers and lakes, and groundwater can be polluted by waste from cities, factories, and farms. Pollution is the introduction of harmful substances into the environment. Water can become so polluted that it can no longer be used or can even be deadly.

Point-Source and Nonpoint-Source Pollution

Pollution that comes from one specific site is called **point-source pollution.** For example, wastewater that is released from a factory is point-source pollution. In most cases, this type of pollution can be controlled because its source can be identified.

Nonpoint-source pollution is pollution that comes from many sources. This type of pollution is much more difficult to control because it does not come from a single source. Most nonpoint-source pollution reaches bodies of water by runoff. Some sources of nonpoint-source pollution in North Carolina include agricultural and urban runoff, land clearing, construction, and forestry. **Figure 1** shows an example of a source of nonpoint-source pollution.

Reading Check **What type of pollution is the hardest to control?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *The runoff from this irrigation system could collect pesticides and other pollutants. The result would be nonpoint-source pollution.*

Figure 2 *Waste from farm animals can seep into groundwater and cause nitrate pollution.*

Health of a Water System

You might not realize it, but water quality affects your quality of life as well as other organisms that depend on water. Therefore, it is important to understand how the properties of water influence water quality.

point-source pollution pollution that comes from a specific site

nonpoint-source pollution pollution that comes from many sources rather than from a single, specific site

Dissolved Oxygen

Just as you need oxygen to live, so do fish and other organisms that live in lakes and streams. The oxygen dissolved in water is called *dissolved oxygen,* or DO. Levels of DO that are below 4.0 mg/L in fresh water can cause stress and possibly death for organisms that live in the water. Pollutants such as sewage, fertilizer runoff, and animal waste can decrease DO levels.

Temperature

Temperature changes also affect DO levels. For example, cold water holds more oxygen than warm water does. Facilities such as nuclear power plants can increase the temperature of lakes and rivers when they use the water as a cooling agent. Such an increase in water temperature is called *thermal pollution*, which causes a decrease in DO levels.

Nitrates

Nitrates are naturally occurring compounds of nitrogen and oxygen. Small amounts of nitrates in water are normal. However, elevated nitrate levels in water can be harmful to organisms. An excess of nitrates in lakes and rivers can also lower DO levels. As shown in **Figure 2,** nitrate pollution can come from animal wastes or fertilizers that seep into groundwater.

QuickLab

Measuring Alkalinity

1. Identify two water sources from which to collect water samples.
2. Fill a **plastic cup** with water from one source. Fill a **second plastic cup** with water from the second source. Label each cup with its source.
3. Using a **pH test kit,** measure the pH of each sample. Follow the instructions in the test kit, and determine the pH of each of the two samples. Record your observations.
4. What did the results for the two samples indicate about the two sources?
5. Use **water test kits** to measure DO and nitrate levels in the two water samples, and discuss whether your results indicate a healthy or unhealthy environment.

pH

The pH of a body of water identifies the acid/base balance of the water. Normal pH in a healthy water system ranges from about 6.5 to 8.5. Within this range, chemicals dissolved in water are available as nutrients that can be used by aquatic organisms. However, a lower or higher pH may disrupt the availability of nutrients in a water system.

Turbidity

Another indicator of water quality is turbidity. *Turbidity* is a measure of the concentration of particles suspended in water. High turbidity reduces light penetration and visibility in the water. Common sources of turbidity are suspended sediments, such as silt and clay, wastewater discharge from industry, and, at times of abnormally high concentrations, microscopic plants called *phytoplankton*. High concentrations of particles significantly reduce light penetration. A lack of light negatively affects the health of aquatic organisms and reduces photosynthesis.

Biological Indicators of Water Quality

Scientists use a variety of aquatic plants and animals as indicators of water quality. Among the most important biological indicators of the health of a water system are fishes. Fishes live in water their entire life and respond to chemical, physical, and biological changes in their environment in characteristic ways. The fishes shown in **Figure 3** are an obvious indicator of a change that has taken place in a body of water. This fish die-off is an indicator of thermal pollution. Other organisms that are used to indicate water quality are aquatic plants, aquatic insects, mussels, leeches, and worms.

Figure 3 *This fish die-off in Brazil occurred as a result of thermal pollution, which decreased the level of dissolved oxygen in the water.*

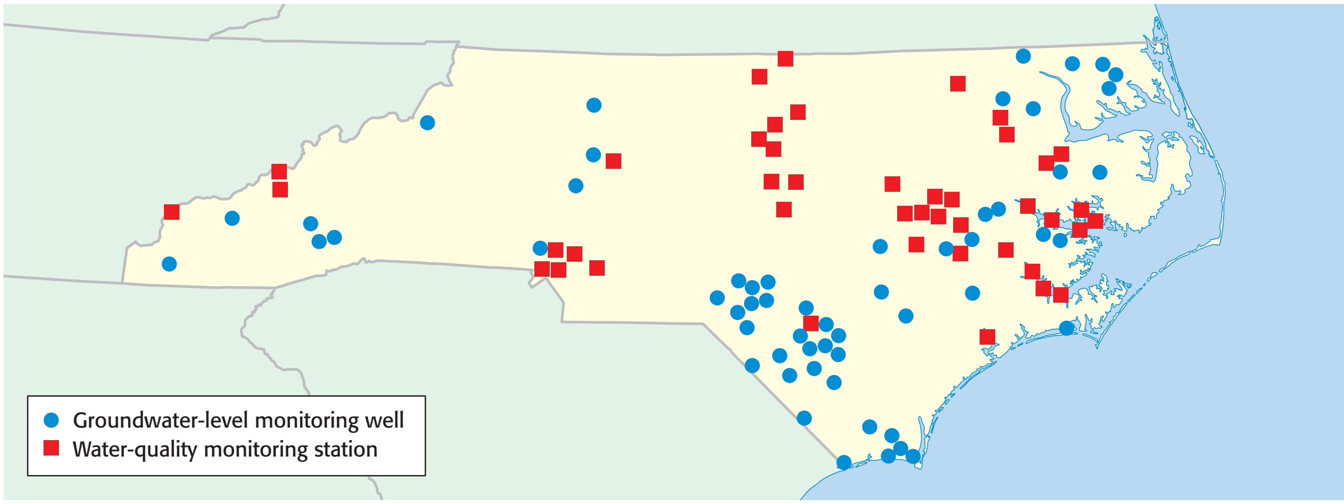


Figure 4 *Federal, state, and municipal water-quality monitoring programs are in effect throughout North Carolina. The map above shows water-quality monitoring stations and groundwater-level monitoring wells in the state as of the year 2000.*

Monitoring Water Quality

A number of government programs designed to monitor surface water and groundwater quality are currently being conducted in North Carolina. For example, the Charlotte and Raleigh-Durham areas are being monitored to determine the effects of their rapidly growing populations on water quality. Other programs monitor the effects of agriculture on water quality. In addition, a network of wells has been drilled to measure groundwater levels. **Figure 4** shows the locations of water-quality monitoring stations and groundwater-level monitoring wells in North Carolina.

Water-quality monitoring programs look for chemical and biological imbalances in a body of water. Detecting these imbalances can help scientists correct problems in an unhealthy water supply. Chemical imbalances in water can be detected by measuring pH and the levels of dissolved oxygen and nitrates. Biological imbalances in an aquatic ecosystem can be measured by counting the relative numbers of biological indicator species. Finally, turbidity can be measured by instruments that indicate water clarity at various depths.

Water quality can also be monitored by instruments mounted aboard aircraft and satellites. These instruments measure biological activity, turbidity, and water temperature. For example, a satellite image of Lake Tahoe, located on the California–Nevada border, is shown in **Figure 5.**

Figure 5 *This satellite photo helps scientists monitor the quality of the water in Lake Tahoe.*

Reading Check **What is the purpose of a water-quality monitoring program?**

Cleaning Polluted Water

When you flush the toilet or watch water go down the shower drain, do you ever wonder where the water goes? If you live in a city or large town, the water flows through sewer pipes to a sewage treatment plant. **Sewage treatment plants** are facilities that clean the waste materials out of water. These plants help protect the environment from water pollution. They also protect us from diseases that are easily transmitted through dirty water.

CONNECTION TO Social Studies

Economic Trade-Offs The State of North Carolina, together with the United States government and local city governments, are monitoring the effect of human population on drinking water in the Raleigh-Durham area. What economic trade-offs might the residents of these cities have to make in return for having a clean water supply? Brainstorm some economic trade-offs that residents of the Raleigh-Durham area may eventually have to make. Debate these trade-offs with your classmates.

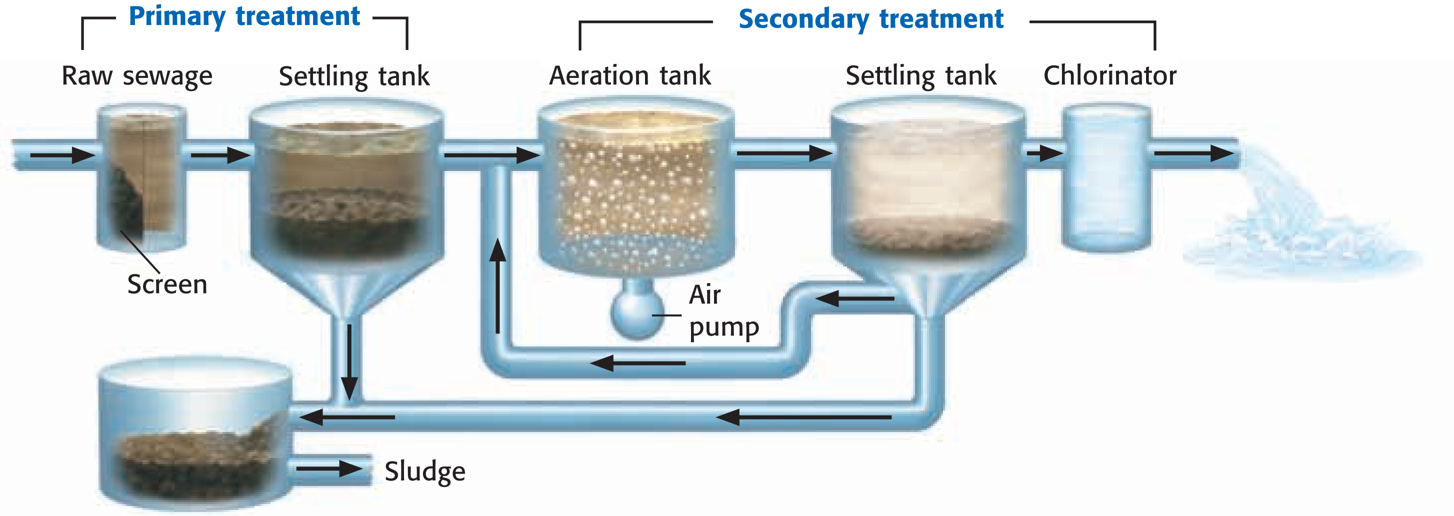
Primary Treatment

When water reaches a sewage treatment plant, it is cleaned in two ways. First, it goes through a series of steps known as *primary treatment*. In primary treatment, dirty water is passed through a large screen to catch solid objects, such as paper, rags, and bottle caps. The water is then placed in a large tank, where smaller particles, or sludge, can sink and be filtered out. These particles include things such as food, coffee grounds, and soil. Any floating oils and scum are skimmed off the surface.

Secondary Treatment

After undergoing primary treatment, the water is ready for *secondary treatment*. In secondary treatment, the water is sent to an aeration tank, where it is mixed with oxygen and bacteria. The bacteria feed on the wastes and use the oxygen. The water is then sent to another settling tank, where chlorine is added to disinfect the water. The water is finally released into a water source—a river, a lake, or the ocean. **Figure 6** shows the major components of a sewage treatment plant.

Figure 6 *If you live in a city, the water used in your home most likely ends up at a sewage treatment plant, where the water is cleaned.*



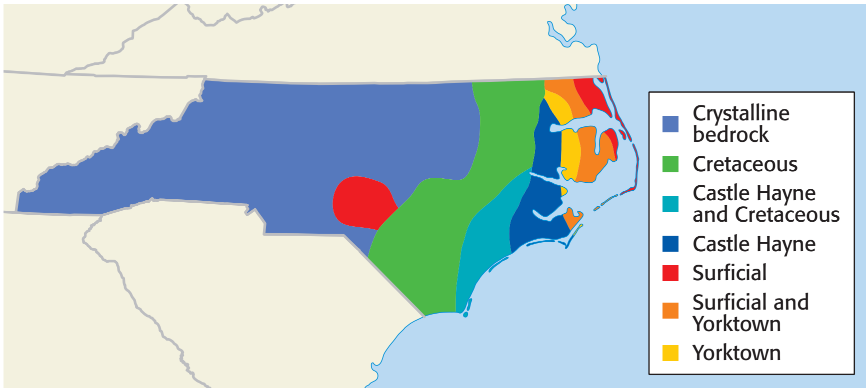


Figure 7 *The richest supply of groundwater in North Carolina comes from the aquifers located in the eastern part of the state. The sediments in eastern North Carolina allow more water storage than the crystalline rocks in the rest of the state do.*

Where the Water Comes From

More than half of all the people living in North Carolina depend on groundwater for their water supply. Groundwater in North Carolina is stored in aquifers that are located in the subsurface throughout the state. **Figure 7** shows the locations of these aquifers. The most important groundwater sources are the aquifers located in the coastal plains of eastern North Carolina. These aquifers supply much of the water for the state's cities, industries, and agriculture.

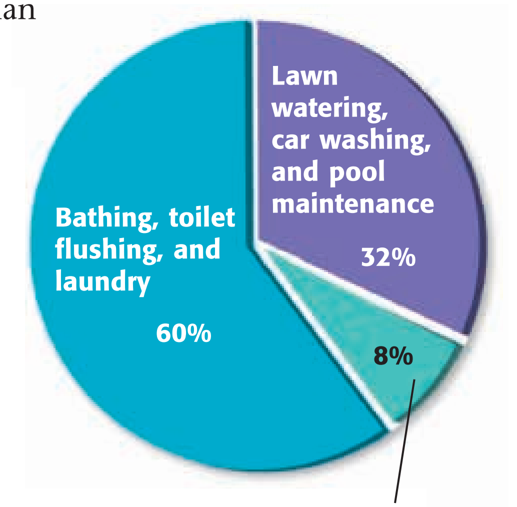
sewage treatment plant a facility that cleans the waste materials found in water that comes from sewers or drains

Where the Water Goes

Think of some ways that you use water in your home. Do you water the lawn? Do you do the dishes? The graph in **Figure 8** shows how an average household in the United States uses water. Notice that less than 8% of the water we use in our homes is used for drinking. Most is used for flushing toilets, doing laundry, bathing, and watering lawns and plants.

The water we use in our homes is not the only way water is used. More water is used in industry and agriculture than in homes.

Figure 8 *The average household in the United States uses about 100 gal of water per day. This pie graph shows some common uses of these 100 gal.*



Water in Agriculture

Most of the water that is lost during farming is lost through evaporation and runoff. High-pressure overhead sprinklers are particularly inefficient. Nearly half of the water released evaporates and never reaches plant roots. New technology, such as drip irrigation systems, has helped conserve water in agriculture. A drip irrigation system delivers small amounts of water directly to plant roots. This system allows plants to absorb the water before the water has a chance to evaporate or become runoff.

Reading Check **How does the drip irrigation system help conserve water?**

Figure 9 *Dishwashers and washing machines should be run only when they are full to conserve water.*

Water in Industry

About 19% of water used in the world is used for industrial purposes. Water is used to manufacture goods, cool power stations, clean industrial products, extract minerals, and generate energy for factories.

Because water resources have become expensive, many industries are trying to conserve, or use less, water. One way industries conserve water is by recycling it. In the United States, most of the water used in factories is recycled at least once. At least 90% of this recycled water can be treated and returned to surface water.

MATH PRACTICE

Agriculture in Israel

From 1950 to 1980, Israel reduced the amount of water used in agriculture from 83% to 5%. Israel did so primarily by switching from overhead sprinklers to drip irrigation. A small farm uses 10,000 L of water per day for overhead sprinkler irrigation. How much water would the farm save in 1 year by using a drip irrigation system that uses 75% less water than a sprinkler system?

Conserving Water at Home

There are many ways that people can conserve water at home. For example, many people save water by installing low-flow shower heads and low-flush toilets, because these items use much less water. To avoid watering lawns, some people plant only native plants in their yards. Native plants grow well in the local climate and don't need extra watering.

Your behavior can also help you conserve water. For example, you can take shorter showers. You can avoid running the water while brushing your teeth. And when you run the dishwasher or the washing machine, make sure it is full, as shown in **Figure 9.**

Reading Check **List ways in which you can conserve water in your home.**

SECTION
Review

Summary

- Point-source pollution and nonpoint-source pollution are two kinds of water pollution.
- Pollutants can change pH, decrease oxygen levels, increase nitrate levels, and increase turbidity in water. These changes can cause harm to plants, animals, and humans.
- Certain organisms can be indicators of the health of a water system.
- Wastewater can be treated by sewage treatment plants and septic systems.
- The purpose of water-quality monitoring programs is to detect imbalances that indicate poor water-system health.
- Water quality can be monitored by instruments aboard aircraft and satellites.
- Water can be conserved by using only the water that is needed, by recycling water, and by using drip irrigation systems.
- Many water-conservation methods can be used in the home.

Using Key Terms

1. Use each of the following terms in a separate sentence: *point-source pollution, nonpoint-source pollution, sewage treatment plant,* and *septic tank*.

Understanding Key Ideas

2. Which of the following can help protect fish from acid rain?
   a. dissolved oxygen
   b. nitrates
   c. balancing pH
   d. point-source pollution
3. Which kind of water pollution is often caused by the runoff of fertilizers?
4. Describe what DO is.
5. What factors affect the level of dissolved oxygen in water?
6. List four water-monitoring methods that can indicate poor water quality in a water system.
7. What are some of the ways in which water can be conserved in the home?

Critical Thinking

8. **Making Inferences** How do bacteria help break down the waste in water treatment plants?
9. **Making Inferences** Why is it better to water your lawn at night instead of during the day?

Interpreting Graphics

Use the table below to answer the question that follows.

Daily Water Use in the United States (per person)

Use	Water (L)
Lawn watering and pools	95
Toilet flushing	90
Bathing	70
Brushing teeth	10
Cleaning (inside and outside)	20
Cooking and drinking	10
Other	5

10. What percentage of daily water use do cooking and drinking make up?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Water Pollution and Conservation

SciLinks code: HSM1630

Model-Making Lab

Water Cycle—What Goes Up . . .

OBJECTIVES

Design a model that follows the same processes as those of the water cycle.

Identify each stage of the water cycle in the model.

MATERIALS

- beaker
- gloves, heat-resistant
- graduated cylinder
- hot plate
- plate, glass, or watch glass
- tap water, 50 mL
- tongs or forceps

SAFETY

Why does a bathroom mirror fog up? Where does water go when it dries up? Where does rain come from? These questions relate to the major parts of the water cycle—condensation, evaporation, and precipitation. In this activity, you will make a model of the water cycle.

Procedure

1. Use the graduated cylinder to pour 50 mL of water into the beaker. Note the water level in the beaker.
2. Put on your safety goggles and gloves. Place the beaker securely on the hot plate. Turn the heat to medium, and bring the water to a boil.
3. While waiting for the water to boil, practice picking up and handling the glass plate or watch glass with the tongs. Hold the glass plate a few centimeters above the beaker, and tilt it so that the lowest edge of the glass is still above the beaker.
4. Observe the glass plate as the water in the beaker boils. Record the changes you see in the beaker, in the air above the beaker, and on the glass plate held over the beaker. Write down any changes you see in the water.

5. Continue until you have observed steam rising off the water, the glass plate becoming foggy, and water dripping from the glass plate.
6. Carefully set the glass plate on a counter or other safe surface as directed by your teacher.
7. Turn off the hot plate, and allow the beaker to cool. Move the hot beaker with gloves or tongs if you are directed to do so by your teacher.

Analyze the Results

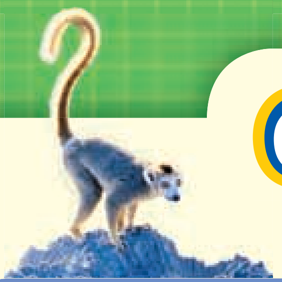
1. **Constructing Charts** Copy the illustration shown above. On your sketch, draw and label the water cycle as it happened in your model. Include arrows and labels for *evaporation, condensation,* and *precipitation*.
2. **Analyzing Results** Compare the water level in the beaker now with the water level at the beginning of the experiment. Was there a change? Explain why or why not.

Draw Conclusions

3. **Making Predictions** If you had used a scale or a balance to measure the mass of the water in the beaker before and after this activity, would the mass have changed? Explain.
4. **Analyzing Charts** How is your model similar to the Earth's water cycle? On your sketch of the illustration, label where the processes shown in the model reflect the Earth's water cycle.
5. **Drawing Conclusions** When you finished this experiment, the water in the beaker was still hot. What stores much of the energy in the Earth's water cycle?

Applying Your Data

As rainwater runs over the land, the water picks up minerals and salts. Do these minerals and salts evaporate, condense, and precipitate as part of the water cycle? Where do they go?



Chapter Review

USING KEY TERMS

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. A stream that flows into a lake or into a larger stream is a water cycle.
2. The area along a river that forms from sediment deposited when the river overflows is a delta.
3. A rock's ability to let water pass through it is called porosity.

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

4. *divide* and *watershed*
5. *artesian springs* and *wells*
6. *point-source pollution* and *nonpoint-source pollution*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Which of the following processes is not part of the water cycle?
   - **a.** evaporation
   - **b.** percolation
   - **c.** condensation
   - **d.** deposition
8. Which features are common in youthful river channels?
   - **a.** meanders
   - **b.** flood plains
   - **c.** rapids
   - **d.** sandbars
9. Which depositional feature is found at the coast?
   - **a.** delta
   - **b.** flood plain
   - **c.** alluvial fan
   - **d.** placer deposit
10. Caves are mainly a product of
    - **a.** erosion by rivers.
    - **b.** river deposition.
    - **c.** water pollution.
    - **d.** erosion by groundwater.
11. Which of the following is necessary for aquatic life to survive?
    - **a.** dissolved oxygen
    - **b.** nitrates
    - **c.** alkalinity
    - **d.** point-source pollution
12. During primary treatment at a sewage treatment plant,
    - **a.** water is sent to an aeration tank.
    - **b.** water is mixed with bacteria and oxygen.
    - **c.** dirty water is passed through a large screen.
    - **d.** water is sent to a settling tank where chlorine is added.

Short Answer

13. Identify and describe the location of the water table.
14. Explain how surface water enters an aquifer.
15. Why are caves usually found in limestone-rich regions?

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *zone of aeration, zone of saturation, water table, gravity, porosity,* and *permeability*.

17 **Identifying Relationships** What is water's role in erosion and deposition?

18 **Analyzing Processes** What are the features of a river channel that has a steep gradient?

19 **Analyzing Processes** Why is groundwater hard to clean?

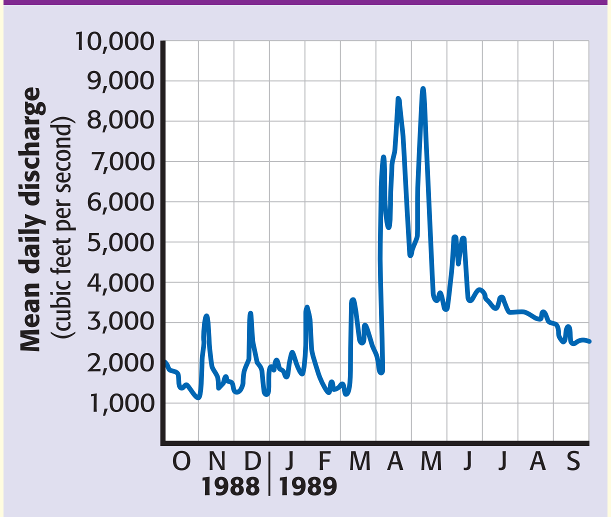
20 **Evaluating Conclusions** How can water be considered both a renewable and a nonrenewable resource? Give an example of each case.

21 **Analyzing Processes** Does water vapor lose or gain energy during the process of condensation? Explain.

INTERPRETING GRAPHICS

The hydrograph below illustrates data collected on river flow during field investigations over a period of 1 year. The discharge readings are from the Yakima River, in Washington. Use the hydrograph below to answer the questions that follow.

Hydrograph of the Yakima River



22 In which months is there the highest river discharge?

23 Why is there such a high river discharge during these months?

24 What might cause the peaks in river discharge between November and March?

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 In parts of Yellowstone National Park, boiling water from deep in the ground blasts into the sky. These blasts of steam come from lakes of strange-colored boiling mud that gurgle and hiss. These features are called geysers. Yellowstone's most popular geyser is named Old Faithful. It is given this name because it erupts every 60 min to 70 min without fail. A geyser is formed when a narrow vent connects one or more underground chambers to Earth's surface. These underground chambers are heated by nearby molten rock. As underground water flows into the vent and chambers, it is heated above 100°C. This superheated water quickly turns to steam and explodes, projecting scalding water 60 m into the air. And Old Faithful erupts right on schedule!

1. In the passage, what does *scalding* mean?

A muddy
B burning
C gurgling
D steaming

2. According to the passage, what happens to underground water when geysers form?

F It is heated by molten rock.
G It is cycled to Earth's center.
H It travels 60 m through vents.
I It is poured into volcanoes.

3. Which of the following is a fact in the passage?

A Old Faithful erupts every 60 min.
B Old Faithful is located in Yellowstone National Park.
C There are six geysers at Yellowstone National Park.
D Molten rock explodes from geysers.

Passage 2 In the Mississippi Delta, long-legged birds step lightly through the marsh and hunt fish or frogs for breakfast. Hundreds of species of plants and animals start another day in this fragile ecosystem. This delta ecosystem is in danger of being destroyed. The threat comes from efforts to make the river more useful. Large portions of the river bottom were dredged to deepen the river for ship traffic. Underwater channels were built to control flooding. What no one realized was that sediments that once formed new land now passed through the channels and flowed out into the ocean. Those river sediments had once replaced the land that was lost every year to erosion. Without them, the river can't replace land lost to erosion. So, the Mississippi River Delta is shrinking. By 1995, more than half of the wetlands were already gone—swept out to sea by waves along the Louisiana coast.

1. In the passage, what does *dredged* mean?

A moved to the side
B circulated
C cleaned
D scooped up

2. Based on the passage, which of the following statements about the Mississippi River is true?

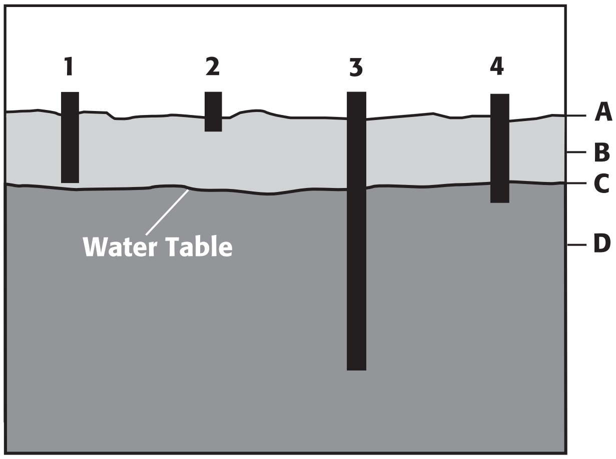
F The river never floods.
G The river is not wide enough for ships.
H The river's delicate ecosystem is in danger.
I The river is disappearing.

3. Which of the following is a fact in the passage?

A By 1995, more than half of the Mississippi River was gone.
B Underwater channels controlled flooding.
C Channels help form new land.
D Sediment cannot replace lost land.

INTERPRETING GRAPHICS

The chart below shows four wells drilled at different depths. Use the chart below to answer the questions that follow.



1. A well-drilling company offers the four types of wells shown in the chart. Which well is most likely to be a reliable source of groundwater?

A 1
B 2
C 3
D 4

2. If the area experienced heavy rains, toward which level would the water table move?

F The water table would move toward level B.
G The water table would move toward level D.
H The water table would stay at level C.
I The water table will be gone.

3. If the water table moves to level D, which wells will still be able to provide water?

A all wells
B wells 1 and 2
C well 3
D wells 3 and 4

4. Which well is most likely to be an unreliable source of groundwater?

F 1
G 2
H 3
I 4

MATH

Read each question below, and choose the best answer.

1. A river flows at a speed of 10 km/h. If a boat travels upstream at a speed of 15 km/h, how far will it travel in 3 h?

A 10 km
B 15 km
C 20 km
D 25 km

2. Water contamination is often measured in parts per million (ppm). If the concentration of a pollutant is 5 ppm, there are 5 parts of the pollutant in 1 million parts of water. If the concentration of gasoline is 3 ppm in 2,000,000 L of water, how many liters of gasoline are in the water?

F 3 L
G 6 L
H 9 L
I 10 L

3. One family uses 70 L of water a day for showering. If everyone in the family agreed to shorten his or her shower from 10 min to 5 min, how many liters of water would be saved each day?

A 5 L
B 10 L
C 35 L
D 70 L

4. A family uses 800 L of water per day. Of those 800 L, 200 L are used for flushing the toilet. Calculate the percentage of water that the family uses to flush the toilet.

F 25%
G 30%
H 50%
I 60%

5. A river flows at a speed of 8 km/h. If you floated on a raft in this river, how far will you have traveled after 5 h?

A 5 km
B 16 km
C 40 km
D 80 km

Science in Action

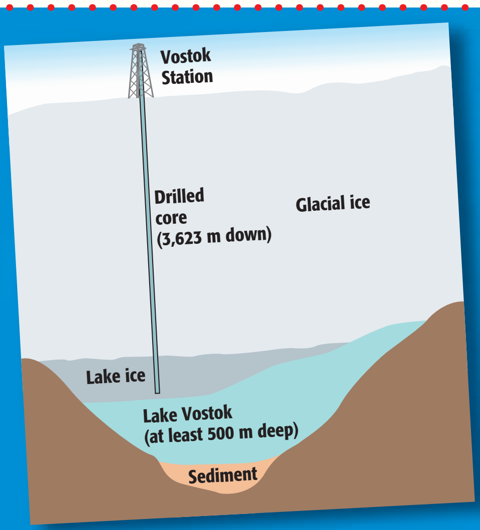
Weird Science

Secret Lake

Would you believe there is a freshwater lake more than 3 km below an Antarctic glacier near the South Pole? It is surprising that Lake Vostok can remain in a liquid state at a place where the temperature can fall below –50°C. Scientists believe that the intense pressure from the overlying ice heats the lake and keeps it from freezing. Geothermal energy, which is the energy within the surface of the Earth, also contributes to warmer temperatures. The other unique thing about Lake Vostok is the discovery of living microbes under the glacier that covers the lake!

Language Arts ACTIVITY

Look up the word *geothermal* in the dictionary. What is the meaning of the roots *geo-* and *-thermal*? Find other words in the dictionary that begin with the root *geo-*.



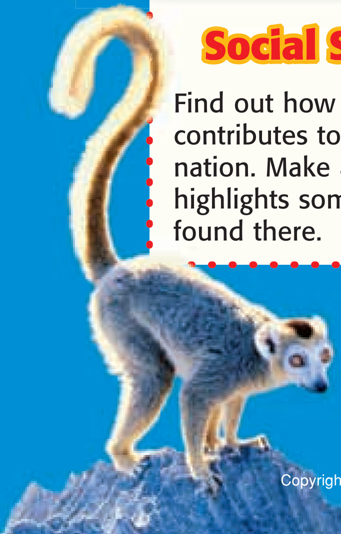
Scientific Discoveries

Sunken Forests

Imagine having your own little secret forest. In Ankarana National Park, in Madagascar, there are plenty of them. Within the limestone mountain of the park, caves have formed from the twisting path of the flowing groundwater. In many places in the caves, the roof has collapsed to form a sinkhole. The light that now shines through the collapsed roof of the cave has allowed miniature sunken forests to grow. Each sunken forest has unique characteristics. Some have crocodiles. Others have blind cavefish. You can even find some species that can't be found anywhere else in the world!

Social Studies ACTIVITY

Find out how Madagascar's geography contributes to the biodiversity of the island nation. Make a map of the island that highlights some of the unique forms of life found there.



People in Science

Rita Colwell

A Water Filter for All Did you ever drink a glass of water through a piece of cloth? Dr. Rita Colwell, director of the National Science Foundation, has found that filtering drinking water through a cloth can actually decrease the number of disease-causing bacteria in the water. This discovery is very important for the people of Bangladesh, where deadly outbreaks of cholera are frequent. People are usually infected by the cholera bacteria by drinking contaminated water. Colwell knew that filtering the water would remove the bacteria. The water would then be safe to drink. Unfortunately, filters were too expensive for most of the people to buy. Colwell tried filtering the water with a sari. A sari is a long piece of colorful cloth that many women in Bangladesh wear as skirtlike cloth. Filtering the water with the sari cloth did the trick. The amount of cholera bacteria in the water was reduced. Fewer people contracted cholera, and many lives were saved!

Math ACTIVITY

With the cloth water-filter method, there was a 48% reduction in the occurrence of cholera. If there were 125 people out of 100,000 who contracted cholera before the cloth-filter method was used, how many people per 100,000 contracted cholera after using the cloth-filter method?

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Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS11.

3

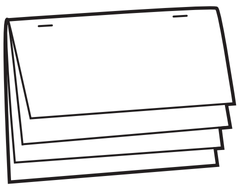
Exploring the Oceans

About the PHOTO

Are two heads better than one? Although it may look like this reef lizardfish has two heads, it's actually swallowing another fish whole! Reef lizardfish are commonly found in the Western Pacific Ocean. Unlike most other types of lizardfish, the reef lizardfish prefers to rest on hard surfaces and is usually seen in pairs.

PRE-READING ACTIVITY

FOLDNOTES **Layered Book** Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Characteristics of ocean water," "The ocean floor," "Ocean zones," and "Resources from the ocean." As you read the chapter, write information you learn about each category under the appropriate tab.



START-UP ACTIVITY

Exit Only?

To study what life underwater would be like, scientists sometimes live in underwater laboratories. How do these scientists enter and leave these labs? Believe it or not, the simplest way is through a hole in the lab's floor. You might think water would come in through the hole, but it doesn't. How is this possible? Do the following activity to find out.

Procedure

1. Fill a **large bowl** about two-thirds full of **water.**
2. Turn a **clear plastic cup** upside down.
3. Slowly guide the cup straight down into the water. Be careful not to guide the cup all the way to the bottom of the bowl. Also, be careful not to tip the cup.
4. Record your observations.

Analysis

1. How does the air inside the cup affect the water below the cup?
2. How do your findings relate to the hole in the bottom of an underwater research lab?

SECTION 1

Earth's Oceans

What makes Earth so different from Mars? What does Earth have that Mercury doesn't?

Earth stands out from the other planets in our solar system primarily for one reason—71% of the Earth's surface is covered with water. Most of Earth's water is found in the global ocean. The global ocean is divided by the continents into four main oceans. The divisions of the global ocean are shown in **Figure 1.** The ocean is a unique body of water that plays many parts in regulating Earth's environment.

READING WARM-UP

Objectives

- List the major divisions of the global ocean.
- Describe the history of Earth's oceans.
- Identify the properties of ocean water.
- Describe the interactions between the ocean and the atmosphere.

Terms to Learn

salinity
water cycle

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Divisions of the Global Ocean

The largest ocean is the *Pacific Ocean*. It flows between Asia and the Americas. The volume of the *Atlantic Ocean*, the second-largest ocean, is about half the volume of the Pacific. The *Indian Ocean* is the third-largest ocean. The *Arctic Ocean* is the smallest ocean. This ocean is unique because much of its surface is covered by ice. Therefore, the Arctic Ocean has not been fully explored.

Figure 1 *The global ocean is divided by the continents into four main oceans.*

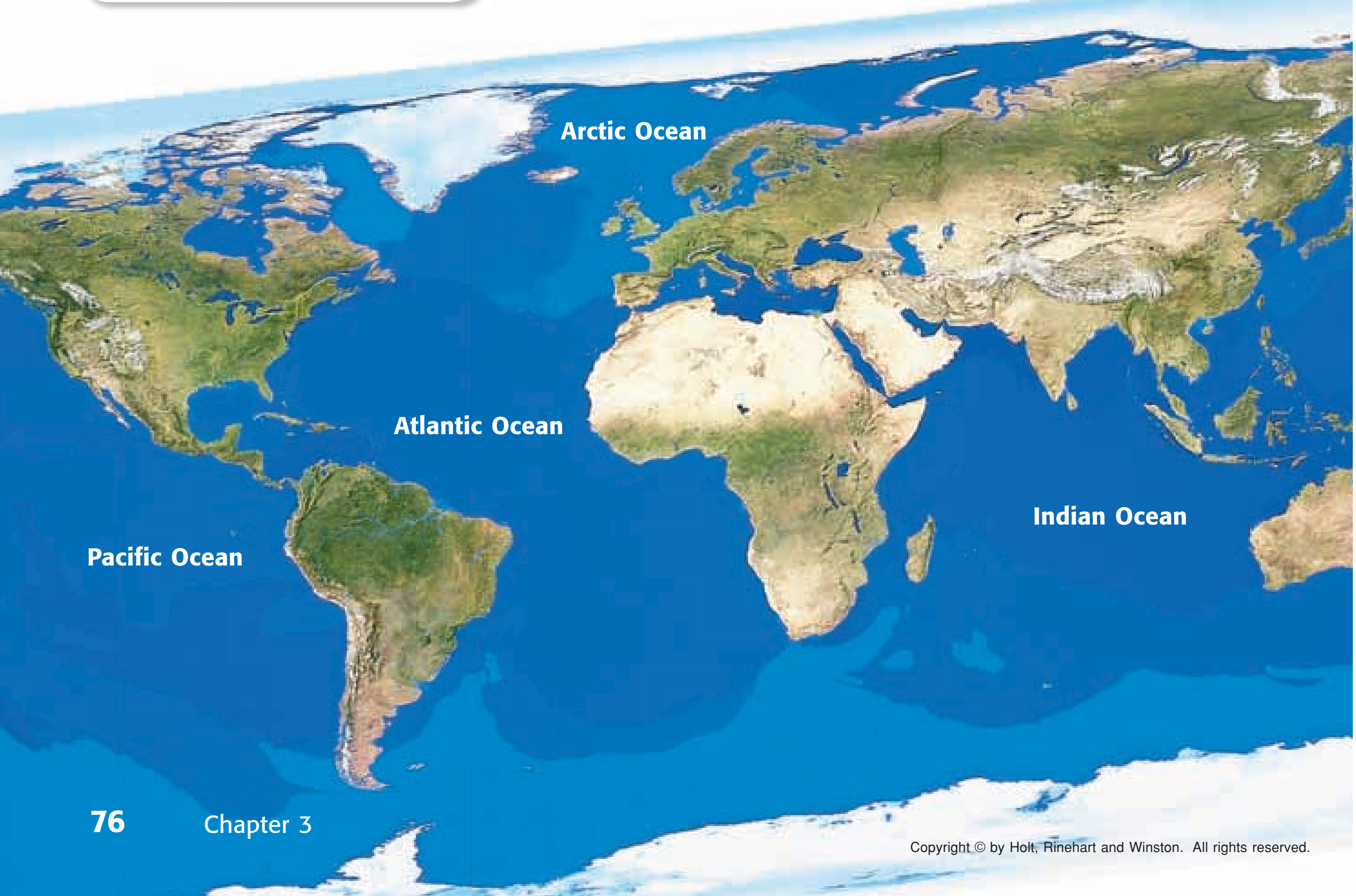
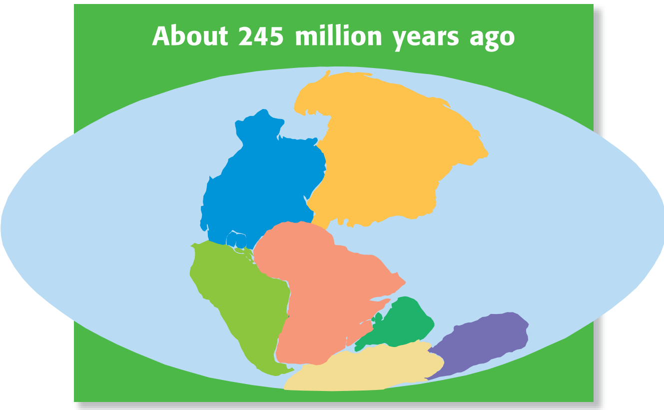
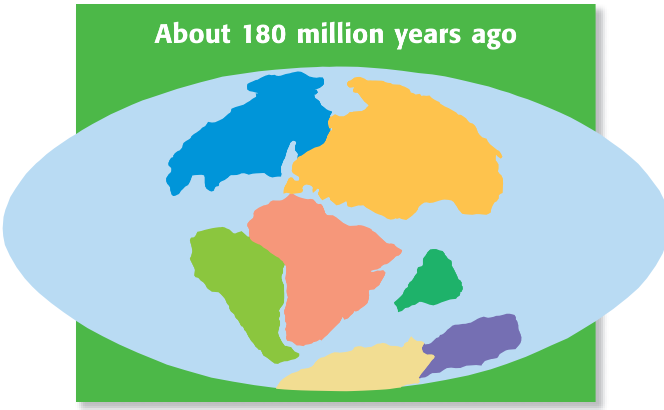


Figure 2 **The History of Earth's Oceans**

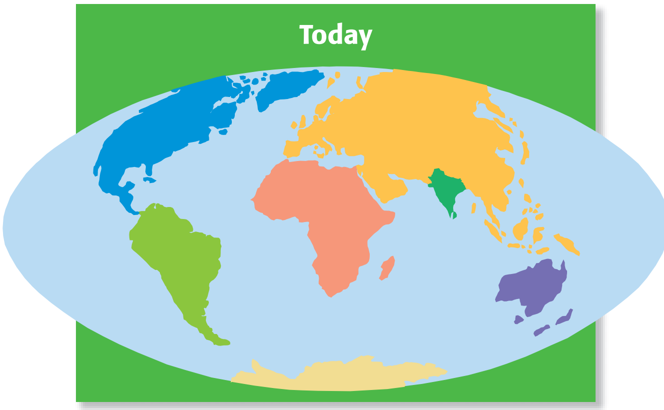


The continents were one giant landmass called Pangaea. The oceans were one giant body of water called Panthalassa.



As Pangaea broke apart, the North Atlantic Ocean and the Indian Ocean began to form.

The South Atlantic Ocean was much smaller than it is today.



The continents continue to move at a rate of 1 to 10 cm per year. The Pacific Ocean is getting smaller. However, the other oceans are growing.

How Did the Oceans Form?

About 4.5 billion years ago, Earth was a very different place. There were no oceans. Volcanoes spewed lava, ash, and gases all over the planet. The volcanic gases began to form Earth's atmosphere. Meanwhile, Earth was cooling. Sometime before 4 billion years ago, Earth cooled enough for water vapor to condense. This water began to fall as rain. The rain filled the deeper levels of Earth's surface, and the first oceans began to form.

The shape of the Earth's oceans has changed a lot over time. Much has been learned about the oceans' history. Some of this history is shown in **Figure 2.**

Reading Check **How did the first oceans begin to form on Earth?** (*See the Appendix for answers to Reading Checks.*)

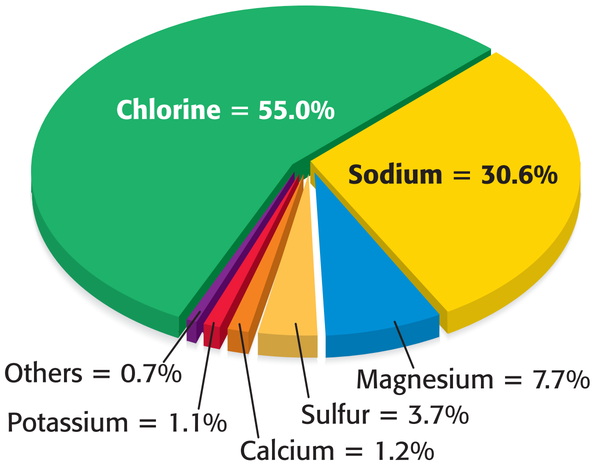


Figure 3 *This pie graph shows the relative percentages of dissolved solids (by mass) in ocean water.*

Characteristics of Ocean Water

You know that ocean water is different from the water that flows from your sink at home. For one thing, ocean water is not safe to drink. But the dissolved gases and minerals it contains are the characteristics that make ocean water special.

Dissolved Gases

Nitrogen, N_2, oxygen, O_2, and carbon dioxide, CO_2, are the main gases dissolved in ocean water. These are also the main gases that exist in the atmosphere. Of the three gases, carbon dioxide dissolves most easily in ocean water.

Temperature can affect the amount of gas that dissolves in water. For example, gases dissolve more easily in cold water than in warm water. So, as water temperature rises, less gas remains dissolved in ocean water and more gas is released into the atmosphere.

Reading Check **How does temperature affect the amount of gas that dissolves in water?**

Chock-Full of Solids

Have you ever tasted water while swimming in the ocean? It tasted really salty, didn't it? Most of the salt in the ocean is the same kind of salt that we sprinkle on our food. This salt is called *sodium chloride,* which consists of the elements sodium, Na, and chlorine, Cl.

Salts have been added to the ocean for billions of years. As rivers and streams flow toward the oceans, the rivers and streams dissolve various minerals on land. The running water carries these dissolved minerals to the ocean. At the same time, water is evaporating from the ocean and is leaving the dissolved solids behind. The most abundant dissolved solid in the ocean is sodium chloride. **Figure 3** shows the relative percentages of the dissolved solids in ocean water.

salinity a measure of the amount of dissolved salts in a given amount of liquid

Salinity

A measure of the amount of dissolved solids in a given amount of liquid is called **salinity.** Salinity is usually measured as grams of dissolved solids per kilogram of water. Think of it this way: 1 kg (1,000 g) of ocean water can be evaporated to 35 g of dissolved solids, on average. Therefore, if you evaporated 1 kg of ocean water, 965 g of fresh water would be removed and 35 g of solids would remain.

Reading Check **What does salinity measure?**

Figure 4 *Salinity varies in different parts of the ocean because of variations in evaporation, circulation, and freshwater inflow.*

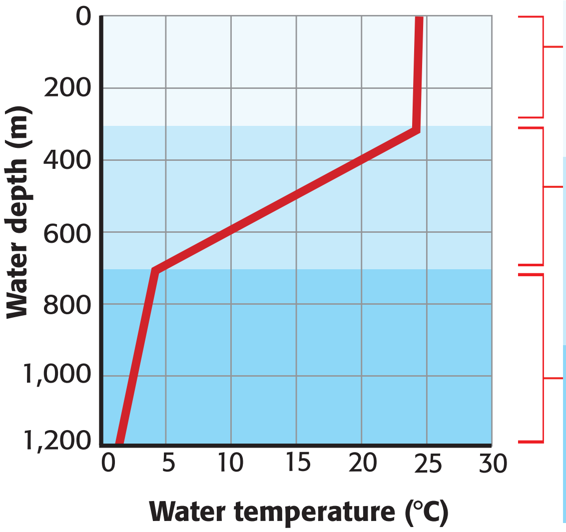
Changes in Salinity

Climate can affect salinity. For example, coastal water in places that have hot, dry climates has a high salinity. Coastal water in cool, humid places has a low salinity. This difference is because heat increases the evaporation rate. Evaporation removes water but leaves salts and other dissolved solids behind. Water movement can also affect salinity. Slow-moving bodies of water such as bays, gulfs, and seas develop a higher salinity than other parts of the ocean, as shown in **Figure 4.**

Temperature Zones

The temperature of ocean water decreases as depth increases. However, this temperature change does not happen gradually from the ocean's surface to its bottom. **Figure 5** shows how ocean water can be divided into three layers by temperature.

Figure 5 **Temperature Zones in the Ocean**



Surface zone The *surface zone* is the warm, top layer of ocean water. It can extend to 300 m below sea level. Sunlight heats the top 100 m of the surface zone. Surface currents mix the heated water with cooler water below.

Thermocline The *thermocline* is the second layer of ocean water. It can extend from 300 m below sea level to about 700 m below sea level. In the thermocline, temperature drops with increased depth faster than it does in the other two zones.

Deep zone The *deep zone* is the bottom layer that extends from the base of the thermocline to the bottom of the ocean. The temperature in this zone can range from 1°C to 3°C.

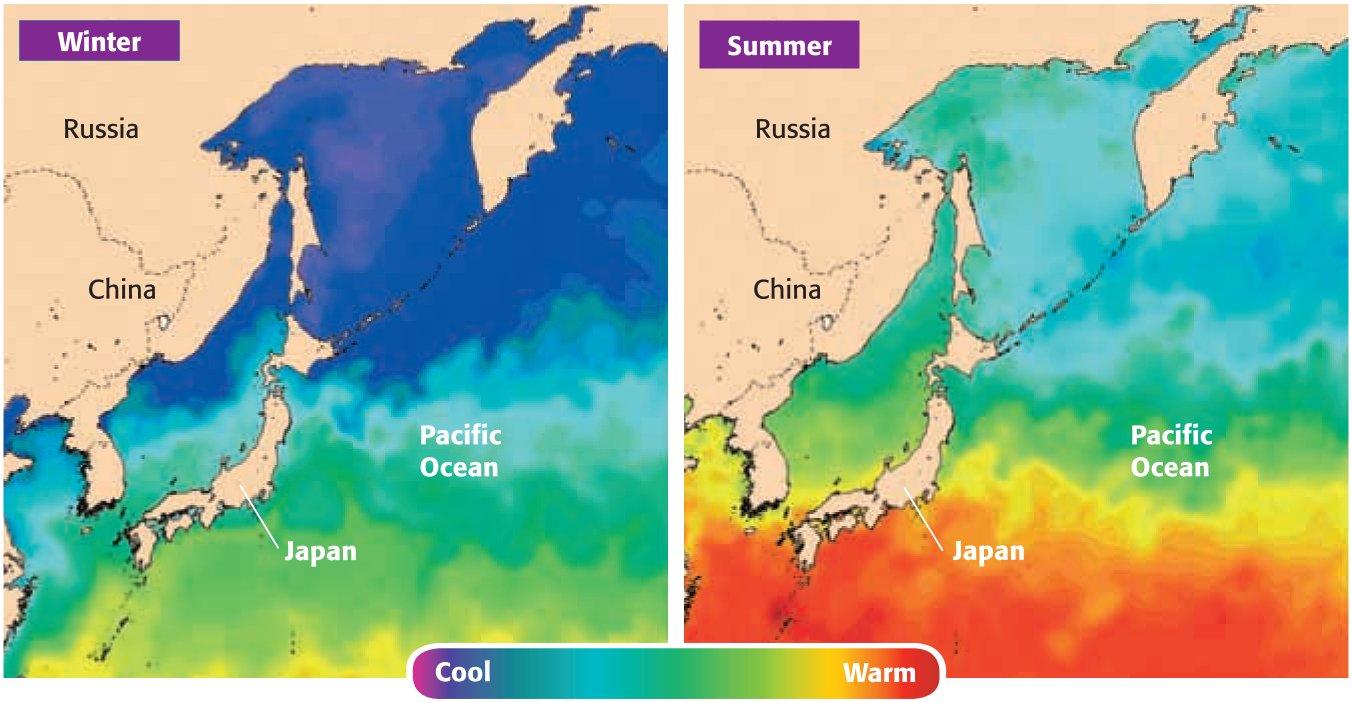


Figure 6 *These satellite images show that the surface temperatures in the northern Pacific Ocean change with the seasons.*

Surface Temperature Changes

If you live near the coast, you may know how different a swim in the ocean feels in December than it feels in July. Temperatures in the surface zone vary with latitude and the time of year. Surface temperatures range from 1°C near the poles to about 24°C near the equator. Parts of the ocean along the equator are warmer because they receive more direct sunlight per year than areas closer to the poles. However, both hemispheres receive more direct sunlight during their summer seasons. Therefore, the surface zone is heated more in the summer. **Figure 6** shows how surface-zone temperatures vary depending on the time of year.

Reading Check **Why are parts of the ocean along the equator warmer than those closer to the poles?**

CONNECTION TO Geology

Submarine Volcanoes Geologists estimate that approximately 80% of the volcanic activity on Earth takes place on the ocean floor. Most of the volcanic activity occurs as magma slowly flows onto the ocean floor where tectonic plates pull away from each other. Other volcanic activity is the result of volcanoes that are located on the ocean floor. Both of these types of volcanoes are called *submarine volcanoes*. Submarine volcanoes behave differently than volcanoes on land do. Research how submarine volcanoes behave underwater. Then, create a model of a submarine volcano based on the information you find.

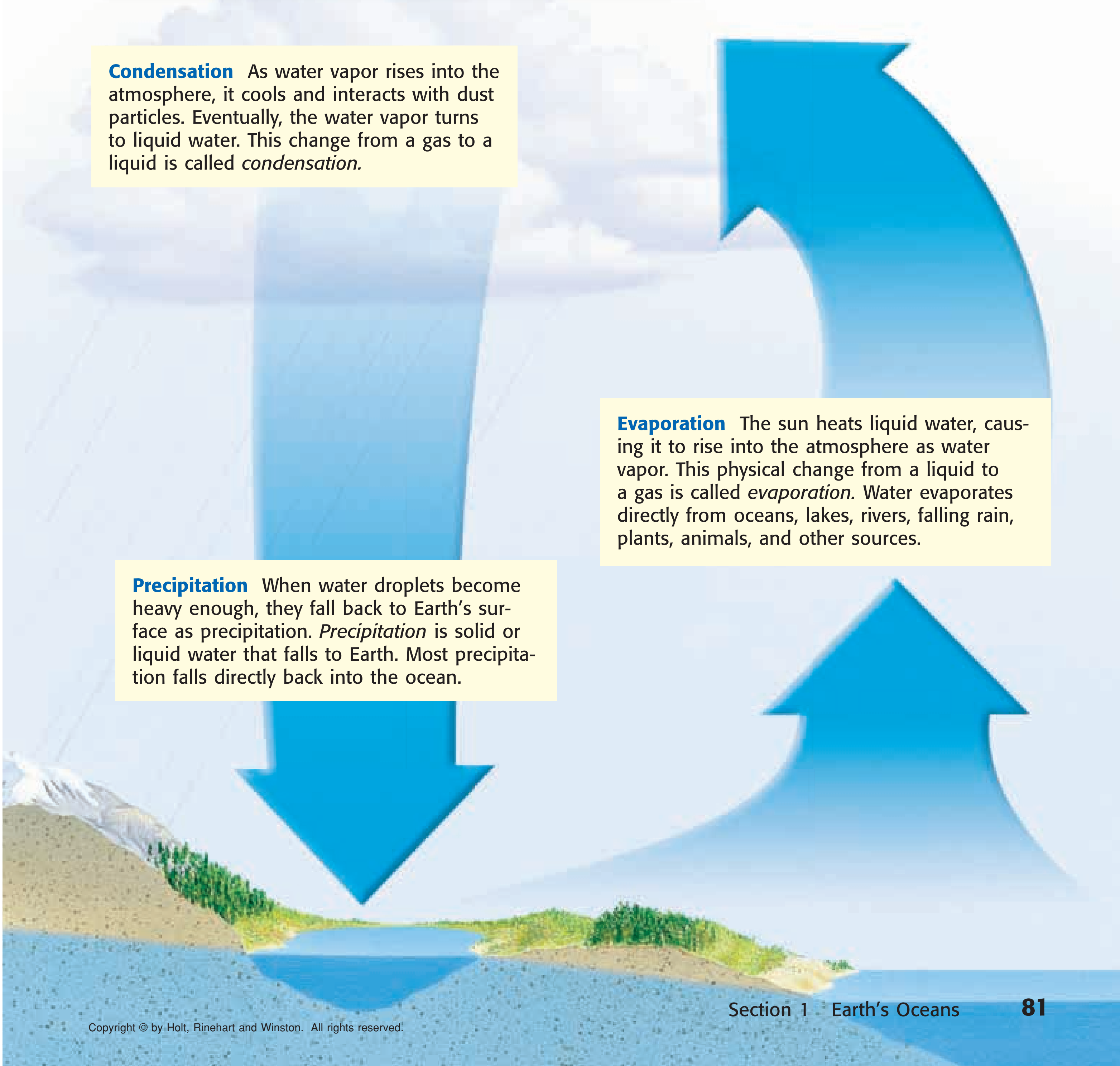
ACTIVITY

The Ocean and the Water Cycle

If you could sit on the moon and look down at Earth, what would you see? You would notice that Earth's surface is made up of three basic components—water, land, and clouds (air). All three are part of a process called the water cycle, as shown in **Figure 7.** The **water cycle** is the continuous movement of water from the ocean to the atmosphere to the land and back to the ocean. The ocean is an important part of the water cycle because nearly all of Earth's water is in the ocean.

water cycle the continuous movement of water from the ocean to the atmosphere to the land and back to the ocean

Figure 7 **The Water Cycle**



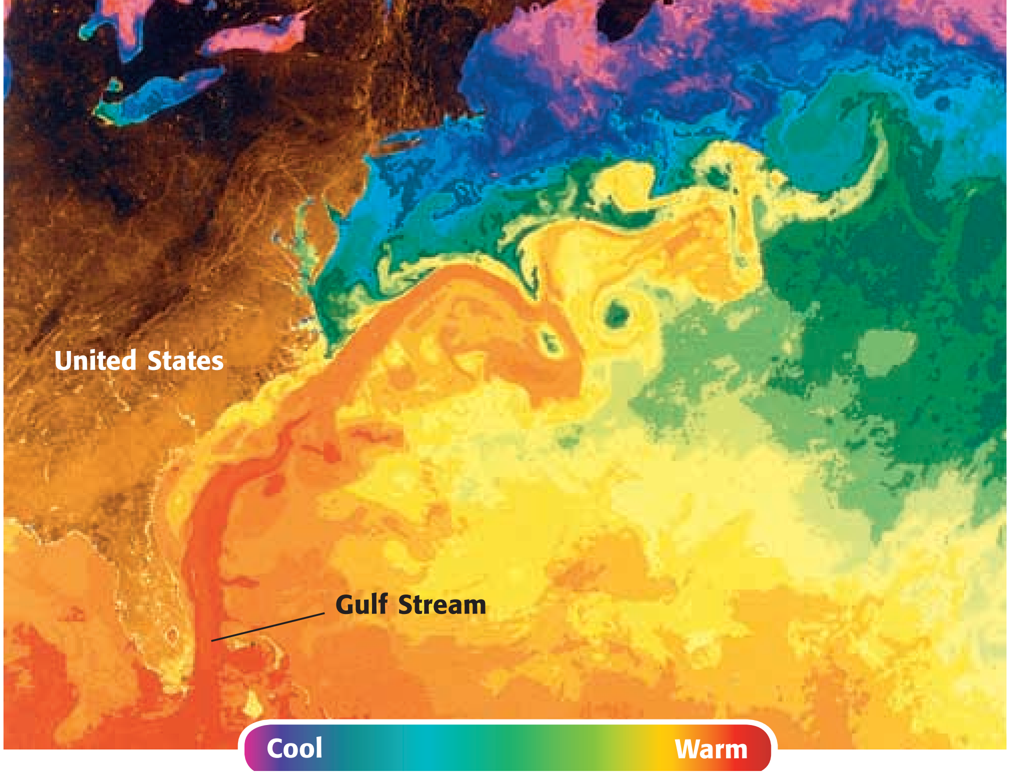


Figure 8 *This infrared satellite image shows the Gulf Stream moving warm water from lower latitudes to higher latitudes.*

A Global Thermostat

The ocean plays an important part in keeping the Earth suitable for life. Perhaps the most important function of the ocean is to absorb and hold energy from sunlight. This function regulates temperatures in the atmosphere.

A Thermal Exchange

The ocean absorbs and releases thermal energy much more slowly than dry land does. If it were not for this property of the ocean, the air temperature on Earth could vary greatly from above 100°C during the day to below –100°C at night. This rapid exchange of thermal energy between the atmosphere and the Earth's surface would cause violent weather patterns. Life as you know it could not exist under these conditions.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5OCEW.**

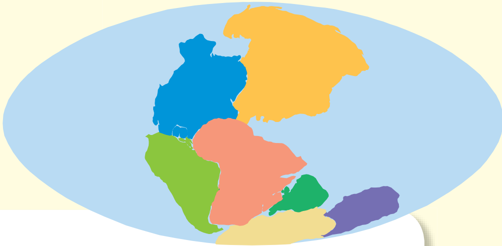
Reading Check **How would the air temperature on land be different if the ocean did not release thermal energy so slowly?**

Have Heat, Will Travel

The ocean also regulates temperatures at different locations of the Earth. At the equator, the sun's rays are more direct than at the poles. As a result, the waters there are warmer than waters at higher latitudes. However, currents in the ocean move water and the energy it contains. Part of this movement is shown in **Figure 8.** This circulation of warm water causes some coastal lands to have warmer climates than they would have without the currents. The British Isles, for example, have a warmer climate than most regions at the same latitude. This warmer climate is due to the warm water of the Gulf Stream.

SECTION

Review



Summary

- The global ocean is divided by the continents into four main oceans: Pacific Ocean, Atlantic Ocean, Indian Ocean, and Arctic Ocean.
- The four oceans as we know them today formed within the last 300 million years.
- Salts have been added to the ocean for billions of years. Salinity is a measure of the amount of dissolved salts in a given weight or mass of liquid.
- The three temperature zones of ocean water are the surface zone, the thermocline, and the deep zone.
- The water cycle is the continuous movement of water from the ocean to the atmosphere to the land and back to the ocean. The ocean plays the largest role in the water cycle.
- The ocean stabilizes Earth's weather conditions by absorbing and holding thermal energy.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *salinity* and *water cycle*.

Understanding Key Ideas

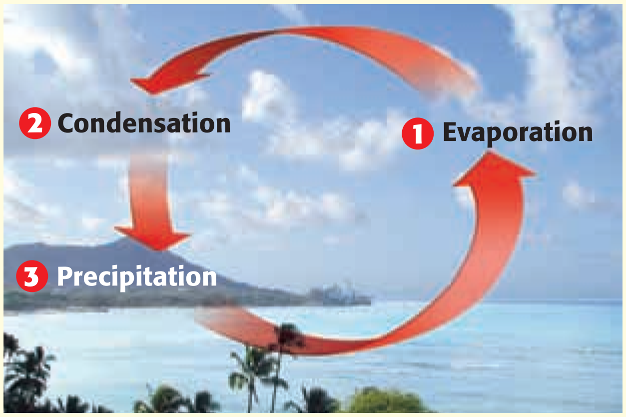
2. The top layer of ocean water that extends to 300 m below sea level is called the
   a. deep zone.
   b. surface zone.
   c. Gulf Stream.
   d. thermocline.
3. Name the major divisions of the global ocean.
4. Explain how Earth's first oceans formed.
5. Why is the ocean an important part of the water cycle?
6. Describe one characteristic of ocean water that makes it different from the water that flows from your sink at home.

Critical Thinking

7. **Making Inferences** Describe how the ocean plays a role in stabilizing Earth's weather conditions.
8. **Identifying Relationships** List one factor that affects salinity in the ocean and one factor that affects ocean temperatures. Explain how each factor affects salinity or temperature.

Interpreting Graphics

Use the image below to answer the questions that follow.



9. At which stage would solid or liquid water fall to the Earth?
10. At which stage would the sun's energy cause liquid to rise into the atmosphere as water vapor?

SECTION 2

The Ocean Floor

What lies at the bottom of the ocean? How deep is the ocean?

These questions were once unanswerable. By using new technology, scientists have learned a lot about the ocean floor. Scientists have discovered landforms on the ocean floor and have measured depths for almost the entire ocean floor.

READING WARM-UP

Objectives

- Describe technologies for studying the ocean floor.
- Identify the two major regions of the ocean floor.
- Classify subdivisions and features of the two major regions of the ocean floor.

Terms to Learn

continental shelf
continental slope
continental rise
abyssal plain
mid-ocean ridge
rift valley
seamount
ocean trench

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

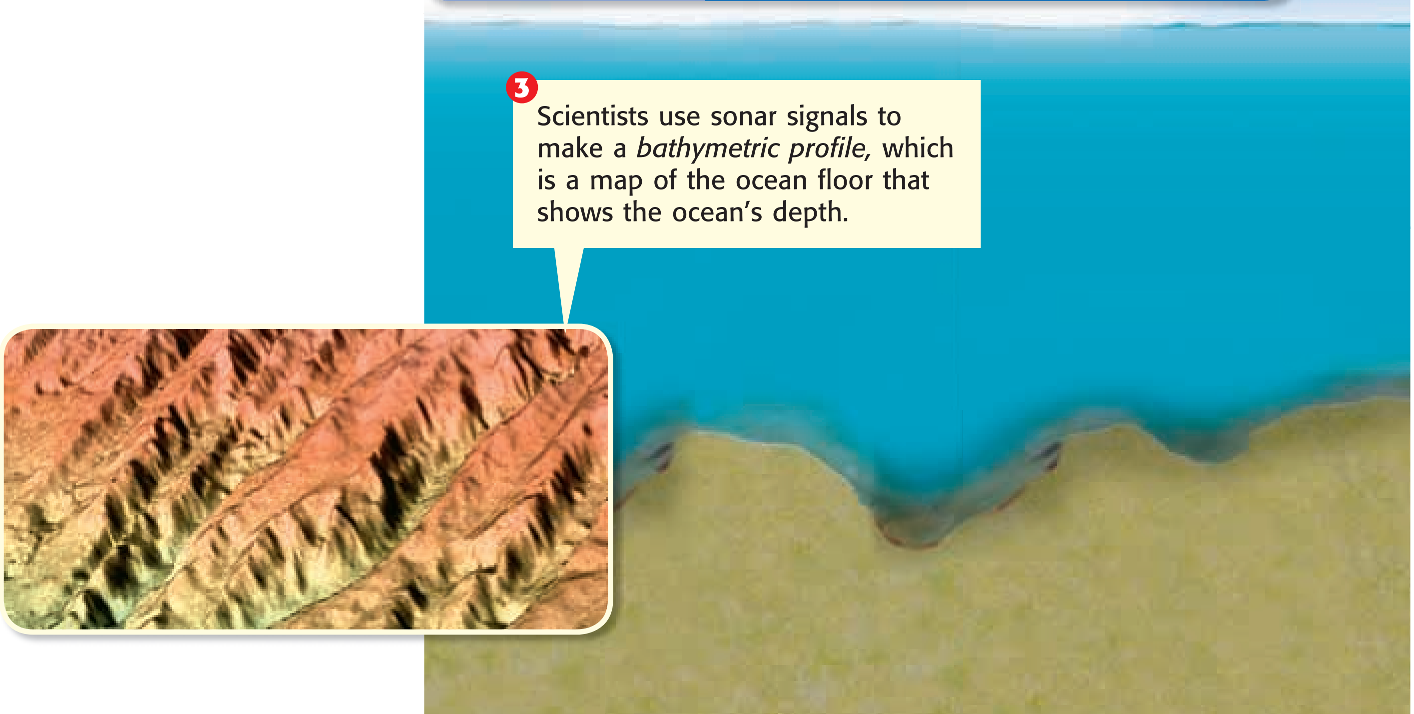
Studying the Ocean Floor

Sending people into deep water to study the ocean floor can be risky. Fortunately, there are other ways to study the deep ocean. These ways include surveying from the ocean surface and from high above in space.

Seeing by Sonar

Sonar stands for ***so****und* ***n****avigation* ***a****nd* ***r****anging*. This technology is based on the echo-ranging behavior of bats. Scientists use sonar to determine the ocean's depth by sending sound pulses from a ship down into the ocean. The sound moves through the water, bounces off the ocean floor, and returns to the ship. The deeper the water is, the longer the round trip takes. Scientists then calculate the depth by multiplying half the travel time by the speed of sound in water (about 1,500 m/s). This process is shown in **Figure 1.**

Figure 1 **Ocean Floor Mapping with Sonar**



Oceanography via Satellite

In the 1970s, scientists began studying Earth from satellites in orbit around the Earth. In 1978, scientists launched the satellite *Seasat*. This satellite focused on the ocean, sending images back to Earth that allowed scientists to measure the direction and speed of ocean currents.

Studying the Ocean with *Geosat*

Geosat, once a top-secret military satellite, has been used to measure slight changes in the height of the ocean's surface. Different underwater features, such as mountains and trenches, affect the height of the water above them. Scientists measure the different heights of the ocean surface and use the measurements to make detailed maps of the ocean floor. Maps made using satellite measurements, such as the map in **Figure 2,** can cover much more territory than maps made using ship-based sonar readings.

Reading Check **How do scientists use satellites to make detailed maps of the ocean floor?** (*See the Appendix for answers to Reading Checks.*)

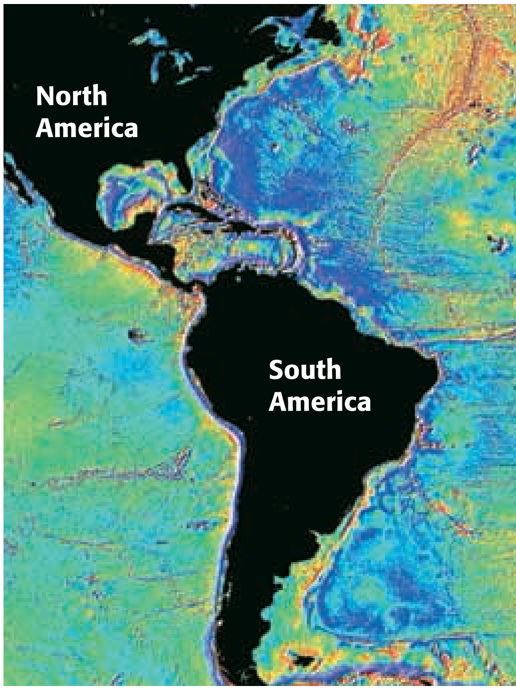
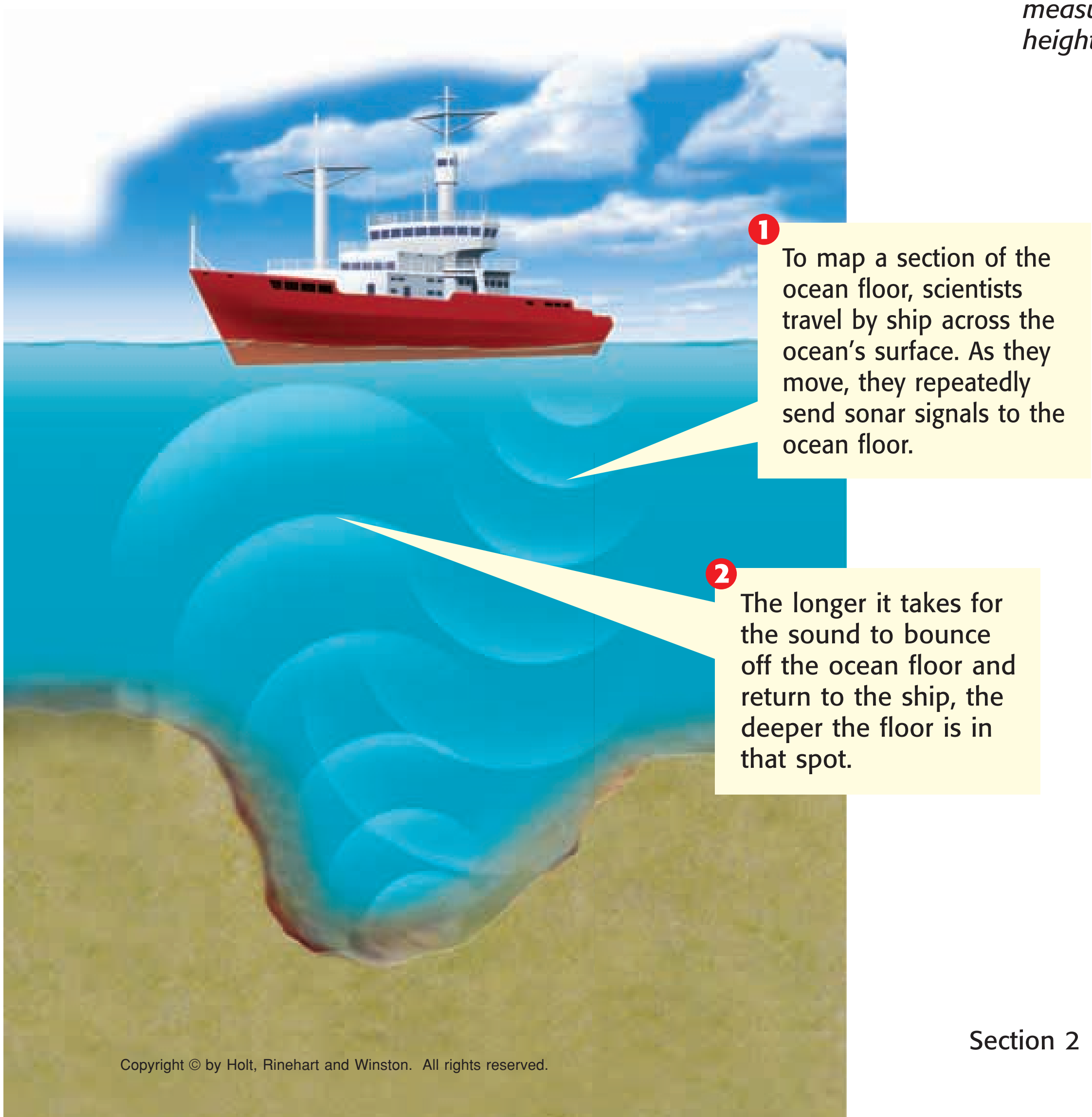


Figure 2 *This map was generated by satellite measurements of different heights of the ocean surface.*



Revealing the Ocean Floor

Can you imagine being an explorer assigned to map uncharted areas on the planet? You might think that there are not many uncharted areas left because most of the land has already been explored. But what about the bottom of the ocean?

The ocean floor is not a flat surface. If you could go to the bottom of the ocean, you would see a number of impressive features. You would see the world's longest mountain chain, which is about 64,000 km (40,000 mi) long as well as canyons deeper than the Grand Canyon. And because it is underwater and some areas are so deep, much of the ocean floor is still not completely explored.

Reading Check **How long is the longest mountain chain in the world? Where is it located?**

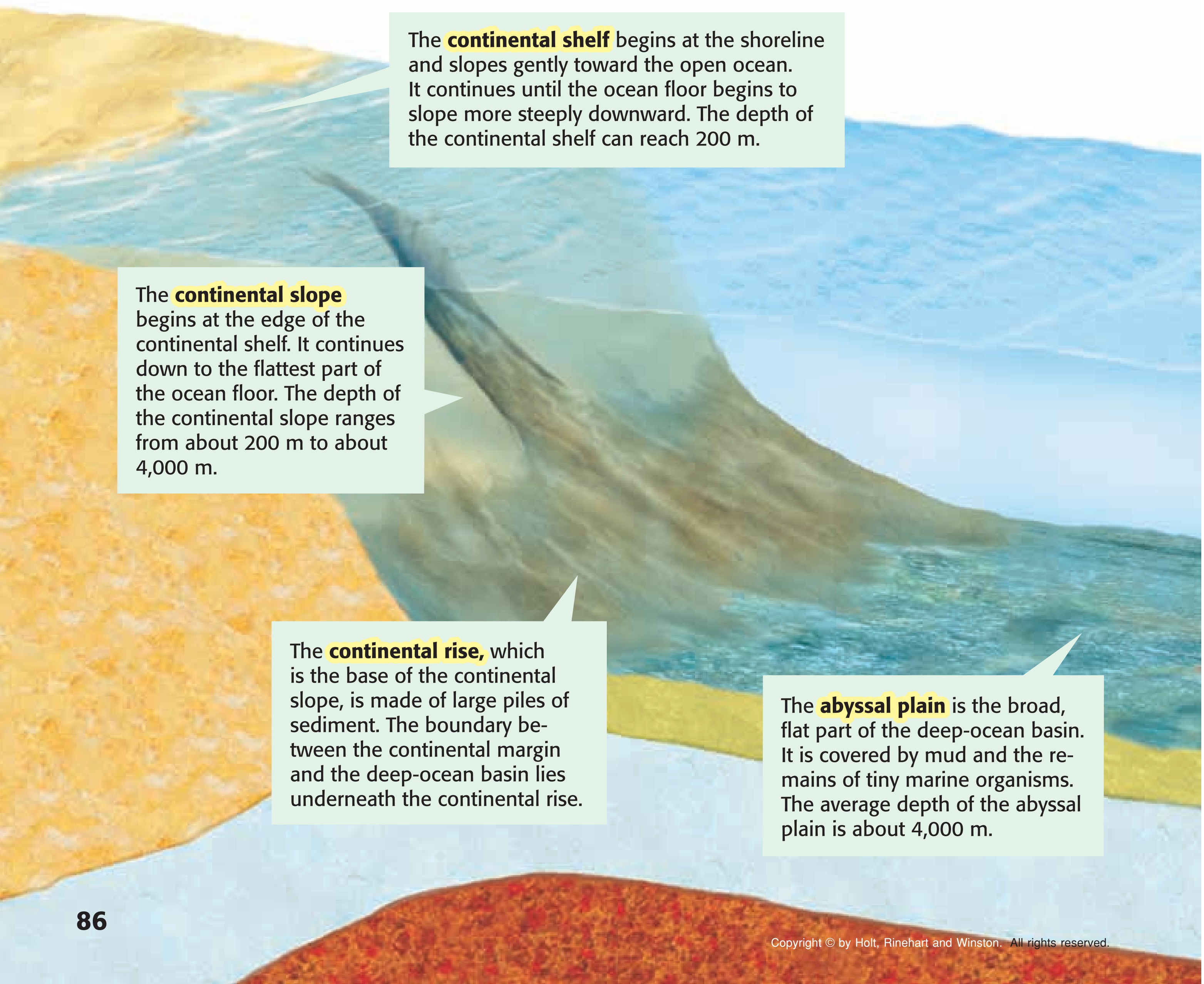
continental shelf the gently sloping section of the continental margin located between the shoreline and the continental slope

continental slope the steeply inclined section of the continental margin located between the continental rise and the continental shelf

continental rise the gently sloping section of the continental margin located between the continental slope and the abyssal plain

abyssal plain a large, flat, almost level area of the deep-ocean basin

Figure 3 **The Ocean Floor**



Regions of the Ocean Floor

If you journeyed to the ocean floor, you would first notice two major regions. The *continental margin* is made of continental crust, and the *deep-ocean basin* is made of oceanic crust. Imagine that the ocean is a giant swimming pool. The continental margin is the shallow end of the pool, and the deep-ocean basin is the deep end of the pool. The figure below shows how these two regions are subdivided.

Underwater Real Estate

As you can see in **Figure 3** below, the continental margin is subdivided into the continental shelf, the continental slope, and the continental rise. These divisions are based on depth and changes in slope. The deep-ocean basin consists of the abyssal (uh BIS uhl) plain, mid-ocean ridges, rift valleys, and ocean trenches. All of these features form near the boundaries of Earth's *tectonic plates*. On parts of the deep-ocean basin that are not near plate boundaries, there are thousands of seamounts. Seamounts are submerged volcanic mountains on the ocean floor.

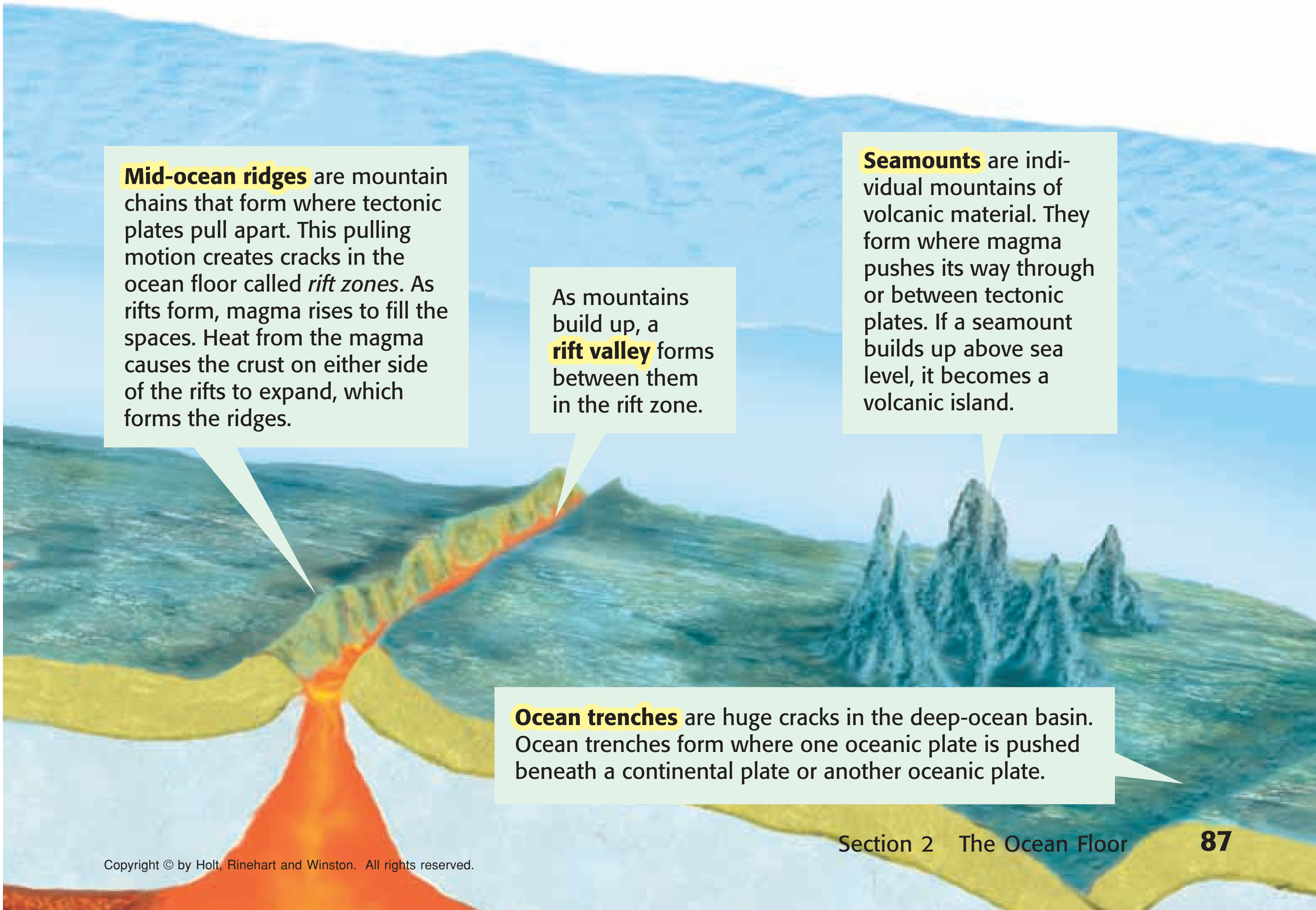
Reading Check **What are the subdivisions of the continental margin?**

mid-ocean ridge a long, undersea mountain chain that forms along the floor of the major oceans

rift valley a long, narrow valley that forms as tectonic plates separate

seamount a submerged mountain on the ocean floor that is at least 1,000 m high and that has a volcanic origin

ocean trench a steep, long depression in the deep-sea floor that runs parallel to a chain of volcanic islands or a continental margin



Exploring the Ocean with Underwater Vessels

Just as astronauts explore space with rockets, scientists explore the oceans with underwater vessels. These vessels contain the air that the explorers need to breathe and all of the scientific instruments that the explorers need to study the oceans.

Piloted Vessels: *Alvin* and *Deep Flight*

One research vessel used to travel to the deep ocean is called *Alvin*. *Alvin* is 7 m long and can reach some of the deepest parts of the ocean. Scientists have used *Alvin* for many underwater missions, including searches for sunken ships, the recovery of a lost hydrogen bomb, and explorations of the sea floor. In 1977, scientists aboard *Alvin* discovered an oasis of life around hydrothermal vents near the Galápagos Islands. Ecosystems near hydrothermal vents are unique because some organisms living around the vent do not rely on photosynthesis for energy. Instead, these organisms rely on chemicals in the water as their source of energy.

Another modern vessel that scientists use to explore the deep ocean is an underwater airplane called *Deep Flight*. This vessel, shown in **Figure 4,** moves through the water in much the same way that an airplane moves through the air. Future models of *Deep Flight* will be designed to transport pilots to the deepest parts of the ocean, which are more than 11,000 m deep.

Reading Check **Why is the ecosystem discovered by *Alvin* unique?**

CONNECTION TO Social Studies

The JASON Project The JASON project, started by oceanographer Dr. Robert Ballard, allows students and teachers to take part in virtual field trips to some of the most exotic locations on Earth. Using satellite links and the Internet, students around the world have participated in scientific expeditions to places such as the Galápagos Islands, the Sea of Cortez, and deep-sea hydrothermal vents. Using the Internet, research where the JASON project is headed next!

Figure 4 *Like the Wright brothers' first successful airplane,* Deep Flight *sets the stage for a bright future—this time in underwater "flight."*

Robotic Vessels: *JASON II* and *Medea*

Exploring the deep ocean by using piloted vessels is expensive and can be very dangerous. For these reasons, scientists use robotic vessels to explore the ocean. One interesting robot team consists of *JASON II* and *Medea*. These robots are designed to withstand pressures much greater than those found in the deepest parts of the ocean. *JASON II* is "flown" by a pilot at the surface and is used to explore the ocean floor. *Medea* is attached to *JASON II* with a tether and explores above the sea floor. In the future, unpiloted "drone" robots shaped like fish may be used. Another robot under development uses the ocean's thermal energy for power. These robots could explore the ocean for years and send data to scientists at the surface.

SECTION Review

Summary

- Scientists study the ocean floor from the surface using sonar and satellites.
- The ocean floor is divided into two regions—the continental margin and the deep-ocean basin.
- The continental margin consists of the continental shelf, the continental slope, and the continental rise.
- The deep-ocean basin consists of the abyssal plain, mid-ocean ridges, rift valleys, seamounts, and ocean trenches.
- Scientists explore the ocean from below the surface by using piloted vessels and robotic vessels.

Using Key Terms

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

1. *continental shelf* and *continental slope*
2. *abyssal plain* and *ocean trench*
3. *mid-ocean ridge* and *seamount*

Understanding Key Ideas

4. Sonar is a technology based on the
   a. *Geosat* satellite.
   b. surface currents in the ocean.
   c. zones of the ocean floor.
   d. echo-ranging behavior of bats.
5. List the two major regions of the ocean floor.
6. Describe the subdivisions of the continental margin.
7. List three technologies for studying the ocean floor, and explain how they are used.
8. List three underwater missions that *Alvin* has been used for.
9. Explain how *Jason II* and *Medea* are used to explore the ocean.
10. Describe how a bathymetric profile is made.

Math Skills

11. Air pressure at sea level is 1 atmosphere (atm). Underwater, pressure increases by 1 atm every 10 m of depth. For example, at a depth of 10 m, water pressure is 2 atm. What is the pressure at 100 m?

Critical Thinking

12. **Making Comparisons** How is exploring the oceans similar to exploring space?
13. **Applying Concepts** Is the ocean floor a flat surface? Explain your answer.

SECTION 3

Life in the Ocean

In which part of the ocean does an octopus live? And where do dolphins spend most of their time?

Just as armadillos and birds occupy very different places on Earth, octopuses and dolphins live in very different parts of the ocean. Trying to study life in the oceans can be a challenge for scientists. The oceans are so large that many forms of marine life have not been discovered, and there are many more organisms that scientists know little about. To make things easier, scientists classify marine organisms into three main groups.

READING WARM-UP

Objectives

- Identify the three groups of marine life.
- Describe how food webs are interconnected.
- Identify the four ecological zones of marine environments.
- List the characteristics of different marine ecosystems.

Terms to Learn

plankton
nekton
benthos
estuary

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the ecological zones of the ocean.

The Three Groups of Marine Life

The three main groups of marine life, as shown in **Figure 1,** are plankton, nekton, and benthos. Marine organisms are placed into one of these three groups according to where they live and how they move. Organisms that float or drift freely near the ocean's surface are called **plankton**. Most plankton are microscopic and provide food for most other organisms in the ocean. Plankton are divided into two groups—those that are plantlike (*phytoplankton*) and those that are animal-like (*zooplankton*). Phytoplankton produce much of the world's oxygen. Organisms that swim actively in the open ocean are called **nekton.** Types of nekton include mammals, such as whales, dolphins, and sea lions, as well as many varieties of fish. **Benthos** are organisms that live on or in the ocean floor. There are many types of benthos, such as crabs, starfish, worms, coral, sponges, seaweed, and clams.

plankton the mass of mostly microscopic organisms that float or drift freely in freshwater and marine environments

nekton all organisms that swim actively in open water, independent of currents

benthos the organisms that live at the bottom of the sea or ocean

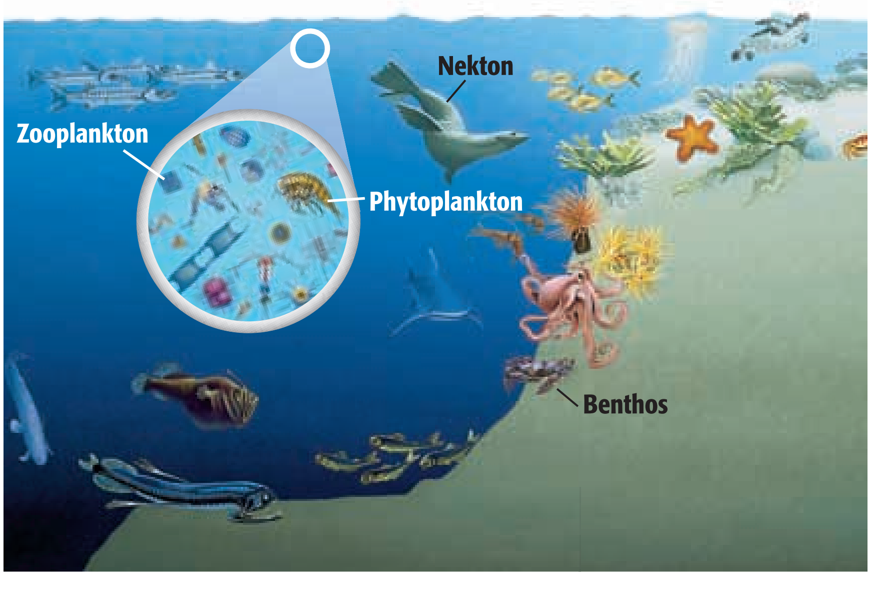


Figure 1 *Plankton, nekton, and benthos are the three groups of organisms that live in the ocean.*

Food Chains and Food Webs

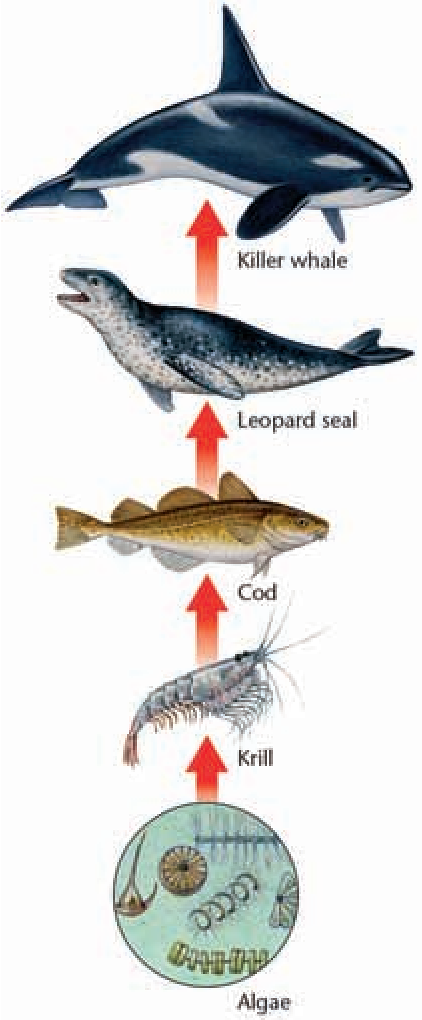
Figure 2 shows an aquatic food chain. A *food chain* is a diagram that shows how energy in food flows from one organism to another. Because few organisms eat just one kind of food, the energy connections in nature are more accurately shown by a food web than by a food chain. A *food web* is a diagram that shows the feeding relationships between organisms in an ecosystem. **Figure 3** shows a simple aquatic food web.

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

Interconnected Food Webs

There are two main food webs on Earth: aquatic food webs and terrestrial food webs. These food webs are interconnected. Research has shown that parts of some aquatic food webs are supported by terrestrial organic matter. This organic matter, in the form of carbon, comes from the trees and other plants located near aquatic ecosystems. Carbon can help support the growth of fish and invertebrates. Amphibians, such as frogs, can also be a part of both types of food webs. A frog may eat a fly on land and then be eaten by a snake in the water. Or a frog may eat an insect in a pond and be eaten by a raccoon on land. Humans are top consumers in both food webs because of the fishing and agricultural industries.

Figure 2 *This food chain shows how energy is transferred from one organism to another.*



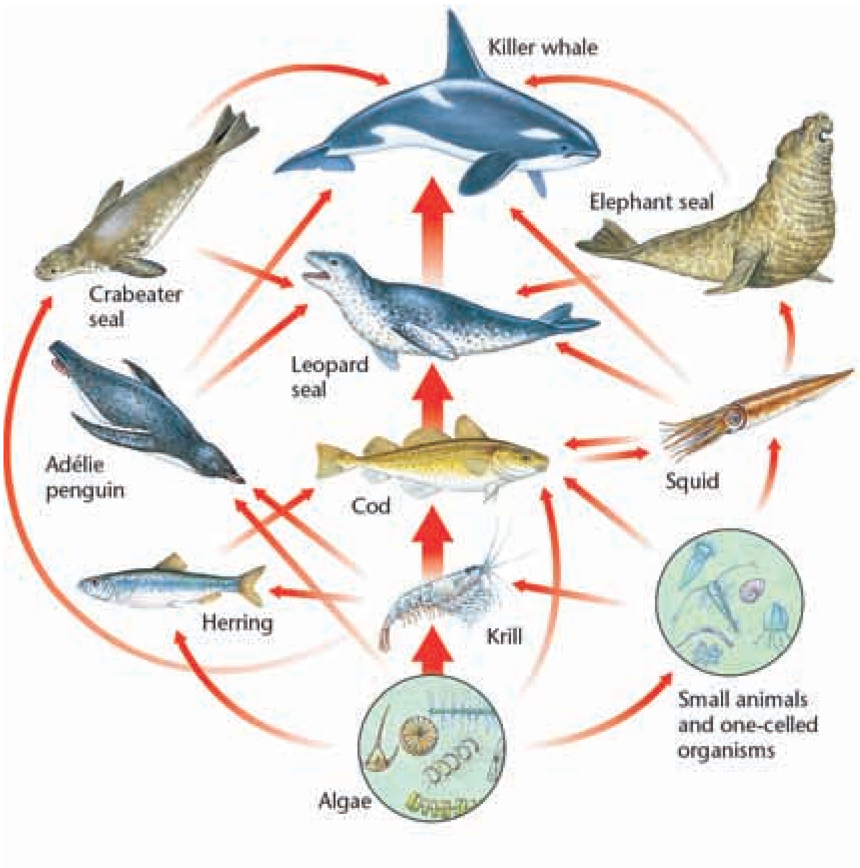


Figure 3 *Notice that in this food web, an arrow goes from the Adélie penguin to the leopard seal, showing that the Adélie penguin is food for the leopard seal. The Adélie penguin is also food for the killer whale.*

Marine Environments

Life in the ocean is affected by water depth and the amount of sunlight that passes into the water. The major ecological zones of marine environments are shown in **Figure 4.**

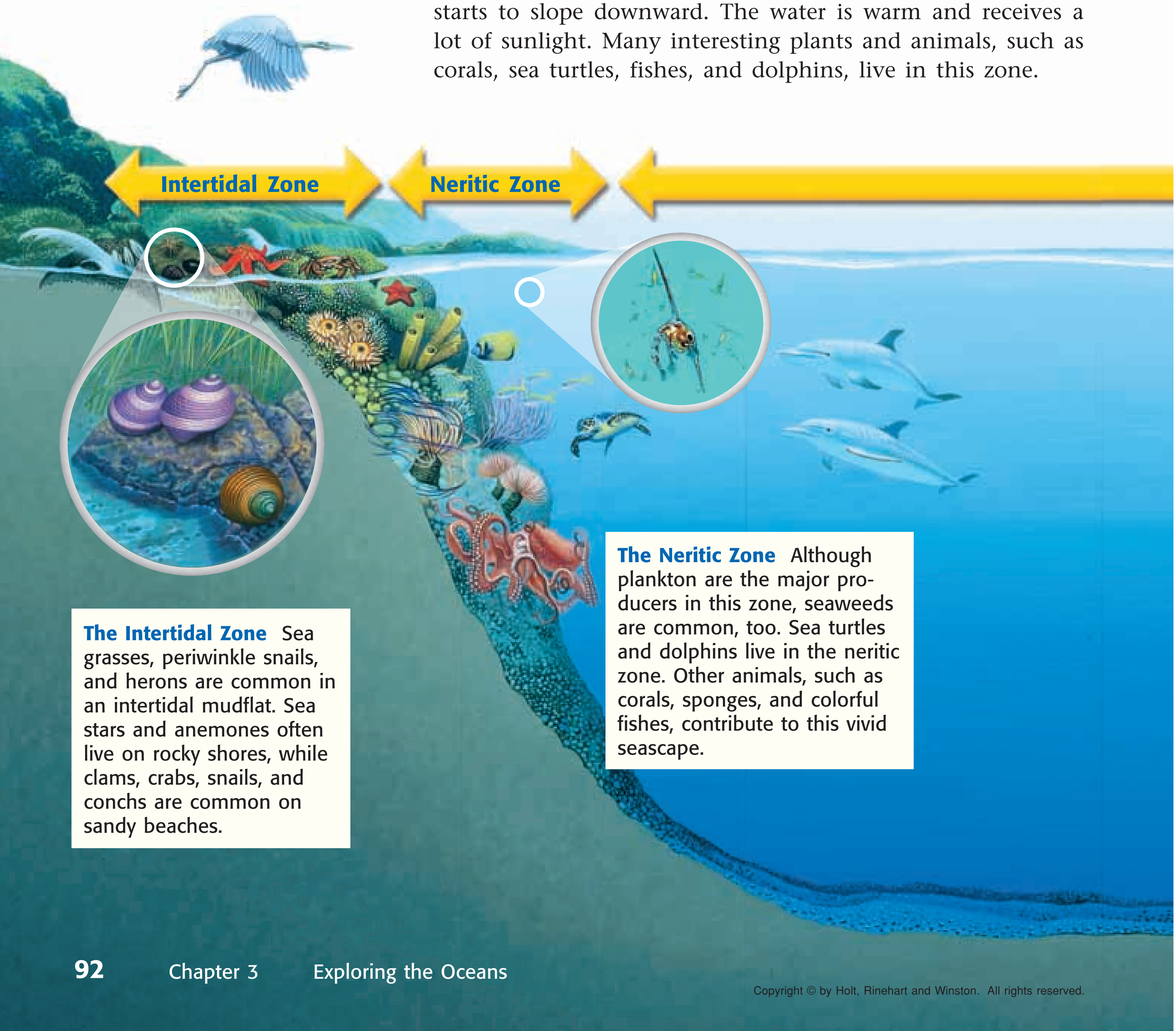
The Intertidal Zone

The intertidal zone is the place where the ocean meets the land. This area is exposed to the air for part of the day. Waves are always crashing on the rock and sand. The animals that live in the intertidal zone have adaptations to survive exposure to air and to keep from being washed away by the waves.

The Neritic Zone

As you move farther away from shore, into the neritic zone (nee RIT ik ZOHN), the water becomes deeper. The ocean floor starts to slope downward. The water is warm and receives a lot of sunlight. Many interesting plants and animals, such as corals, sea turtles, fishes, and dolphins, live in this zone.

Figure 4 *The life in a marine ecosystem depends on water temperature, water depth, and the amount of sunlight the area receives.*



The Intertidal Zone Sea grasses, periwinkle snails, and herons are common in an intertidal mudflat. Sea stars and anemones often live on rocky shores, while clams, crabs, snails, and conchs are common on sandy beaches.

The Neritic Zone Although plankton are the major producers in this zone, seaweeds are common, too. Sea turtles and dolphins live in the neritic zone. Other animals, such as corals, sponges, and colorful fishes, contribute to this vivid seascape.

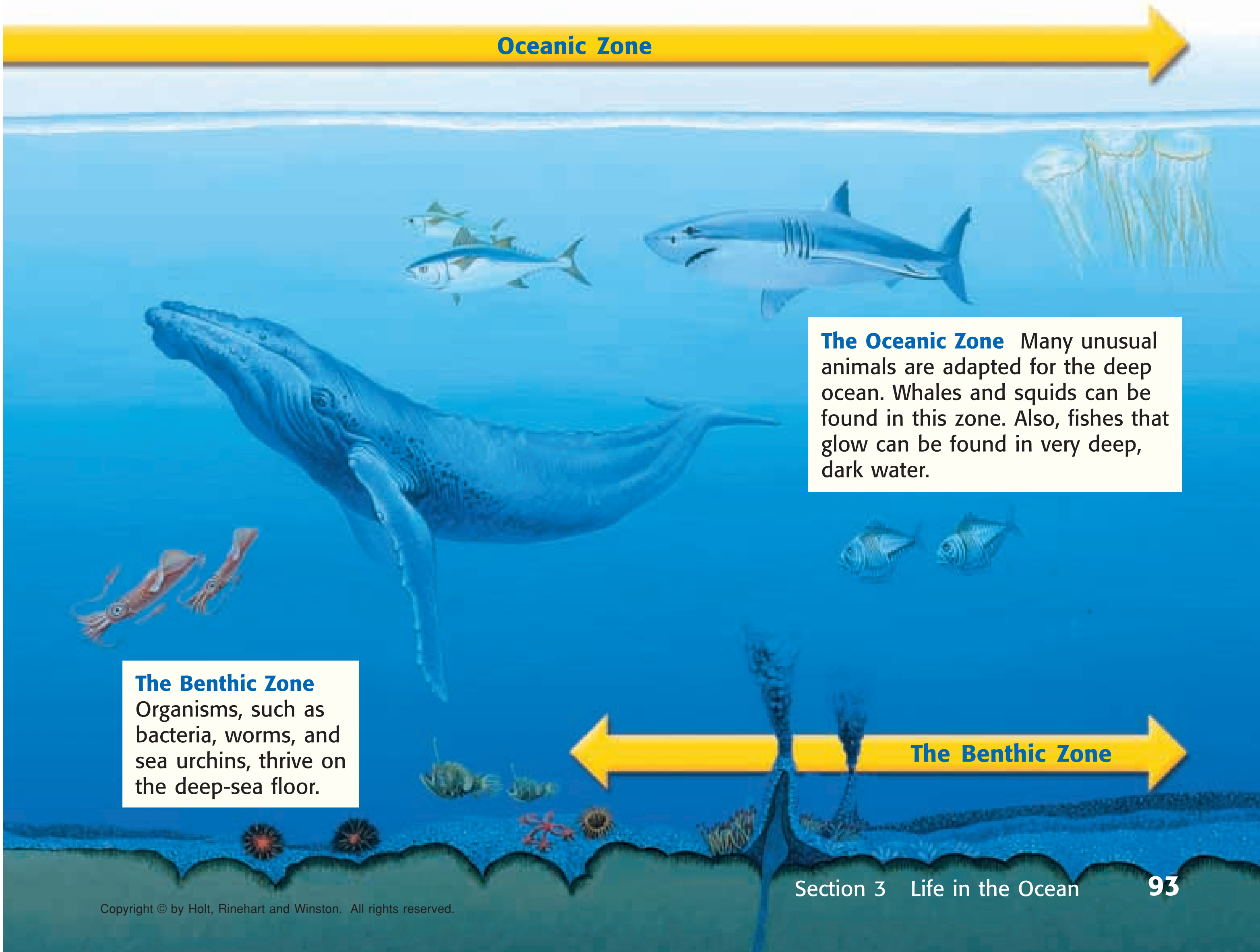
The Oceanic Zone

In the oceanic zone, the sea floor drops sharply. This zone contains the deep water of the open ocean. Plankton can be found near the water surface. Animals, such as fishes, whales, and sharks, are found in the oceanic zone. Some animals in this zone live in very deep water. These animals often get food from material that sinks down from the ocean surface.

The Benthic Zone

The benthic zone is the ocean floor. The deepest parts of the benthic zone do not get any sunlight. They are also very cold. Animals, such as fishes, worms, and crabs, have special adaptations to the deep, dark water. Many of these organisms get food by eating material that sinks from above. Some organisms, such as bacteria, get energy from chemicals that escape from thermal vents on the ocean floor. Thermal vents form at cracks in the Earth's crust.

Reading Check **How do animals in the benthic zone get food?**



The Oceanic Zone Many unusual animals are adapted for the deep ocean. Whales and squids can be found in this zone. Also, fishes that glow can be found in very deep, dark water.

The Benthic Zone Organisms, such as bacteria, worms, and sea urchins, thrive on the deep-sea floor.

Marine Ecosystems

Marine ecosystems of the world are made up of different plant and animal communities. Some marine ecosystems are located on or near the shore, while other marine ecosystems are located in the middle of the ocean or near the poles.

Intertidal Areas

Intertidal areas are found near the shore. These areas include mudflats, sandy beaches, and rocky shores. Intertidal organisms must be able to live both underwater and out of water. The organisms that live in mudflats include worms and crabs. Shorebirds feed on these animals. Organisms that live on sandy beaches include worms, clams, crabs, and plankton. On rocky shores, organisms such as the sea stars in **Figure 5,** have adaptations to keep from being swept away by crashing waves. Other organisms use rootlike structures called *holdfasts* to attach themselves to the rocks. And other organisms attach themselves to rocks by releasing a special glue.

Coral Reefs

Most coral reefs are found in warm, shallow areas of the neritic zone. The reefs are made up of small animals called *corals.* Corals live in large groups. When corals die, they leave their skeletons behind. New corals grow on these remains. Over time, layers of skeletons build up and form a reef. This reef provides a home for many marine animals and plants. These organisms include algae, brightly colored fishes, sponges, sea stars, and sea urchins.

Reading Check How do coral reefs develop?

Figure 5 *Organisms such as sea anemones and sea stars attach themselves to rocks and reefs. These organisms must be able to survive both wet and dry conditions.*

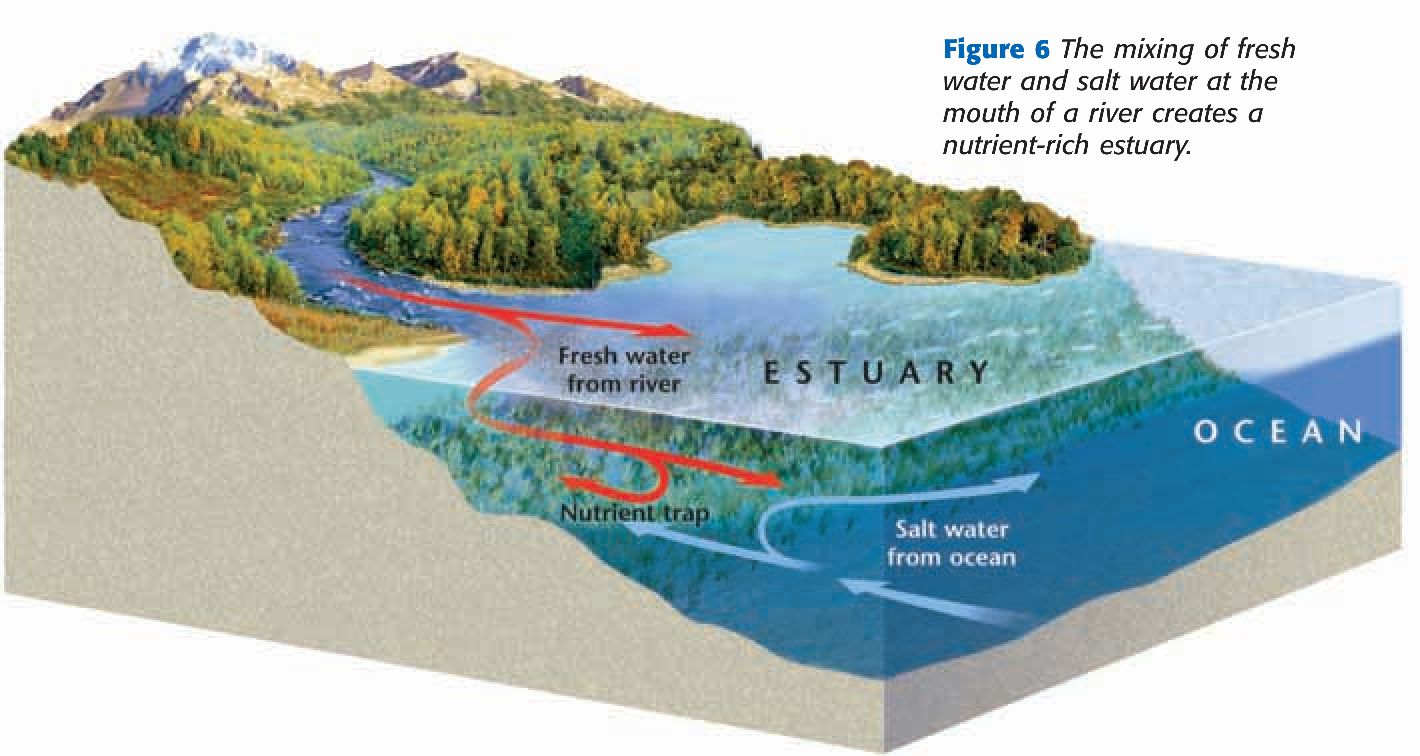


Figure 6 *The mixing of fresh water and salt water at the mouth of a river creates a nutrient-rich estuary.*

Estuaries

An area where fresh water from streams and rivers spills into the ocean is called an **estuary** (ES tyoo er ee). In estuaries, the fresh water from rivers and the salt water from the ocean are always mixing, as shown in **Figure 6.** The fresh water that spills into an estuary from a river is rich in nutrients. Estuaries are very productive ecosystems because they constantly receive nutrients from the river and from the ocean.

estuary an area where fresh water from rivers mixes with salt water from the ocean

Some estuaries are threatened by pollution. Estuaries located along the coasts of North Carolina are threatened by runoff from urban development and agricultural industries. Runoff from these areas can contain chemicals, which cause microorganisms to grow rapidly. The rapid growth of these organisms can kill fish and some plants.

Reading Check **Why are estuaries very productive?**

Plants and Animals of Estuaries

Because stable estuaries are so rich in nutrients, estuaries support large numbers of plankton. The plankton provide food for larger animals, such as fish. Dolphins, manatees, seals, and other mammals often feed on fish and plants in estuaries. Birds, such as the egret in **Figure 7,** also rely on the fish and invertebrates that live in estuaries for food. Estuaries also provide a protected area for migratory birds to rest and breed.

Figure 7 *Many different types of birds live in estuaries. This egret lives in the estuary of Pamlico Sound in North Carolina.*

Figure 8 *Mangrove trees grow in the warm, coastal salt water of mangrove swamps.*

Mangrove Swamps

Marine ecosystems called *mangrove swamps* are swamps located along the coast of tropical areas. Plants called mangrove trees, as shown in **Figure 8,** grow partly in the warm and shallow salt water of mangrove swamps. These types of swamps help protect the coastline from erosion and reduce the damage from tropical storms. Mangrove swamps also provide breeding and feeding areas for many different types of organisms.

The Sargasso Sea

A marine ecosystem called the *Sargasso Sea* (sahr GAS oh SEE) is found in the middle of the Atlantic Ocean. This ecosystem contains floating rafts of algae called *sargassum* (sahr GAS uhm). Many of the animals that live in the Sargasso Sea are the same color as sargassum, which helps the animals hide from predators.

Reading Check What is *sargassum*?

Polar Ice

The Arctic Ocean and the ocean around Antarctica make up another marine ecosystem. These icy waters located at the North and South Poles are rich in nutrients, which support large numbers of plankton. Plankton form the basis of the Arctic and Antarctic food webs. Many fishes, birds, and mammals that live in and around the poles rely on the plankton for food. Other animals, such as Beluga whales feed on many different arctic organisms. Several species of penguins, such as those shown in **Figure 9,** live on the polar ice of Antarctica.

Figure 9 *There are 17 species of penguins. Five of these species live in and around Antarctica.*

SECTION Review

Summary

- The three main groups of marine life are plankton, nekton, and benthos.
- A food chain is a diagram that shows how energy flows from one organism to another. A food web is a diagram that shows the feeding relationships between organisms in an ecosystem.
- Aquatic food webs and terrestrial food webs are interconnected. Aquatic and terrestrial food webs can support each other.
- Organisms, such as amphibians, can be a part of aquatic and terrestrial food webs.
- Four ecological zones of marine environments are the intertidal zone, the neritic zone, the oceanic zone, and the benthic zone.
- The ocean contains unique ecosystems, including intertidal areas, coral reefs, estuaries, mangrove swamps, the Sargasso Sea, and polar ice.

Using Key Terms

1. Use each of the following terms in a separate sentence: *plankton* and *estuary*.

Understanding Key Ideas

2. The ecological zone where the ocean meets the land is called the

a. neritic zone.
b. intertidal zone.
c. benthic zone.
d. oceanic zone.

3. List and briefly describe the three main groups of marine organisms.

4. Describe four major ecological zones of marine environments.

5. Describe five marine ecosystems. For each ecosystem, list an organism that lives there.

6. Why are estuaries important to some migratory birds?

7. Describe two examples that show how aquatic and terrestrial food webs are interconnected.

Math Skills

8. The ocean covers about 71% of the Earth's surface. If the total surface area of the Earth is about 510 million square kilometers, how many square kilometers are covered by the ocean?

Critical Thinking

9. Making Inferences Animals in the Sargasso Sea hide from predators by blending in with the sargassum. Color is only one way to blend in. What is another way that animals can blend in with sargassum?

10. Identifying Relationships Many fishes and other organisms that live in the deep ocean produce light. What are two ways in which this light might be useful?

11. Applying Concepts Imagine that you are studying animals that live in intertidal zones. You just discovered a new animal. Describe the animal and adaptations the animal has to survive in the intertidal zone.

12. Applying Concepts How would the ocean's ecological zones change if sea level dropped 300 m?

SECTION 4

Resources from the Ocean

The next time you enjoy your favorite ice cream, remember that without seaweed, it would be a runny mess!

The ocean offers a vast supply of resources. These resources are put to a number of uses. For example, a seaweed called *kelp* is used as a thickener for many food products, including ice cream. Food, raw materials, energy, and drinkable water are all harvested from the ocean. And there are probably more resources in unexplored parts of the ocean. As human populations have grown, however, the demand for these resources has increased, while the availability has decreased.

READING WARM-UP

Objectives

- List two ways of harvesting the ocean's living resources.
- Identify three nonliving resources in the ocean.
- Describe the ocean's energy resources.

Terms to Learn

desalination

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Living Resources

People have been harvesting plants and animals from the ocean for thousands of years. Many civilizations formed in coastal regions where the ocean offered plenty of food for a growing population. Today, harvesting food from the ocean is a multi-billion-dollar industry.

Fishing the Ocean

Of all the marine organisms, fish are the largest group of organisms that are taken from the ocean. Almost 75 million tons of fish are harvested each year. With improved technology, such as drift nets, fishers have become better at taking fish from the ocean. **Figure 1** shows the large number of fish that can be caught using a drift net. In recent years, many people have become concerned that we are overfishing the ocean. We are taking more fish than can be naturally replaced. Also, animals other than fish, especially dolphins and turtles, can be accidentally caught in drift nets. Today, the fishing industry is making efforts to prevent overfishing and damage to other wildlife from drift nets.

Figure 1 *Drift nets are fishing nets that cover kilometers of ocean. Whole schools of fish can be caught with a single drift net.*

Farming the Ocean

Overfishing reduces fish populations. Recently, laws regulating fishing have become stricter. As a result, it is becoming more difficult to supply our demand for fish. Many people have begun to raise ocean fish in fish farms to help meet the demand. Fish farming requires several holding ponds. Each pond contains fish at a certain level of development. **Figure 2** shows a holding pond in a fish farm. When the fish are old enough, they are harvested and packaged for shipping.

Fish are not the only seafood harvested in a farmlike setting. Shrimp, oysters, crabs, and mussels are raised in enclosed areas near the shore. Mussels and oysters are grown attached to ropes. Huge nets line the nursery area, preventing the animals from being eaten by their natural predators.

Reading Check **How can fish farms help reduce overfishing?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 *Eating fish raised in a fish farm helps lower the number of fish harvested from the ocean.*

Savory Seaweed

Many types of seaweed, which are species of alga, are harvested from the ocean. For example, kelp, shown in **Figure 3,** is a seaweed that grows as much as 33 cm a day. Kelp is harvested and used as a thickener in jellies, ice cream, and similar products. Seaweed is rich in protein. In fact, several species of seaweed are staples of the Japanese diet. For example, some kinds of sushi, a Japanese dish, are wrapped in seaweed.

Figure 3 *Kelp, a type of alga, can grow up to 33 cm a day. It is harvested and used in a number of products, including ice cream.*

Nonliving Resources

Humans also harvest many nonliving resources from the ocean. These resources provide raw materials, drinkable water, and energy for our growing population. Some resources are easy to get, while others are very difficult to harvest.

Oil and Natural Gas

Modern civilization continues to be very dependent on oil and natural gas for energy. Oil and natural gas are *nonrenewable resources*. They are used up faster than they can be replenished naturally. Both oil and natural gas are found under layers of impermeable rock. Petroleum engineers must drill through this rock in order to reach these resources.

Reading Check **What are nonrenewable resources? Give an example of a nonrenewable resource.**

Searching for Oil

How do engineers know where to drill for oil and natural gas? They use seismic equipment. Special devices send powerful pulses of sound to the ocean floor. The pulses move through the water and penetrate the rocks and sediment below. The pulses are then reflected back toward the ship, where they are recorded by electronic equipment and analyzed by a computer. The computer readings indicate how rock layers are arranged below the ocean floor. Petroleum workers, such as the one in **Figure 4,** use these readings to locate a promising area to drill.

Figure 4 *Petroleum workers, such as the one below, drill for oil and gas in the ocean floor. By using seismic equipment, workers can decide which spot will be best for drilling.*

Figure 5 *Most desalination plants, like this one in Kuwait, use evaporation to separate ocean water from the salt it contains.*

Fresh Water and Desalination

In parts of the world where fresh water is limited, people desalinate ocean water. **Desalination** (DEE SAL uh NAY shuhn) is the process of removing salt from sea water. After the salt is removed, the fresh water is then collected for human use. But desalination is not as simple as it sounds, and it is very expensive. Countries with enough annual rainfall rely on the fresh water provided by precipitation and do not need costly desalination plants. Some countries located in drier parts of the world must build desalination plants to provide enough fresh water. One of these plants is shown in **Figure 5.** Saudi Arabia, located in the desert region of the Middle East, has one of the largest desalination plants in the world.

desalination a process of removing salt from ocean water

Reading Check **Explain where desalination plants are most likely to be built.**

Quick Lab

The Desalination Plant

1. Measure **1,000 mL of warm water** in a **graduated cylinder.** Pour the water in a **large pot.**
2. Carefully, add **35 g of table salt.** Stir the water until all of the salt is dissolved.
3. Place the pot on a **hot plate,** and allow all of the water to boil away.
4. Using a **wooden spoon,** scrape the salt residue from the bottom of the pot.
5. Measure the mass of the salt that was left in the bottom of the pot. How much salt did you separate from the water?
6. How does this activity model what happens in a desalination plant? What would be done differently in a desalination plant?

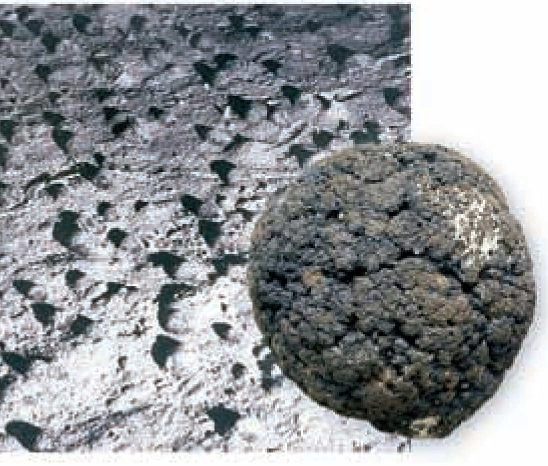


Figure 6 *Manganese nodules are difficult to mine because they are located on the deep ocean floor.*

Sea-Floor Minerals

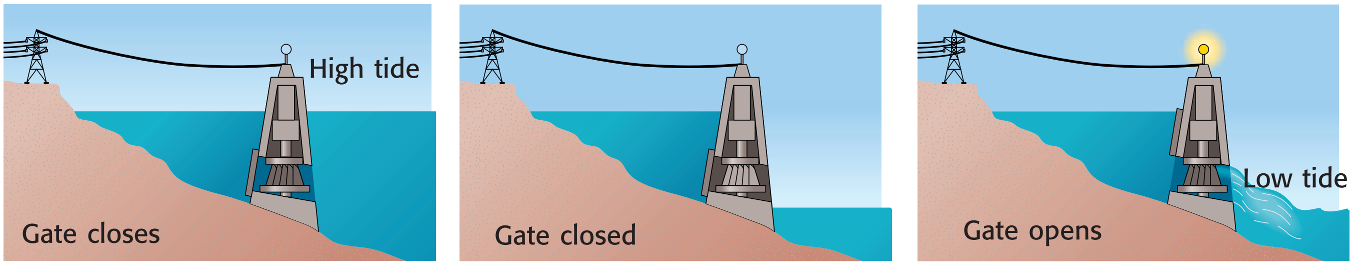
Mining companies are interested in mineral nodules that are lying on the ocean floor. These nodules are made mostly of manganese, which can be used to make certain types of steel. They also contain iron, copper, nickel, and cobalt. Other nodules are made of phosphates, which are used to make fertilizer.

Nodules are formed from dissolved substances in sea water that stick to solid objects, such as pebbles. As more substances stick to the coated pebble, a nodule begins to grow. Manganese nodules can be as small as a marble or as large as a soccer ball. The photograph in **Figure 6** shows a number of nodules on the ocean floor. Scientists estimate that 15% of the ocean floor is covered with these nodules. However, these nodules are located in the deeper parts of the ocean, and mining them is costly and difficult.

Tidal Energy

The ocean generates a great deal of energy simply because of its constant movement. The gravitational pulls of the sun and moon cause the ocean to rise and fall as tides. *Tidal energy* is energy generated from the movement of tides. Tidal energy can be an excellent source of power. If the water during high tide can be rushed through a narrow coastal passageway, the water's force can be powerful enough to generate electrical energy. **Figure 7** shows how this process works. Tidal energy is a clean, inexpensive, and renewable resource. A *renewable resource* can be replenished, in time, after being used. Unfortunately, tidal energy is practical only in a few parts of the world. These areas must have a coastline with shallow, narrow channels. For example, the coastline at Cook Inlet, in Alaska, is ideal for generating electrical energy.

Figure 7 **Using Tides to Generate Electrical Energy**



1. As the tide rises, water enters a bay behind a dam. The gate then closes at high tide.
2. The gate remains closed as the tide lowers.
3. At low tide, the gate opens, and the water rushes through the dam and moves the turbines, which, in turn, generate electrical energy.

Wave Energy

Have you ever stood on the beach and watched as waves crashed on the shore? This constant motion is an energy resource. Wave energy, like tidal energy, is a clean, renewable resource. Recently, computer programs have been developed to analyze wave energy. Researchers have found certain areas of the world where wave energy can generate enough electrical energy to make building power plants worthwhile. Wave energy in the North Sea is strong enough to produce power for parts of Scotland and England.

Reading Check **Why would wave energy be a good alternative energy resource?**

SECTION Review

Summary

- Humans depend on the ocean for living and nonliving resources.
- Fish and other marine life are being raised in ocean farms to help feed growing human populations.
- Nonliving ocean resources include oil and natural gas, water, minerals, and tidal and wave energy.

Using Key Terms

1. In your own words, write a definition for the term *desalination*.

Understanding Key Ideas

2. Mineral nodules on the ocean floor are
   a. renewable resources.
   b. easily mined.
   c. used during the process of desalination.
   d. nonliving resources.
3. List two ways of harvesting the ocean's living resources.
4. Name four nonliving resources in the ocean.
5. Explain how fish farms help meet the demand for fish.
6. Explain how engineers decide where to drill for oil and natural gas in the ocean.

Math Skills

7. A kelp plant is 5 cm tall. If it grows an average of 29 cm per day, how tall will the kelp plant be after 2 weeks?

Critical Thinking

8. **Analyzing Processes** Explain why tidal energy and wave energy are considered renewable resources.
9. **Predicting Consequences** Define the term *overfishing* in your own words. What would happen to the population of fish in the ocean if laws did not regulate overfishing? What would happen to the ocean ecosystem?
10. **Analyzing Ideas** What is one benefit and one consequence of building a desalination plant? Would a desalination plant be beneficial to your local area? Explain why or why not.

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Topic: Ocean Resources

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SECTION 5

Ocean Pollution

It's a hot summer day at the beach. You can hardly wait to swim in the ocean. You run to the surf only to be met by piles of trash washed up on the shore. Where did all that trash come from?

READING WARM-UP

Objectives

- Explain the difference between point-source pollution and nonpoint-source pollution.
- Identify three different types of point-source ocean pollution.
- Describe what is being done to control ocean pollution.

Terms to Learn

nonpoint-source pollution
point-source pollution

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Humans have thrown their trash in the ocean for hundreds, if not thousands, of years. This trash has harmed the plants and animals that live in the oceans, as well as the people and animals that depend on them. Fortunately, we are more aware of ocean pollution, and we are learning from our mistakes.

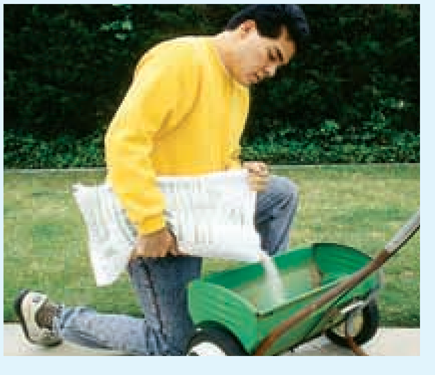
Nonpoint-Source Pollution

There are many sources of ocean pollution. Some of these sources are easily identified, but others are more difficult to pinpoint. **Nonpoint-source pollution** is pollution that comes from many sources rather than from a single site. Some common sources of nonpoint-source pollutants are shown in **Figure 1.** Most ocean pollution is nonpoint-source pollution. Human activities on land can pollute streams and rivers, which then flow into the ocean and bring the pollutants with them. For example, stormwater runoff from urban development and agricultural industries in North Carolina can pollute coastal waters, which flow into the ocean. This type of runoff can change the levels of nutrients in the water, which can cause populations of organisms to decrease. Because nonpoint-source pollutants can enter bodies of water in many different ways, these pollutants are very hard to regulate and control.

Figure 1 **Examples of Nonpoint-Source Pollution**

Oil and gasoline that have leaked from cars onto streets can wash into storm sewers and then drain into waterways.

Thousands of personal watercraft, such as boats can leak gasoline and oil directly into bodies of water.



Pesticides, herbicides, and fertilizer from residential lawns, golf courses, and farmland can wash into waterways.

Figure 2 *This barge is headed out to the open ocean, where it will dump the trash it carries.*

Point-Source Pollution

Water pollution caused by a leaking oil tanker, a factory, or a wastewater treatment plant is one type of point-source pollution. **Point-source pollution** is pollution that comes from a specific site. Even when the source of pollution is known, cleanup of the pollution is difficult.

nonpoint-source pollution pollution that comes from many sources rather than from a single, specific site

point-source pollution pollution that comes from a specific site

Trash Dumping

People dump trash in many places, including the ocean. In the 1980s, scientists became alarmed by the kinds of trash that were washing up on beaches. Bandages, vials of blood, and syringes (needles) were found among the waste. Some of the blood in the vials even contained the AIDS virus. The Environmental Protection Agency (EPA) began an investigation and discovered that hospitals in the United States produce an average of 3 million tons of medical waste each year. Because of stricter laws, much of this medical waste is now buried in sanitary landfills. However, dumping trash in the deeper part of the ocean is still a common practice in many countries. The barge in **Figure 2** will dump the trash it carries into the open ocean.

Effects of Trash Dumping

Trash thrown into the ocean can affect the organisms that live in the ocean and those organisms that depend on the ocean for food. Trash such as plastic can be particularly harmful to ocean organisms. This is because most plastic materials do not break down for thousands of years. Marine animals can mistake plastic materials for food and choke or become strangled. The sea gull in **Figure 3** is tangled up in a piece of plastic trash.

Reading Check **What is one effect of trash dumping?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 *Marine animals can be strangled by plastic trash or can choke if they mistake the plastic for food.*

Figure 4 *Sludge is the solid part of waste matter and often carries bacteria. Sludge makes beaches dirty and kills marine animals.*

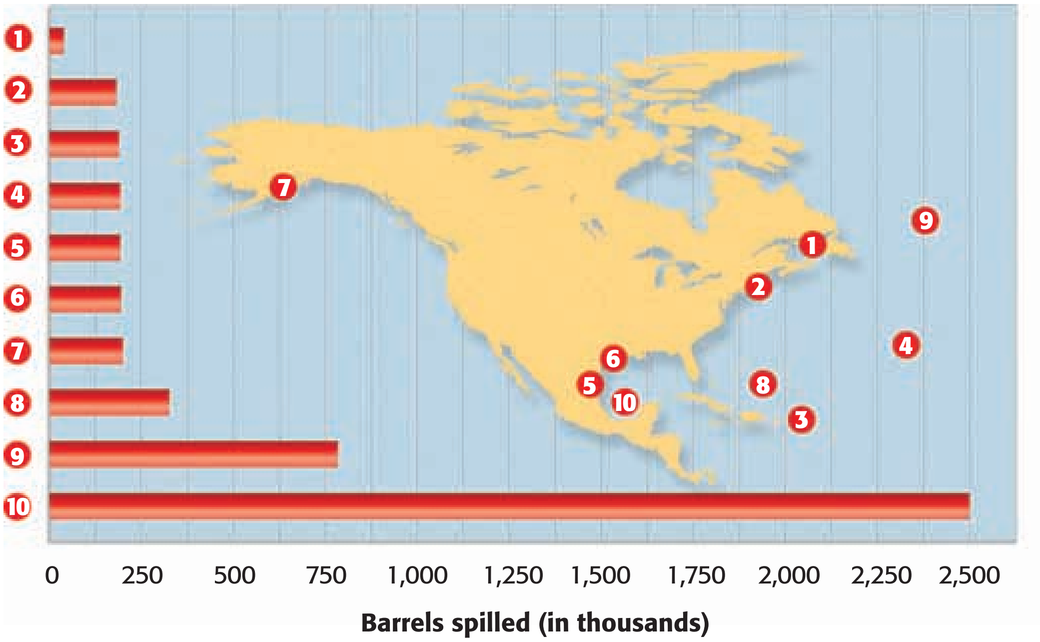
Sludge Dumping

By 1990, the United States alone had discharged 38 trillion liters of treated sludge into the waters along its coasts. Sludge is part of raw sewage. *Raw sewage* is all the liquid and solid wastes that are flushed down toilets and poured down drains. After collecting in sewer drains, raw sewage is sent through a treatment plant, where it undergoes a cleaning process that removes solid waste. The solid waste is called *sludge,* as shown in **Figure 4.** In many areas, people dump sludge into the ocean several kilometers offshore, intending for it to settle and stay on the ocean floor. Unfortunately, currents can stir the sludge up and move it closer to shore. This sludge can pollute beaches and kill marine life. Many countries have banned sludge dumping, but it continues to occur in many areas of the world.

Oil Spills

Because oil is in such high demand across the world, large tankers must transport billions of barrels of it across the oceans. If not handled properly, these transports can turn disastrous and cause oil spills. **Figure 5** shows some of the major oil spills that have occurred off the coast of North America.

Figure 5 *This map shows some of the major oil spills that have occurred off the coast of North America in the last 30 years.*



1 *Kurdistan* Gulf of St. Lawrence, Canada, 1979

2 *Argo Merchant* Nantucket, MA, 1976

3 Storage Tank Benuelan, Puerto Rico, 1978

4 *Athenian Venture* Atlantic Ocean, 1988

5 Unnamed Tanker Tuxpan, Mexico, 1996

6 *Burmah Agate* Galveston Bay, TX, 1979

7 *Exxon Valdez* Prince William Sound, AK, 1989

8 *Epic Colocotronis* Caribbean Sea, 1975

9 *Odyessey* North Atlantic Ocian, 1988

10 Exploratory Well Bay of Campeche, 1979

Effects of Oil Spills

One of the oil spills shown on the map in **Figure 5** occurred in Prince William Sound, Alaska, in 1989. The supertanker *Exxon Valdez* struck a reef and spilled more than 260,000 barrels of crude oil along the shorelines of Alaska. The amount of spilled oil is roughly equivalent to 125 olympic-sized swimming pools.

Although some animals were saved, such as the bird in **Figure 6,** many plants and animals died as a result of the spill. Alaskans who made their living from fishing lost their businesses. The Exxon Oil Company spent $2.1 billion to try to clean up the mess. But Alaska's wildlife and economy will continue to suffer for decades.

While oil spills can harm plants, animals, and people, they are responsible for only about 5% of oil pollution in the oceans. Most of the oil that pollutes the oceans is caused by nonpoint-source pollution on land from cities and towns.

Figure 6 *Many oil-covered animals were rescued and cleaned after the* Exxon Valdez *spill.*

Preventing Oil Spills

Today, many oil companies are using new technology to safeguard against oil spills. Tankers are now being built with two hulls instead of one. The inner hull prevents oil from spilling into the ocean if the outer hull of the ship is damaged. **Figure 7** shows the design of a double-hulled tanker.

Reading Check **How can two hulls on an oil tanker help prevent an oil spill?**

Figure 7 *If the outer hull of a double-hulled tanker is punctured, the oil will still be contained within the inner hull.*

Saving Our Ocean Resources

Although humans have done much to harm the ocean's resources, we have also begun to do more to save them. We can become good stewards for the conservation of ocean resources through actions such as international treaties, volunteer cleanups, and legislation.

Nations Take Notice

When ocean pollution reached an all-time high, many countries recognized the need to work together to solve the problem. In 1989, a treaty was passed by 64 countries that prohibits the dumping of certain metals, plastics, oil, and radioactive wastes into the ocean. Even though many other international agreements and laws restricting ocean pollution have been made, waste dumping and oil spills still occur. Therefore, waste continues to wash ashore, as shown in **Figure 8.** Enforcing pollution-preventing laws at all times is often difficult.

Citizens Taking Charge

Citizens of many countries have demanded that their governments do more to solve the growing problem of ocean pollution. Because of public outcry, the United States now spends more than $130 million each year to protect the oceans and beaches. United States citizens have also begun to take the matter into their own hands. In the early 1980s, citizens began organizing beach cleanups. One of the largest cleanups is the semiannual Adopt-a-Beach program, shown in **Figure 8,** which originated with the Texas Coastal Cleanup campaign. Millions of tons of trash have been gathered from the beaches, and people are being educated about the hazards of ocean dumping.

SCHOOL to HOME

Coastal Cleanup

WRITING SKILL You can be a part of a coastal cleanup. Every September, people from all over the world set aside one day to help clean up trash and debris from beaches. You can join this international effort! With a parent, write a letter to the Ocean Conservancy to see what you can do to help clean up coastal areas.

ACTIVITY

Figure 8 *Making an effort to pick up trash on a beach can help make the beach safer for plants, animals, and people.*

Action in the United States

The United States, like many other countries, has taken additional measures to control local pollution. For example, in 1972, Congress passed the Clean Water Act, which put the Environmental Protection Agency in charge of issuing permits for any dumping of trash into the ocean. Later that year, a stricter law—the U.S. Marine Protection, Research, and Sanctuaries Act—was passed. This act prohibits the dumping of any material that would affect human health or welfare, the marine environment or ecosystems, or businesses that depend on the ocean.

Reading Check **What is the U.S. Marine Protection, Research, and Sanctuaries Act?**

SECTION Review

Summary

- The two main types of ocean pollution are nonpoint-source pollution and point-source pollution.
- Types of nonpoint-source pollution include oil and gasoline from cars, trucks, and watercraft, as well as the use of pesticides, herbicides, and fertilizers.
- Types of point-source ocean pollution include trash dumping, sludge dumping, and oil spills.
- Efforts to save ocean resources include international treaties and volunteer cleanups.

Using Key Terms

1. Use the following terms in the same sentence: *point-source pollution* and *nonpoint-source pollution*.

Understanding Key Ideas

2. Which of the following is an example of nonpoint-source pollution?
   - **a.** a leak from an oil tanker
   - **b.** oil and gasoline washed into waterways from streets
   - **c.** an unlined landfill
   - **d.** water discharged by a factory
3. List three types of ocean pollution. How can each of these types be prevented or minimized?
4. Which part of raw sewage is a type of ocean pollution?

Math Skills

5. Only 3% of Earth's water is drinkable. What portion of Earth's water is not drinkable?
6. A ship spilled 750,000 barrels of oil when it accidentally struck a reef. The oil company was able to recover 65% of the oil spilled. How many barrels of oil were not recovered?

Critical Thinking

7. **Identifying Relationships** List and describe three measures that governments have taken to control ocean pollution.
8. **Evaluating Data** What were two effects of the *Exxon Valdez* oil spill? Describe two ways in which oil spills can be prevented.
9. **Applying Concepts** List two examples of nonpoint-source pollution that occur in your area. Explain why they are nonpoint-source pollution.
10. **Predicting Consequences** How can trash dumping and sludge dumping affect food chains in the ocean?

SCILINKS
NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Ocean Pollution
SciLinks code: HSM1063

Model-Making Lab

Probing the Depths

In the 1870s, the crew of the ship the HMS *Challenger* used a wire and a weight to discover and map some of the deepest places in the world's oceans. The crew members tied a wire to a weight and dropped the weight overboard. When the weight reached the bottom of the ocean, they hauled the weight back up to the surface and measured the length of the wet wire. In this way, they were eventually able to map the ocean floor. In this activity, you will model this method of mapping by making a map of an ocean-floor model.

OBJECTIVES

Model a method of mapping the ocean floor.

Construct a map of an ocean-floor model.

MATERIALS

- clay, modeling (1 lb)
- pencil, unsharpened (8 of equal length)
- ruler, metric
- scissors
- shoe box with lid

SAFETY

Procedure

1. Use the clay to make a model ocean floor in the shoe box. The model ocean floor should have some mountains and valleys.
2. Cut eight holes in a line along the center of the lid. The holes should be just big enough for a pencil to slide through. Place the lid on the box.
3. Exchange boxes with another student or group of students. Do not look into the box.
4. Copy the table shown on the facing page onto a piece of paper. Also, copy the graph shown on the facing page.
5. Measure the length of the probe (pencil) in centimeters. Record the length in your data table.
6. Gently insert the probe into the first hole position in the box until the probe touches the model ocean floor. Do not push the probe down. Pushing the probe down could affect your reading.
7. Make sure that the probe is straight up and down, and measure the length of probe showing above the lid. Record your data in the data table.
8. Use the formula below to calculate the depth in centimeters.

$$\textit{length of probe} - \textit{length of probe showing}\ \text{(cm)} = \textit{depth}\ \text{(cm)}$$

Ocean Depth Table				
Hole position	Length of probe	Length of probe showing (cm)	Depth (cm)	Depth (m) scale of 1cm = 200m
1				
2				
3				
4				
5				
6				
7				
8				

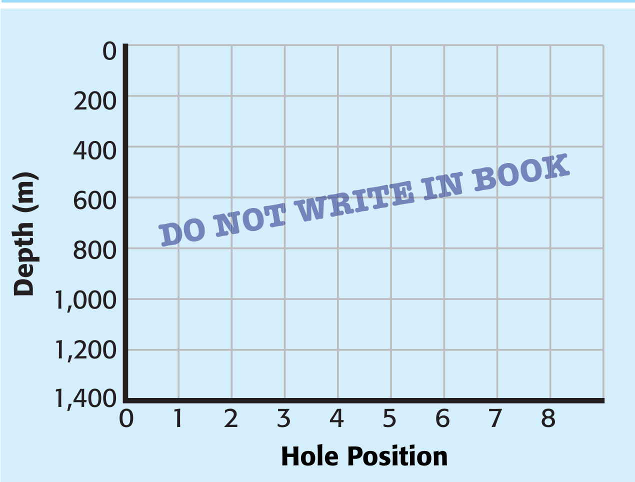
9 To better represent real ocean depths, use the scale 1 cm = 200 m to convert the depth in centimeters to depth in meters. Add the data to your table.

10 Plot the depth in meters for hole position 1 on your graph.

11 Repeat steps 6–10 for the other hole positions.

12 After plotting the data for the eight hole positions, connect the plotted points with a smooth curve.

Depth of Shoe Box



13 Put a pencil in each of the holes in the shoe box. Compare the rise and fall of the eight pencils with the shape of your graph.

Analyze the Results

1 **Describing Events** How deep was the deepest point of your ocean-floor model? How deep was the shallowest point of your ocean-floor model?

2 **Explaining Events** Did your graph resemble the ocean-floor model, as shown by the pencils in step 13? If not, why not?

Draw Conclusions

3 **Applying Conclusions** Why is measuring the real ocean floor difficult? Explain your answer.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

continental shelf
abyssal plain
salinity
nonpoint-source pollution
continental slope
desalination
benthic zone
point-source pollution

1. The region of the ocean floor that is closest to the shoreline is the ___.

2. ___ is the process of removing salt from sea water.

3. ___ is a measure of the amount of dissolved salts in a liquid.

4. The ___ is the broad, flat part of the deep-ocean basin.

5. The deepest parts of the ___ do not get any sunlight.

6. Pollution that comes from many sources rather than a single specific source is called ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. The largest ocean is the
   a. Indian Ocean.
   b. Pacific Ocean.
   c. Atlantic Ocean.
   d. Arctic Ocean.

8. One of the most abundant elements in the ocean is
   a. potassium.
   b. calcium.
   c. chlorine.
   d. magnesium.

9. Which of the following affects the ocean's salinity?
   a. fresh water added by rivers
   b. climate
   c. evaporation
   d. All of the above

10. Most precipitation falls
    a. on land.
    b. into lakes and rivers.
    c. into the ocean.
    d. in rain forests.

11. Which of the following is a nonrenewable resource in the ocean?
    a. fish
    b. tidal energy
    c. oil
    d. All of the above

12. Which of the following gases dissolves most easily in ocean water?
    a. carbon dioxide
    b. oxygen
    c. nitrogen
    d. None of the above

Short Answer

13. Describe three different marine ecosystems.

14. What is a food web?

15 How does temperature affect how gases dissolve in ocean water?

16 Describe two technologies used for studying the ocean floor.

17 Identify the two major regions of the ocean floor, and describe how the continental shelf, the continental slope, and the continental rise are related.

18 In your own words, write a definition for each of the following terms: *plankton, nekton,* and *benthos*. Give two examples of each.

19 List two living resources and two nonliving resources that are harvested from the ocean.

20 Describe how aquatic and terrestrial food webs are interconnected.

21 What kind of pollution is threatening some estuaries?

CRITICAL THINKING

22 **Concept Mapping** Use the following terms to create a concept map: *water cycle, evaporation, condensation, precipitation, atmosphere,* and *oceans*.

23 **Making Inferences** What benefit other than being able to obtain fresh water from salt water comes from desalination?

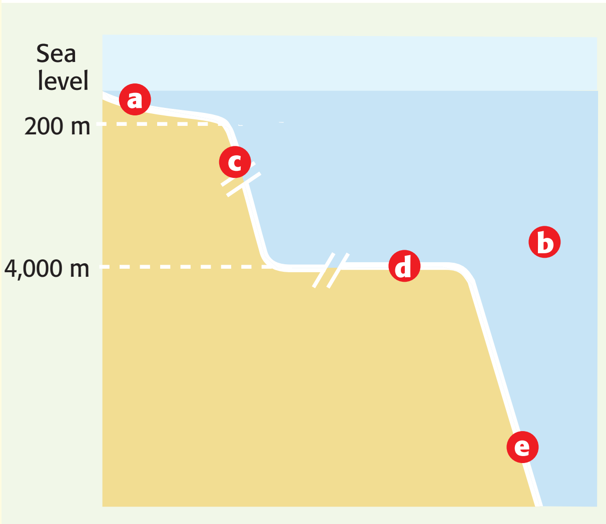
24 **Making Comparisons** Explain the difference between a bathymetric profile and a seismic reading.

25 **Analyzing Ideas** In your own words, define *nonpoint-source pollution* and *point-source pollution*. Give an example of each. What is being done to control ocean pollution?

INTERPRETING GRAPHICS

The graph below shows the ecological zones of the ocean. Use the graph below to answer the questions that follow.

Ecological Zones of the Ocean

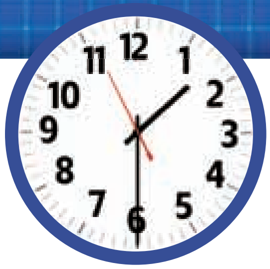


26 At which point would you most likely find whales and squids?

27 At which point would you most likely find organisms that get their energy from chemicals that escape from thermal vents?

28 Which ecological zone is shown at point c?

29 Name an organism that you might find at point a.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Because oil is in such high demand across the world, large tankers must transport billions of barrels of it across the oceans. If not handled properly, these transports can quickly turn disastrous. In 1989, the supertanker *Exxon Valdez* struck a reef and spilled more than 260,000 barrels of crude oil. The effect of this accident on wildlife was catastrophic. Within the first few weeks of the *Exxon Valdez* oil spill, more than half a million birds, including 109 endangered bald eagles, were covered with oil and drowned. Almost half the sea otters in the area also died, either from drowning or from being poisoned by the oil. Alaskans who made their living from fishing lost their businesses. Although many animals were saved and the Exxon Oil Company spent $2.1 billion to clean up the mess, Alaska's wildlife and economy will continue to suffer for decades.

1. What is the main idea of this passage?

A Transporting oil over long distances is difficult.
B The Exxon Oil Company did a great job of cleaning up the oil spill in Alaska.
C Oil spills such as the *Exxon Valdez* spill can create huge problems.
D Alaska's economy will suffer because so much oil was lost.

2. In the passage, which of the following problems was said to be a result of the *Exxon Valdez* oil spill?

F The beach became too slippery to walk on.
G Many people in Alaska had no oil for their cars.
H Exxon had to build a new tanker.
I Many Alaskan fishers lost their businesses.

Passage 2 Whales, dolphins, and porpoises are mammals that belong to the order Cetacea (suh TAY shuh). Cetaceans live throughout the global ocean. They have fishlike bodies and forelimbs called *flippers*. Cetaceans lack hind limbs but have broad, flat tails that help them swim through the water. Cetaceans breathe through blowholes located on the top of the head. They are completely hairless except for a few bristles on their snout. A thick layer of blubber below the skin helps insulate cetaceans against cold temperatures. Cetaceans are divided into two groups: toothed whales and baleen whales. Toothed whales include sperm whales, beluga whales, narwhals, killer whales, dolphins, and porpoises. Baleen whales, such as blue whales, lack teeth. They filter food from the water by using a meshlike net of baleen that hangs from the roof of their mouth.

1. How are organisms that make up the order Cetacea divided?

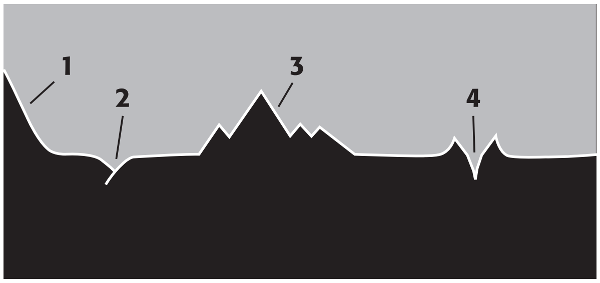
A They are divided into cetaceans that have hair and cetaceans that do not have hair.
B They are divided into cetaceans that have flippers and cetaceans that do not have flippers.
C They are divided into cetaceans that have blowholes and cetaceans that do not have blowholes.
D They are divided into cetaceans that have teeth and cetaceans that do not have teeth.

2. Which of the following statements lists characteristics of all cetaceans?

F Cetaceans have fur and claws and live in rivers.
G Cetaceans have flippers and bristles on the snout and live in oceans.
H Cetaceans have blowholes and flippers and live in lakes.
I Cetaceans have fur, bristles on the snout, and flippers.

INTERPRETING GRAPHICS

Use the image of the ocean floor below to answer the questions that follow.



1. At which point are two tectonic plates separating?

A 1
B 2
C 3
D 4

2. Which point shows an ocean trench?

F 1
G 2
H 3
I 4

3. Which feature might eventually become a volcanic island?

A 1
B 2
C 3
D 4

4. Which features are part of the deep-ocean basin?

F 2, 3, and 4
G 1, 2, and 3
H 1, 3, and 4
I 1, 2, and 4

5. Which feature is part of the continental margin?

A 1
B 2
C 3
D 4

MATH

Read each question below, and choose the best answer.

1. Imagine that you are in the kelp-farming business and your kelp grows 33 cm per day. You begin harvesting when your plants are 50 cm tall. During the first 7 days of harvest, you cut 10 cm off the top of your kelp plants each day. How tall will your kelp plants be after the seventh day of harvesting?

A 80 cm
B 130 cm
C 210 cm
D 211 cm

2. A sample of ocean water contains 36 g of dissolved solids per 1,000 g of water. So, how many grams of dissolved solids will be in 4 kg of ocean water?

F 36,000 g
G 360 g
H 250 g
I 144 g

3. If the average depth of the Pacific Ocean is 4,250 m and the average depth of the Atlantic Ocean is 4,000 m, what is the average depth of the two oceans?

A 4,250 m
B 4,150 m
C 4,125 m
D 4,000 m

4. *Alvin,* a minisub, starts at −300 m, then rises 20 m, then drops 150 m, and finally reaches the ocean floor by dropping another 218 m. At what depth is *Alvin* when it reaches the ocean floor?

F −648 m
G −88 m
H 88 m
I 648 m

5. The speed of sound in water is 1,500 m/s. How far will sound travel in water in 1 min?

A 25 m
B 1,500 m
C 9,000 m
D 90,000 m

Science in Action

Scientific Discoveries

In Search of the Giant Squid

You might think that giant squids exist only in science fiction novels. You aren't alone, because many people have never seen a giant squid or do not know that giant squids exist. Scientists have not been able to study giant squids in the ocean. They have been able to study only dead or dying squids that have washed ashore or that have been trapped in fishing nets. As the largest of all invertebrates, giant squids range from 8 to 25 m long and have a mass of as much as 2,000 kg. Giant squids are very similar to smaller squids. But a giant squid's body parts are much larger. For example, a giant squid's eye may be as large as a volleyball! Because of the size of giant squids, you may think that they don't have any enemies in the ocean, but they do. They are usually eaten by sperm whales that can weigh 20 tons!

Math Activity

A giant squid that washed ashore has a mass of 900 kg. A deep-sea squid that washed ashore has a mass that is 93% smaller than the mass of the giant squid. What is the mass in kilograms of the deep-sea squid?

Science, Technology, and Society

Creating Artificial Reefs

If you found a sunken ship, would you look for hidden treasure? Treasure is not the only thing that sunken ships are known for. Hundreds of years ago, people found that the fishing is often good over a sunken ship. The fishing is good because many marine organisms, such as seaweed, corals, and oysters, live only where they can attach to a hard surface in clear water. They attract other organisms to the sunken ship and eventually form a reef community. Thus, in recent years, many human communities have created artificial reefs by sinking objects such as warships, barges, concrete, airplanes, and school buses in the ocean. Like natural reefs, artificial reefs provide a home for organisms and protect organisms from predators.

Social Studies Activity

WRITING SKILL Research how some artificial reefs are created off the coast of some states in the United States. Write a report that describes some of the objects used to create artificial reefs. In your report also include what countries other than the United States create artificial reefs and what are the benefits and disadvantages of creating artificial reefs.

People in Science

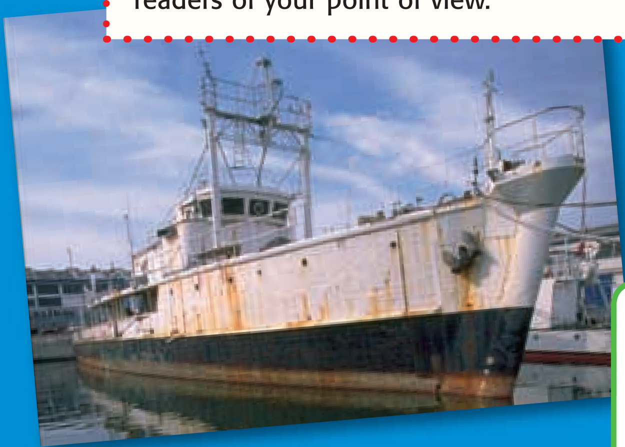
Jacques Cousteau

Ocean Explorer Jacques Cousteau was born in France in 1910. Cousteau performed his first underwater diving mission at age 10 and became very fascinated with the possibilities of seeing and breathing underwater. As a result, in 1943, Cousteau and Emile Gagnan developed the first aqualung, a self-contained breathing system for underwater exploration. Using the aqualung and other underwater equipment that he developed, Cousteau began making underwater films. In 1950, Cousteau transformed the *Calypso*, a retired minesweeper boat, into an oceanographic vessel and laboratory. For the next 40 years, Cousteau sailed with the *Calypso* around the world to explore and film the world's oceans. Cousteau produced more than 115 films, many of which have won awards.

Jacques Cousteau opened the eyes of countless people to the sea. During his long life, Cousteau explored Earth's oceans and documented the amazing variety of life that they contain. He was an environmentalist, inventor, and teacher who inspired millions with his joy and wonder of the ocean. Cousteau was an outspoken defender of the environment. He campaigned vigorously to protect the oceans and environment. Cousteau died in 1997 at age 87. Before his death, he dedicated the *Calypso II,* a new research vessel, to the children of the world.

Language Arts ACTIVITY

WRITING SKILL Ocean pollution and overfishing are subjects of intense debate. Think about these issues, and discuss them with your classmates. Take notes on what you discuss with your classmates. Then, write an essay in which you try to convince readers of your point of view.



Cousteau sailed his ship, the Calypso, *around the world exploring and filming the world's oceans.*

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4

The Movement of Ocean Water

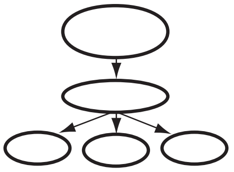
About the PHOTO

No, this isn't a traffic jam or the result of careless navigation. Hurricane Hugo is to blame for this major boat pile up. When Hurricane Hugo hit South Carolina's coast in 1989, the hurricane's strong winds created large ocean waves. These ocean waves carried these boats right onto the shore.

PRE-READING ACTIVITY

Graphic Organizer

Concept Map Before you read the chapter, create the graphic organizer entitled "Concept Map" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the concept map with details about each type of ocean water movement.



START-UP ACTIVITY

When Whirls Collide

Some ocean currents flow in a clockwise direction, while other ocean currents flow in a counterclockwise direction. Sometimes these currents collide. In this activity, you and your lab partner will demonstrate how two currents flowing in opposite directions affect one another.

Procedure

1. Fill a large **tub** with **water** 5 cm deep.
2. Add **10 drops of red food coloring** to the water at one end of the tub.
3. Add **10 drops of blue food coloring** to the water at the other end of the tub.
4. Using a **pencil,** quickly stir the water at one end of the tub in a clockwise direction while your partner stirs the water at the other end in a counterclockwise direction. Stir both ends for 5 s.
5. Draw what you see happening in the tub immediately after you stop stirring. (Both ends should be swirling.)

Analysis

1. How did the blue water and the red water interact?
2. How does this activity relate to how ocean currents interact?

SECTION 1

Currents

Imagine that you are stranded on a desert island. You stuff a distress message into a bottle and throw it into the ocean. Is there any way to predict where your bottle may land?

READING WARM-UP

Objectives

- Describe surface currents.
- List the three factors that control surface currents.
- Describe deep currents.
- Identify the three factors that form deep currents.

Terms to Learn

ocean current
surface current
Coriolis effect
deep current

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Actually, there is a way to predict where the bottle will end up. Ocean water contains streamlike movements of water called **ocean currents.** Currents are influenced by a number of factors, including weather, the Earth's rotation, and the position of the continents. With knowledge of ocean currents, people are able to predict where objects in the open ocean will be carried.

ocean current a movement of ocean water that follows a regular pattern

One Way to Explore Currents

In the 1940s, a Norwegian explorer named Thor Heyerdahl tried to answer questions about human migration across the ocean. Heyerdahl theorized that the inhabitants of Polynesia originally sailed from Peru on rafts powered only by the wind and ocean currents. In 1947, Heyerdahl and a crew of five people set sail from Peru on a raft, which is shown in **Figure 1.**

On the 97th day of their expedition, Heyerdahl and his crew landed on an island in Polynesia. Currents had carried the raft westward more than 6,000 km across the South Pacific. This landing supported Heyerdahl's theory that ocean currents carried the ancient Peruvians across the Pacific to Polynesia.

Reading Check **What was Heyerdahl's theory, and how did he prove it?** (*See the Appendix for answers to Reading Checks.*)

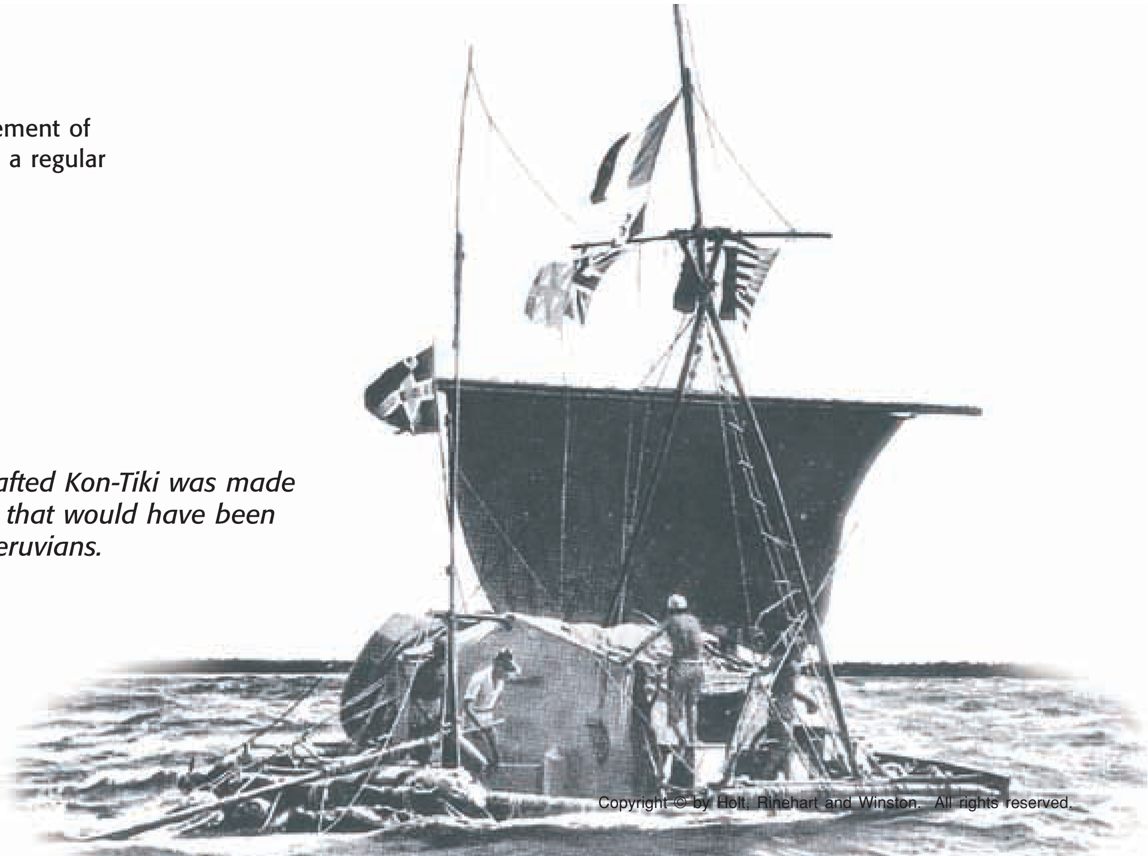


Figure 1 *The handcrafted Kon-Tiki was made mainly from materials that would have been available to ancient Peruvians.*

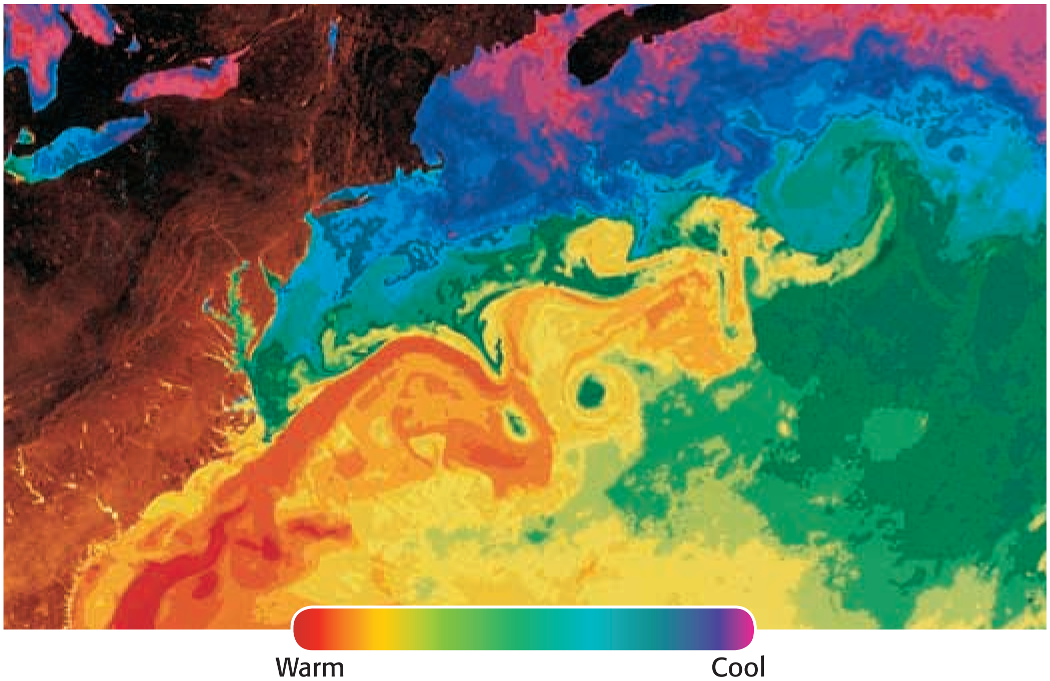


Figure 2 *This infrared satellite image shows the Gulf Stream current moving warm water from lower latitudes to higher latitudes.*

Surface Currents

Horizontal, streamlike movements of water that occur at or near the surface of the ocean are called **surface currents.** Surface currents can reach depths of several hundred meters and lengths of several thousand kilometers and can travel across oceans. The Gulf Stream, shown in **Figure 2,** is one of the longest surface currents—it transports 25 times more water than all the rivers in the world.

Surface currents are controlled by three factors: global winds, the Coriolis effect, and continental deflections. These three factors keep surface currents flowing in distinct patterns around the Earth.

surface current a horizontal movement of ocean water that is caused by wind and that occurs at or near the ocean's surface

Global Winds

Have you ever blown gently on a cup of hot chocolate? You may have noticed ripples moving across the surface, as in **Figure 3.** These ripples are caused by a tiny surface current created by your breath. In much the same way that you create ripples, winds that blow across the Earth's surface create surface currents in the ocean.

Different winds cause currents to flow in different directions. Near the equator, the winds blow ocean water east to west, but closer to the poles, ocean water is blown west to east. Merchant ships often use these currents to travel more quickly back and forth across the oceans.

Figure 3 *Winds form surface currents in the ocean, much like blowing on a cup of hot chocolate forms ripples.*

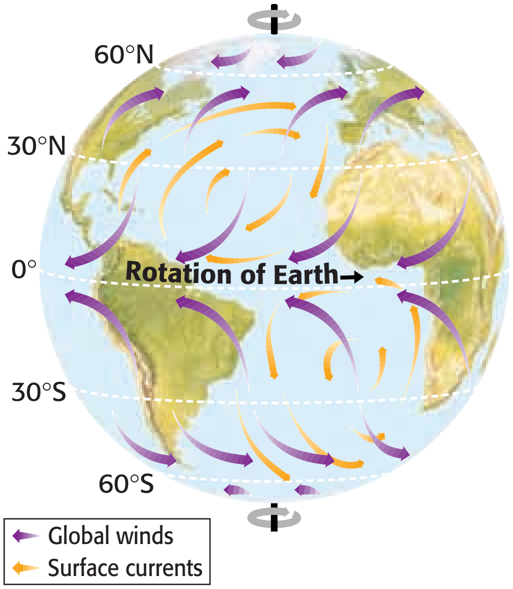


Figure 4 *The rotation of the Earth causes surface currents (yellow arrows) and global winds (purple arrows) to curve as they move across the Earth's surface.*

Coriolis effect the apparent curving of the path of a moving object from an otherwise straight path due to the Earth's rotation

The Coriolis Effect

The Earth's rotation causes wind and surface currents to move in curved paths rather than in straight lines. The apparent curving of moving objects from a straight path due to the Earth's rotation is called the **Coriolis effect.** To understand the Coriolis effect, imagine trying to roll a ball straight across a turning merry-go-round. Because the merry-go-round is spinning, the path of the ball will curve before it reaches the other side. **Figure 4** shows how the Coriolis effect causes surface currents in the Northern Hemisphere to turn clockwise, and surface currents in the Southern Hemisphere to turn counterclockwise.

Reading Check **What causes currents to move in curved paths instead of straight lines?**

Continental Deflections

If the Earth's surface were covered only with water, surface currents would travel freely across the globe in a very uniform pattern. However, you know that water does not cover the entire surface of the Earth. Continents rise above sea level over roughly one-third of the Earth's surface. When surface currents meet continents, the currents *deflect,* or change direction. Notice in **Figure 5** how the Brazil Current deflects southward as it meets the east coast of South America.

SCHOOL to HOME

Coriolis Effect in Your Sink?

WRITING SKILL Some people think the Coriolis effect can be seen in sinks. Does water draining from sinks turns clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere? Research this question at the library, on the Internet, and in your sink at home with a parent. Write what you learn in your **science journal.**

ACTIVITY

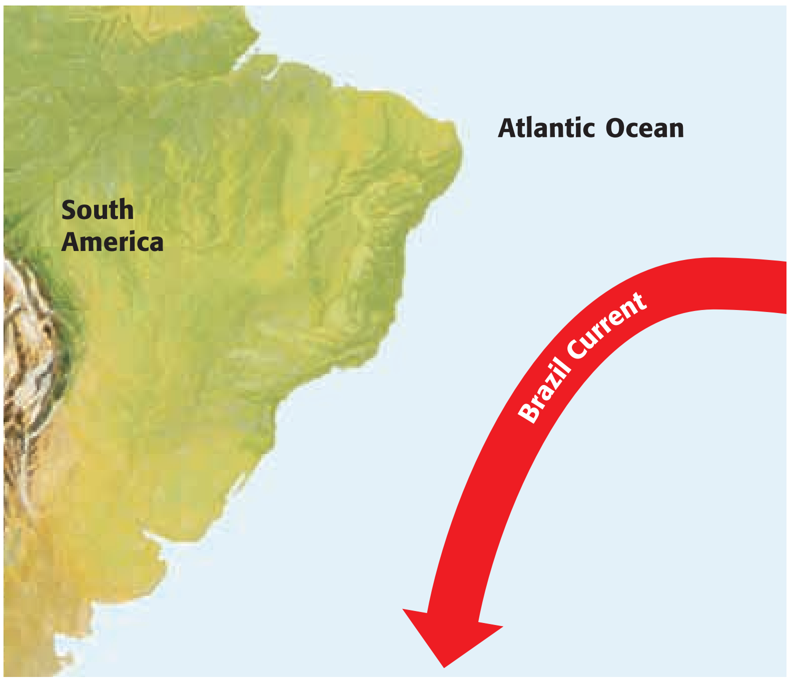


Figure 5 *If South America were not in the way, the Brazil Current would probably flow farther west.*

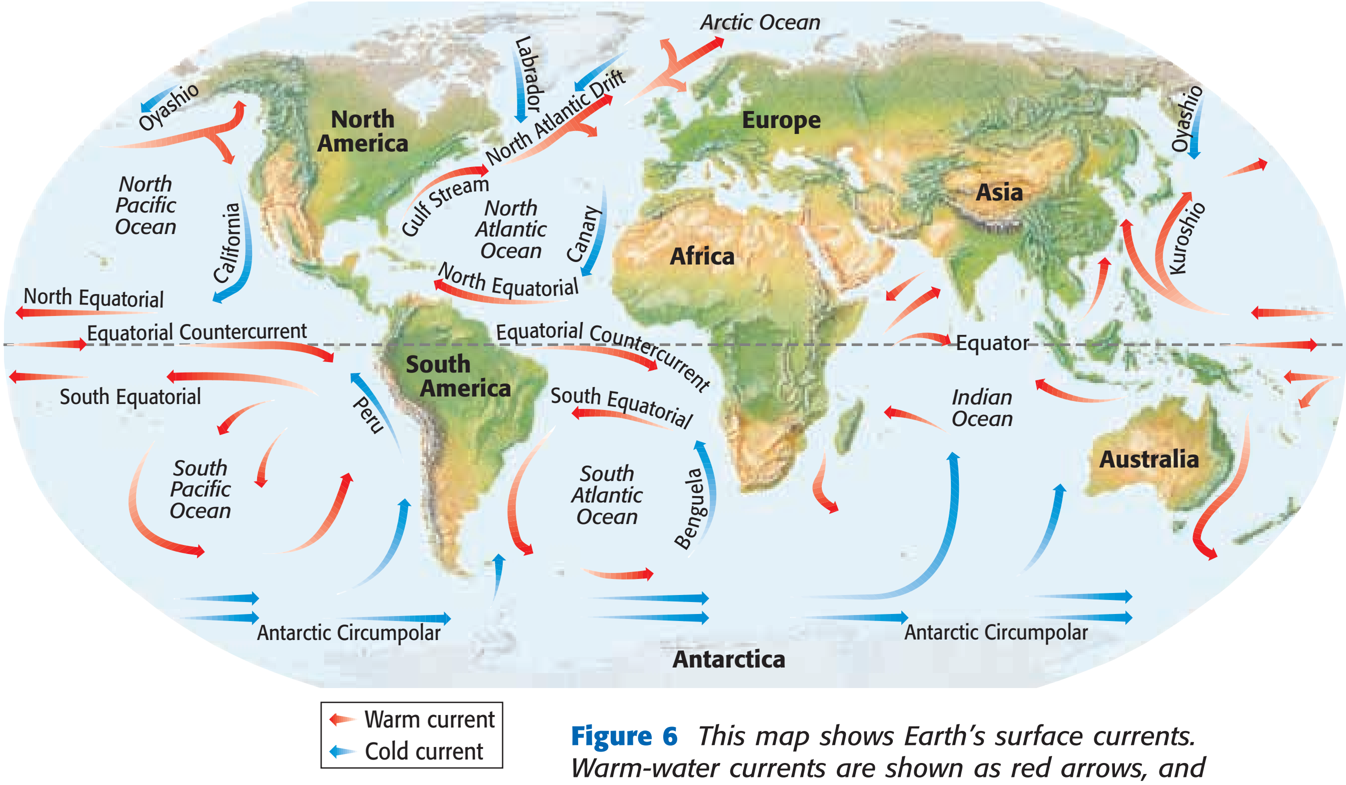


Figure 6 *This map shows Earth's surface currents. Warm-water currents are shown as red arrows, and cold-water currents are shown as blue arrows.*

Taking Temperatures

All three factors—global winds, the Coriolis effect, and continental deflections—work together to form a pattern of surface currents on Earth. But currents are also affected by the temperature of the water in which they form. Warm-water currents begin near the equator and carry warm water to other parts of the ocean. Cold-water currents begin closer to the poles and carry cool water to other parts of the ocean. As you can see on the map in **Figure 6,** all the oceans are connected and both warm-water and cold-water currents travel from one ocean to another.

Reading Check **What three factors form a pattern of surface currents on Earth?**

Deep Currents

Streamlike movements of ocean water located far below the surface are called **deep currents.** Unlike surface currents, deep currents are not directly controlled by wind. Instead, deep currents form in parts of the ocean where water density increases. *Density* is the amount of matter in a given space, or volume. The density of ocean water is affected by temperature and *salinity*—a measure of the amount of dissolved salts or solids in a liquid. Both decreasing the temperature of ocean water and increasing the water's salinity increase the water's density.

deep current a streamlike movement of ocean water far below the surface

CONNECTION TO Physics

Convection Currents While winds are often responsible for ocean currents, the sun is the initial energy source of the winds and currents. Because the sun heats the Earth more in some places than in others, convection currents are formed. These currents transfer thermal energy. Which ocean currents do you think carry more thermal energy, currents located near the equator or currents located near the poles?

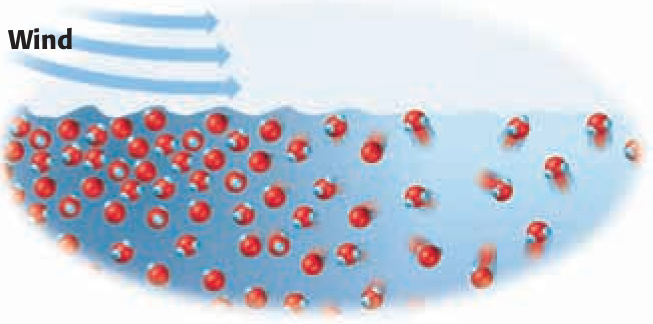
Formation and Movement of Deep Currents

The relationship between the density of ocean water and the formation of deep currents is shown in **Figure 7.** Differences in temperature and salinity—and the resulting differences in density—cause variations in the movement of deep currents. For example, the deepest current, the Antarctic Bottom Water, is denser than the North Atlantic Deep Water. Both currents spread out across the ocean floor as they flow toward each other. Because less-dense water always flows on top of denser water, the North Atlantic Deep Water flows on top of the Antarctic Bottom Water when the currents meet, as shown in **Figure 8.**

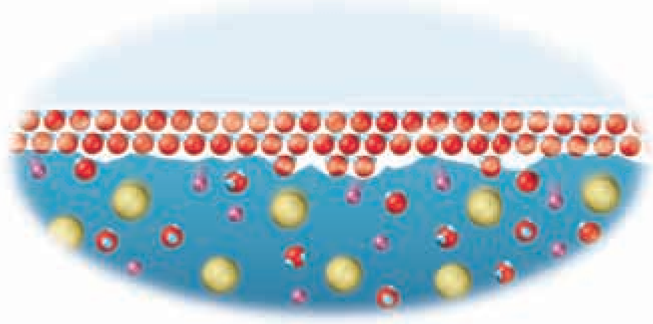
Reading Check **How does the density of ocean water affect deep currents?**

Figure 7 **How Deep Currents Form**

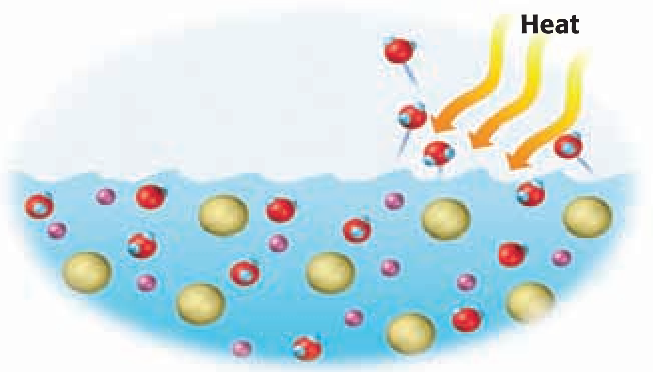
Decreasing Temperature In Earth's polar regions, cold air chills the water molecules at the ocean's surface, which causes the molecules to slow down and move closer together. This reaction causes the water's volume to decrease. Thus, the water becomes denser. The dense water sinks and eventually travels toward the equator as a deep current along the ocean floor.



Increasing Salinity Through Freezing If the ocean water freezes at the surface, ice will float on top of the water because ice is less dense than liquid water. The dissolved solids are squeezed out of the ice and enter the liquid water below the ice. This process increases the salinity of the water. As a result of the increased salinity, the water's density increases.



Increasing Salinity Through Evaporation Another way salinity increases is through evaporation of surface water, which removes water but leaves solids behind. This process is especially common in warm climates. Increasing salinity through freezing or evaporation causes water to become denser, to sink to the ocean floor, and to form a deep current.



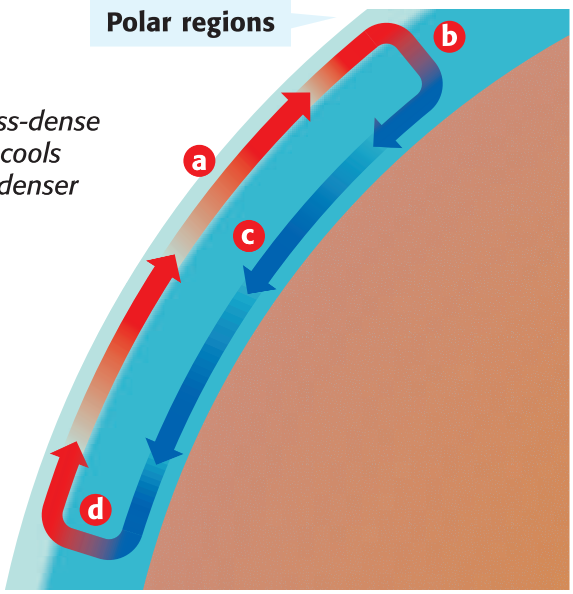


Figure 8 *The warmer, less-dense water in surface currents cools and becomes the colder, denser water in deep currents.*

a Surface currents carry the warmer, less-dense water from other ocean regions to polar regions.

b Warm water from surface currents replaces colder, denser water that sinks to the ocean floor.

c Deep currents carry colder, denser water along the ocean floor from polar regions to other ocean regions.

d Water from deep currents rises to replace water leaving surface currents.

SECTION Review

Summary

- Surface currents are streamlike movements of water at or near the surface of the ocean.
- Surface currents are controlled by three factors: global winds, the Coriolis effect, and continental deflections.
- Deep currents are streamlike movements of ocean water located far below the surface.
- Deep currents form where the density of ocean water increases. Water density depends on temperature and salinity.

Using Key Terms

The statements below are false. For each statement, replace the underlined word to make a true statement.

1. <u>Deep currents</u> are directly controlled by wind.
2. An increase in density in parts of the ocean can cause <u>surface currents</u> to form.

Understanding Key Ideas

3. Surface currents
   - **a.** are formed by wind.
   - **b.** are streamlike movements of water.
   - **c.** can travel across entire oceans.
   - **d.** All of the above
4. List three factors that control surface currents.
5. How does a continent affect the movement of a surface current?
6. Explain how temperature and salinity affect the formation of deep currents.

Math Skills

7. The Gulf Stream flows along the North Carolina coast at 90 million cubic meters per second and at 40 million cubic meters per second when it turns eastward. How much faster is the Gulf Stream flowing along the coast than when it turns eastward?

Critical Thinking

8. **Evaluating Conclusions** If there were no land on Earth's surface, what would the pattern of surface currents look like? Explain your answer.
9. **Making Comparisons** Compare the factors that contribute to the formation of surface currents and deep currents.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Ocean Currents
SciLinks code: HSM1061

SECTION 2

Currents and Climate

The Scilly Isles in England are located as far north as Newfoundland in northeast Canada. But the Scilly Isles experience warm temperatures almost all year long, while Newfoundland has long winters of frost and snow. How can two places at similar latitudes have completely different climates? This difference in climate is caused by surface currents.

READING WARM-UP

Objectives

- Explain how currents affect climate.
- Describe the effects of El Niño.
- Explain how scientists study and predict the pattern of El Niño.

Terms to Learn

upwelling
El Niño
La Niña

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Surface Currents and Climate

Surface currents greatly affect the climate in many parts of the world. Some surface currents warm or cool coastal areas year-round. Other surface currents sometimes change their circulation pattern. Changes in circulation patterns cause changes in atmosphere that affect the climate in many parts of the world.

Warm-Water Currents and Climate

Although surface currents are generally much warmer than deep currents, the temperatures of surface currents do vary. Surface currents are classified as warm-water currents or cold-water currents. Warm-water currents create warmer climates in coastal areas that would otherwise be much cooler. **Figure 1** shows how the Gulf Stream carries warm water from the Tropics to the North Atlantic Ocean. The Gulf Stream flows to the British Isles and creates a relatively mild climate for land at such high latitude. The Gulf Stream is the same current that makes the climate of the Scilly Isles very different from the climate of Newfoundland.

Figure 1 **How Warm-Water Currents Affect Climate**

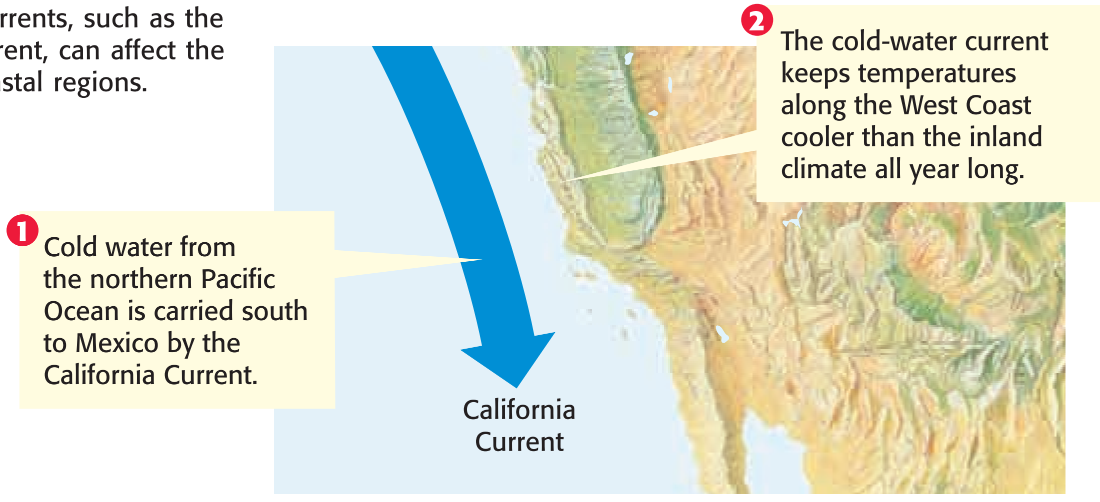
Warm-water currents, such as the Gulf Stream, can affect the climate of coastal regions.

1 The Gulf Stream carries warm water from the Tropics to the North Atlantic Ocean.

2 The Gulf Stream flows to the British Isles and creates a relatively mild climate for land at such a high latitude.

Figure 2 How Cold-Water Currents Affect Climate

Cold-water currents, such as the California Current, can affect the climate of coastal regions.



Cold-Water Currents and Climate

Cold-water currents also affect the climate of the land near where they flow. **Figure 2** shows how the California Current carries cold water from the North Pacific Ocean southward to Mexico. The cold-water California Current keeps the climate along the West Coast cooler than the inland climate year-round.

upwelling the movement of deep, cold, and nutrient-rich water to the surface

Reading Check **How do cold-water currents affect coastal regions?**

Upwelling

When local wind patterns blow along the northwest coast of South America, they cause local surface currents to move away from the shore. This warm water is then replaced by deep, cold water. This movement causes upwelling to occur in the eastern Pacific. **Upwelling** is a process in which cold, nutrient-rich water from the deep ocean rises to the surface and replaces warm surface water, as shown in **Figure 3.** The nutrients from the deep ocean are made up of elements and chemicals, such as iron and nitrate. When these chemicals are brought to the sunny surface, they help tiny plants grow through the process of photosynthesis.

The process of upwelling is extremely important to organisms. The nutrients that are brought to the surface of the ocean support the growth of phytoplankton and zooplankton. These tiny plants and animals support other organisms such as fish and seabirds.

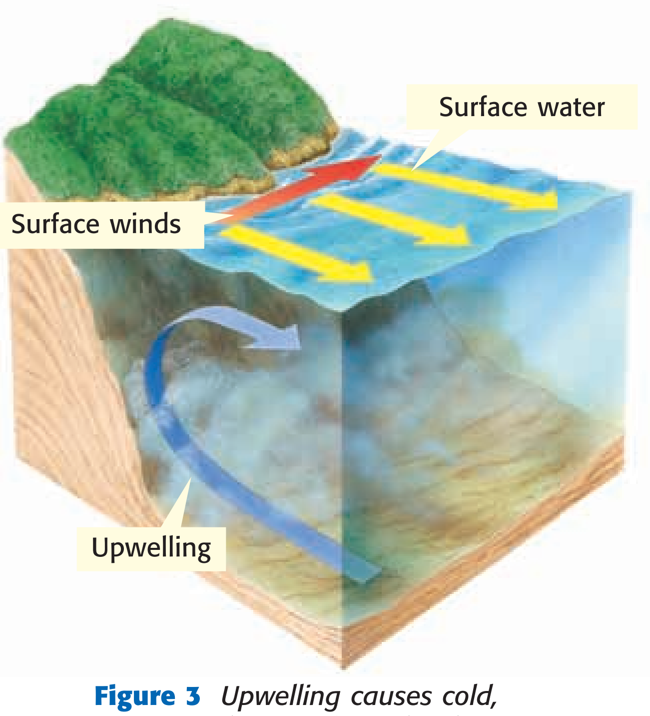


Figure 3 *Upwelling causes cold, nutrient-rich water from the deep ocean to rise to the surface.*

El Niño

Every 2 to 12 years, the South Pacific trade winds move less warm water to the western Pacific than they usually do. Thus, surface-water temperatures along the coast of South America rise. Gradually, this warming spreads westward. This periodic change in the location of warm and cool surface waters in the Pacific Ocean is called **El Niño.** El Niño can last for a year or longer and not only affects the surface waters but also changes the interaction of the ocean and the atmosphere, which in turn changes global weather patterns.

Sometimes, El Niño is followed by La Niña. **La Niña** is a periodic change in the eastern Pacific Ocean in which the surface-water temperature becomes unusually cool. Like El Niño, La Niña also affects weather patterns.

CONNECTION TO Environmental Science

El Niño and Coral Reefs
The increase of surface water temperatures during El Niño can destroy coral reefs. *Coral reefs* are fragile limestone ridges built by tiny coral animals. An increase in surface water temperature and exposure to the sun (due to a decrease in sea level) can cause corals to become bleached and die. Coral reefs support a diverse community of marine life. Create a world map that shows the locations of the coral reefs.

ACTIVITY

El Niño a change in the water temperature in the Pacific Ocean that produces a warm current

La Niña a change in the eastern Pacific Ocean in which the surface water temperature becomes unusually cool

Effects of El Niño

El Niño alters weather patterns enough to cause disasters. These disasters include flash floods and mudslides in areas of the world that usually receive little rain, such as the southern half of the United States and Peru. **Figure 4** shows homes in Southern California destroyed by a mudslide caused by El Niño. While some regions flood, regions that usually get a lot of rain may experience *droughts,* an unusually long period during which rainfall is below average. During El Niño, severe droughts can occur in Indonesia and Australia. Periods of severe drought can lead to crop failure.

During El Niño, the upwelling of nutrient-rich water does not occur off the coast of South America, which affects the organisms that depend on the nutrients for food.

Figure 4 *This damage in Southern California was the result of excessive rain caused by El Niño in 1997.*

Studying and Predicting El Niño

Because El Niño occurs every 2 to 12 years, studying and predicting it can be difficult. However, it is important for scientists to learn as much as possible about El Niño because of its effects on organisms and land.

One way scientists collect data to predict an El Niño is through a network of buoys operated by the National Oceanic and Atmospheric Administration (NOAA). The buoys, some of which are anchored to the ocean floor, are located along the Earth's equator. The buoys record data about surface temperature, air temperature, currents, and winds. The buoys transmit some of the data on a daily basis to NOAA through a satellite in space.

When the buoys report that the South Pacific trade winds are not as strong as they usually are or that the surface temperatures of the tropical oceans have risen, scientists can predict that an El Niño is likely to occur.

Reading Check **Why is it important to study El Niño? Describe one way scientists study El Niño.**

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5H20W.**

SECTION Review

Summary

- Surface currents affect the climate of the land near which they flow.
- Warm-water currents bring warmer climates to coastal regions.
- Cold-water currents bring cooler climates to coastal regions.
- During El Niño, warm and cool surface waters change locations.
- El Niño can cause floods, mudslides, and drought.

Using Key Terms

1. Use each of the following terms in a separate sentence: *upwelling, El Niño,* and *La Niña*.

Understanding Key Ideas

2. The Gulf Stream carries warm water to the North Atlantic Ocean, which contributes to
   - **a.** a harsh winter in the British Isles.
   - **b.** a cold-water surface current that flows to the British Isles.
   - **c.** a mild climate for the British Isles.
   - **d.** a warm-water surface current that flows along the coast of California.
3. Why might the climate in Scotland be relatively mild even though the country is located at a high latitude?
4. Name two disasters caused by El Niño.

Math Skills

5. A fisher usually catches 540 kg of anchovies off the coast of Peru. During El Niño, the fisher caught 85% less fish. How many kilograms of fish did the fisher catch during El Niño?

Critical Thinking

6. **Applying Concepts** Many marine organisms depend on upwelling to bring nutrients to the surface. How might El Niño affect a fisher's way of life?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: El Niño

SciLinks code: HSM0468

SECTION 3

Waves

Have you ever seen a surfer riding waves? Did you ever wonder where the waves come from? And why are some waves big, while others are small?

READING WARM-UP

Objectives

- Identify the parts of a wave.
- Explain how the parts of a wave relate to wave movement.
- Describe how ocean waves form and move.
- Classify types of waves.

Terms to Learn

undertow
longshore current
whitecap
swell
tsunami
storm surge

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, write what you think you will learn under each heading.

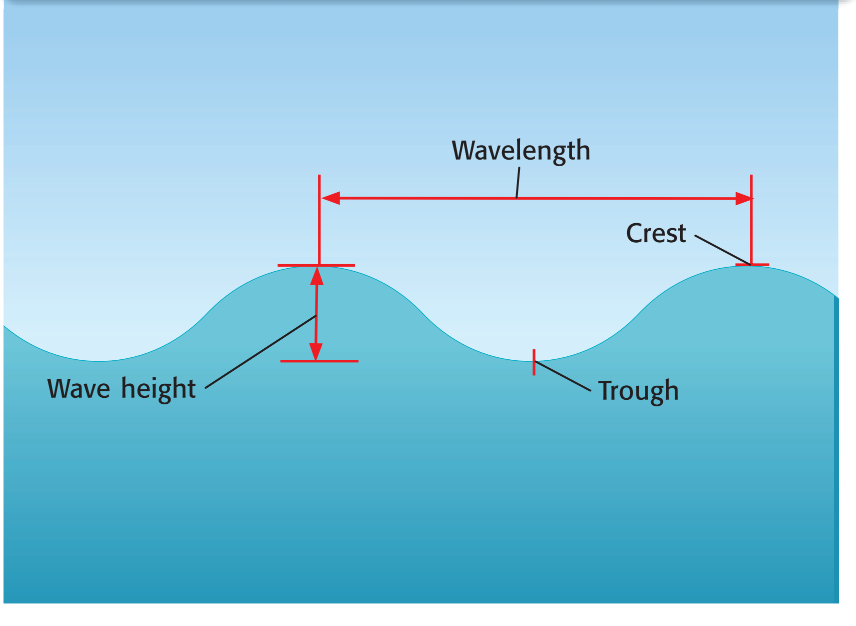
We all know what ocean waves look like. Even if you've never been to the seashore, you've most likely seen waves on TV. But how do waves form and move? Waves are affected by a number of different factors. They can be formed by something as simple as wind or by something as violent as an earthquake. Ocean waves can travel through water slowly or incredibly quickly. Read on to discover the many forces that affect the formation and movement of ocean waves.

Anatomy of a Wave

Waves are made up of two main parts—crests and troughs. A *crest* is the highest point of a wave. A *trough* is the lowest point of a wave. Imagine a roller coaster designed with many rises and dips. The top of a rise on a roller-coaster track is similar to the crest of a wave, and the bottom of a dip in the track resembles the trough of a wave. The distance between two adjacent wave crests or wave troughs is a *wavelength*. The vertical distance between the crest and trough of a wave is called the *wave height*. **Figure 1** shows the parts of a wave.

Reading Check **What is the lowest point of a wave called?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 **Parts of a Wave**



Wave Formation and Movement

If you have watched ocean waves before, you may have noticed that water appears to move across the ocean's surface. However, this movement is only an illusion. Most waves form as wind blows across the water's surface and transfers energy to the water. As the energy moves through the water, so do the waves. But the water itself stays behind, rising and falling in circular movements. Notice in **Figure 2** that the floating bottle remains in the same spot as the waves travel from left to right. This circular motion gets smaller as the water depth increases, because wave energy decreases as the water depth increases. Wave energy reaches only a certain depth. Below that depth, the water is not affected by wave energy.

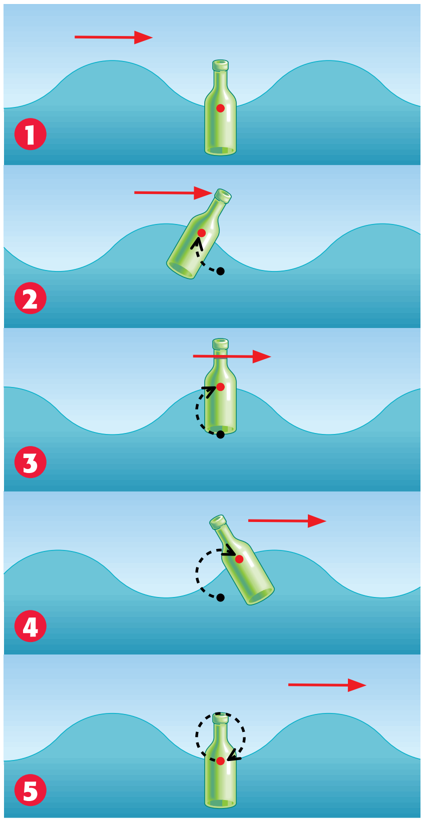


Figure 2 *Like the bottle in this figure, water remains in the same place as waves travel through it.*

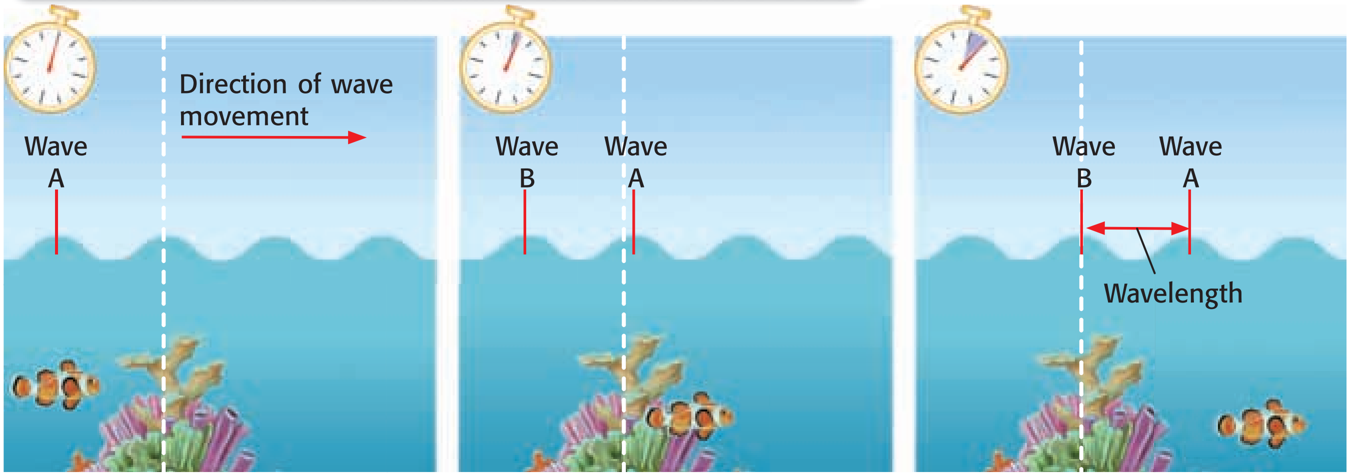
Specifics of Wave Movement

Waves not only come in different sizes but also travel at different speeds. To calculate wave speed, scientists must know the wavelength and the wave period. *Wave period* is the time between the passage of two wave crests (or troughs) at a fixed point, as shown in **Figure 3.** Dividing wavelength by wave period gives you wave speed, as shown below.

$$\frac{\text{wavelength (m)}}{\text{wave period (s)}} = \text{wave speed (m/s)}$$

For any given wavelength, an increase in the wave period will decrease the wave speed and a decrease in the wave period will increase the wave speed.

Figure 3 **Determining Wave Period**



1. Notice that the waves are moving from left to right.
2. The clock begins running as Wave A passes the reef's peak.
3. The clock stops as Wave B passes the reef's peak. The time shown on the clock (5 s) represents the wave period.

Quick Lab

Doing the Wave

1. Tie one end of a **thin piece of rope** to a **doorknob**.
2. Tie a **ribbon** around the rope halfway between the doorknob and the other end of the rope.
3. Holding the rope at the untied end, quickly move the rope up and down and observe the ribbon.
4. How does the movement of the rope and ribbon relate to the movement of water and deep-water waves?
5. Repeat step 3, but move the rope higher and lower this time.
6. How does this affect the waves in the rope?

Types of Waves

As you learned earlier in this section, wind forms most ocean waves. Waves can also form by other mechanisms. Underwater earthquakes and landslides as well as impacts by cosmic bodies can form different types of waves. Most waves move in one way regardless of how they are formed. Depending on their size and the angle at which they hit the shore, waves can generate a variety of near-shore events, some of which can be dangerous to humans.

Deep-Water Waves and Shallow-Water Waves

Have you ever wondered why waves increase in height as they approach the shore? The answer has to do with the depth of the water. *Deep-water waves* are waves that move in water deeper than one-half their wavelength. When the waves reach water shallower than one-half their wavelength, they begin to interact with the ocean floor. These waves are called *shallow-water waves*. **Figure 4** shows how deep-water waves become shallow-water waves as they move toward the shore.

As deep-water waves become shallow-water waves, the water particles slow down and build up. This change forces more water between wave crests and increases wave height. Gravity eventually pulls the high wave crests down, which causes them to crash into the ocean floor as *breakers*. The area where waves first begin to tumble downward, or break, is called the *breaker zone*. Waves continue to break as they move from the breaker zone to the shore. The area between the breaker zone and the shore is called the *surf*.

Reading Check **How do deep-water waves become shallow-water waves?**

Figure 4 **Deep-Water and Shallow-Water Waves**

Deep-water waves become shallow-water waves when they reach depths of less than half of their wavelength.

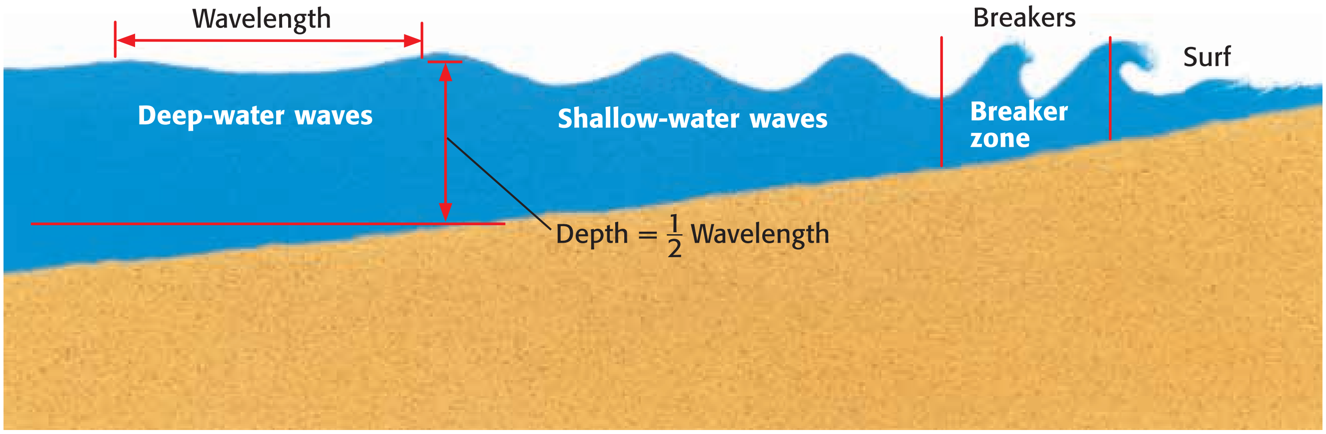
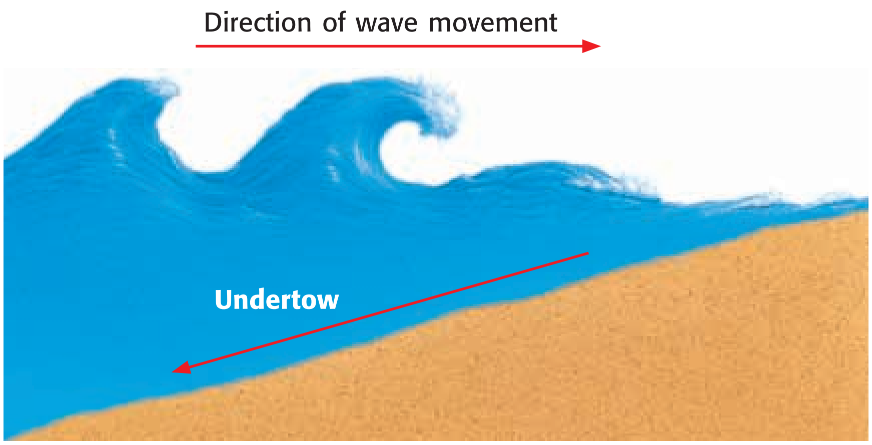


Figure 5 **Formation of an Undertow**

Head-on waves create an undertow.



Shore Currents

When waves crash on the beach head-on, the water they moved through flows back to the ocean underneath new incoming waves. This movement of water, which carries sand, rock particles, and plankton away from the shore, is called an **undertow.** **Figure 5** illustrates the back-and-forth movement of water at the shore.

undertow a subsurface current that is near shore and that pulls objects out to sea

Longshore Currents

When waves hit the shore at an angle, they cause water to move along the shore in a current called a **longshore current,** which is shown in **Figure 6.** Longshore currents transport most of the sediment in beach environments. This movement of sand and other sediment both tears down and builds up the coastline. Unfortunately, longshore currents also carry and spread trash and other types of ocean pollution along the shore.

longshore current a water current that travels near and parallel to the shoreline

Figure 6 *Longshore currents form where waves approach beaches at an angle.*

Figure 7 *Whitecaps (left) break in the open ocean, while swells, (right), roll gently in the open ocean.*

Open-Ocean Waves

Sometimes waves called *whitecaps* form in the open ocean. **Whitecaps** are white, foaming waves with very steep crests that break in the open ocean before the waves get close to the shore. These waves usually form during stormy weather, and they are usually short-lived. Winds that are far away from the shore form waves called *swells*. **Swells** are rolling waves that move steadily across the ocean. Swells have longer wavelengths than whitecaps and can travel for thousands of kilometers. **Figure 7** shows how whitecaps and swells differ.

whitecap the bubbles in the crest of a breaking wave

swell one of a group of long ocean waves that have steadily traveled a great distance from their point of generation

tsunami a giant ocean wave that forms after a volcanic eruption, submarine earthquake, or landslide

Tsunamis

Professional surfers often travel to Hawaii to catch some of the highest waves in the world. But even the best surfers would not be able to handle a tsunami. **Tsunamis** are waves that form when a large volume of ocean water is suddenly moved up or down. This movement can be caused by underwater earthquakes, volcanic eruptions, landslides, underwater explosions, or the impact of a meteorite or comet. The majority of tsunamis occur in the Pacific Ocean because of the large number of earthquakes in that region. **Figure 8** shows how an earthquake can generate a tsunami.

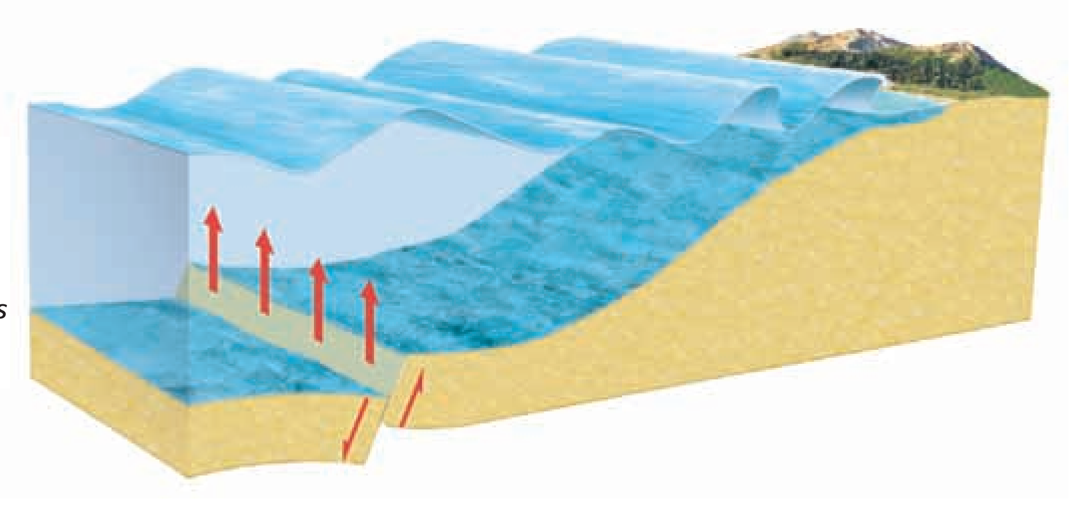


Figure 8 *An upward shift in the ocean floor creates an earthquake. The energy released by the earthquake pushes a large volume of water upward, which creates a series of tsunamis.*

Storm Surges

A local rise in sea level near the shore that is caused by strong winds from a storm, such as a hurricane, is called a **storm surge.** Winds form a storm surge by blowing water into a big pile under the storm. As the storm moves onto shore, so does the giant mass of water beneath it. Storm surges often disappear as quickly as they form, which makes them difficult to study. Storm surges contain a lot of energy and can reach about 8 m in height. Their size and power often make them the most destructive part of hurricanes.

storm surge a local rise in sea level near the shore that is caused by strong winds from a storm, such as those from a hurricane

Reading Check **What is a storm surge? Why are storm surges difficult to study?**

SECTION Review

Summary

- Waves are made up of two main parts—crests and troughs.
- Waves are usually created by the transfer of the wind's energy across the surface of the ocean.
- Waves travel through water near the water's surface, while the water itself rises and falls in circular movements.
- Wind-generated waves are classified as deep-water or shallow-water waves.
- When waves hit the shore at a certain angle, they can create either an undertow or a longshore current.
- Tsunamis are dangerous waves that can be very destructive to coastal communities.

Using Key Terms

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

1. *whitecap* and *swell*
2. *undertow* and *longshore current*
3. *tsunami* and *storm surge*

Understanding Key Ideas

4. Longshore currents transport sediment
   a. to the open ocean.
   b. along the shore.
   c. only during low tide.
   d. only during high tide.
5. Where do deep-water waves become shallow-water waves?
6. Explain how water moves as waves travel through it.
7. Name five events that can cause a tsunami.
8. Describe the two parts of a wave.

Math Skills

9. If a barrier island that is 1 km wide and 10 km long loses 1.5 m of its width per year to erosion by a longshore current, how long will the island take to lose one-fourth of its width?

Critical Thinking

10. **Analyzing Processes** How would you explain a bottle moving across the water in the same direction that the waves are traveling? Make a drawing of the bottle's movement.
11. **Analyzing Processes** Describe the motion of a wave as it approaches the shore.
12. **Applying Concepts** Explain how energy plays a role in the creation of ocean waves.
13. **Making Comparisons** How does the formation of an undertow differ from the formation of a longshore current? How is sand on the beach affected by each?

SECTION 4

Tides

If you stand at some ocean shores long enough, you will see the edge of the ocean shrink away from you. Wait longer, and you will see it return to its original place on the shore. Would you believe the moon causes this movement?

READING WARM-UP

Objectives

- Explain tides and their relationship with the Earth, sun, and moon.
- Describe four different types of tides.
- Analyze the relationship between tides and coastal land.

Terms to Learn

tide	spring tide
tidal range	neap tide

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

You have learned how winds and earthquakes can move ocean water. But less obvious forces move ocean water in regular patterns called tides. **Tides** are daily changes in the level of ocean water. Tides are influenced by the sun and the moon, as shown in **Figure 1,** and they occur in a variety of cycles.

tide the periodic rise and fall of the water level in the oceans and other large bodies of water

The Lure of the Moon

The phases of the moon and their relationship to the tides were first discovered more than 2,000 years ago by a Greek explorer named *Pytheas*. But Pytheas and other early investigators could not explain the relationship. A scientific explanation was not given until 1687, when Sir Isaac Newton's theories on the principle of gravitation were published.

The gravity of the moon pulls on every particle of the Earth. But the pull on liquids is much more noticeable than on solids, because liquids move more easily. Even the liquid in an open soft drink is slightly pulled by the moon's gravity.

Reading Check **How does the moon affect Earth's particles?** (*See the Appendix for answers to Reading Checks.*)

High Tide and Low Tide

How often tides occur and the difference in tidal levels depend on the position of the moon as it revolves around the Earth. The moon's pull is strongest on the part of the Earth directly facing the moon.

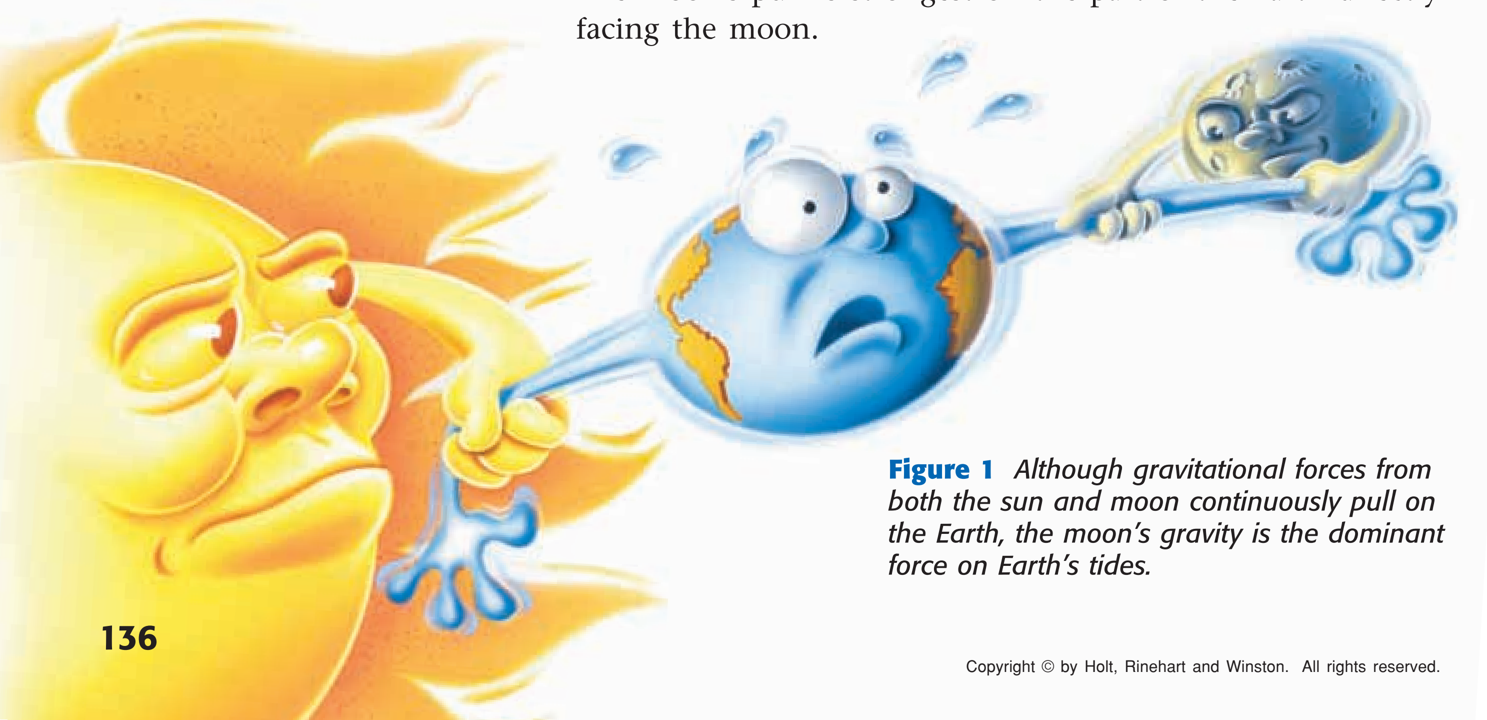


Figure 1 *Although gravitational forces from both the sun and moon continuously pull on the Earth, the moon's gravity is the dominant force on Earth's tides.*

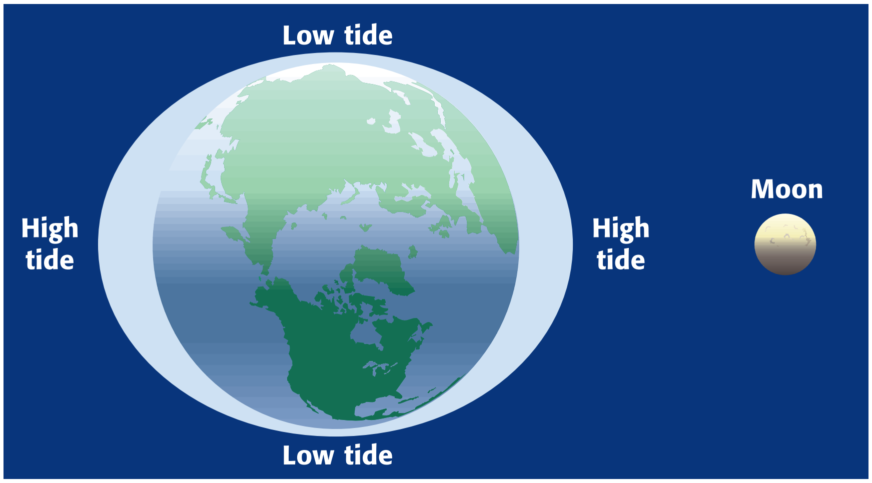


Figure 2 *High tide occurs on the part of Earth that is closest to the moon. At the same time, high tide also occurs on the opposite side of Earth.*

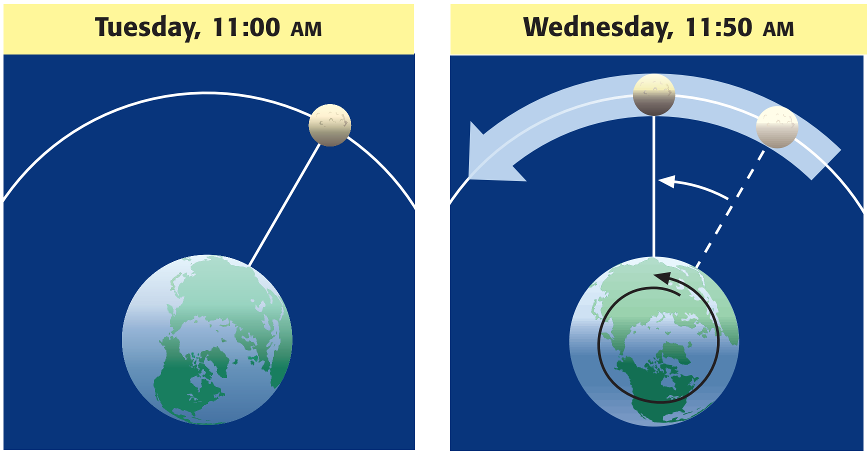
Battle of the Bulge

When part of the ocean is directly facing the moon, the water there bulges toward the moon. At the same time, water on the opposite side of the Earth bulges because of the rotation of the Earth and the motion of the moon around the Earth. These bulges are called *high tides*. Notice in **Figure 2** how the position of the moon causes the water to bulge. Also notice that when high tides occur, water is drawn away from the area between the high tides, which causes *low tides* to form.

Timing the Tides

The rotation of the Earth and the moon's revolution around the Earth determine when tides occur. If the Earth rotated at the same speed that the moon revolves around the Earth, the tides would not alternate between high and low. But the moon revolves around the Earth much more slowly than the Earth rotates. As **Figure 3** shows, a spot on Earth that is facing the moon takes 24 h and 50 m to rotate and face the moon again.

Figure 3 *Tides occur at different locations on Earth because the Earth rotates more quickly than the moon revolves around the Earth.*



CONNECTION TO Language Arts

WRITING SKILL **Mont-St-Michel Is Sometimes an Island?** Mont-St-Michel is located off the coast of France. Mont-St-Michel experiences extreme tides. The tides are so extreme that during high tide, it is an island and during low tide, it is connected to the mainland. Research the history behind Mont-St-Michel and then write a short story describing what it would be like to live there for a day. Be sure to include a description of Mont-St-Michel at high tide and at low tide.

Tidal Variations

The sun also affects tides. The sun is much larger than the moon, but the sun is also much farther away. As a result, the sun's influence on tides is less powerful than the moon's influence. The combined forces of the sun and the moon on the Earth result in tidal ranges that vary based on the positions of all three bodies. A **tidal range** is the difference between levels of ocean water at high tide and low tide.

tidal range the difference in levels of ocean water at high tide and low tide

spring tide a tide of increased range that occurs two times a month, at the new and full moons

neap tide a tide of minimum range that occurs during the first and third quarters of the moon

Reading Check **What is a tidal range?**

Spring Tides

When the sun, Earth, and moon are aligned, spring tides occur. **Spring tides** are tides with the largest daily tidal range and occur during the new and full moons, or every 14 days. The first time spring tides occur is when the moon is between the sun and Earth. The second time spring tides occur is when the moon and the sun are on opposite sides of the Earth. **Figure 4** shows the positions of the sun, Earth, and moon during spring tides.

Neap Tides

When the sun, Earth, and moon form a 90° angle, neap tides occur. **Neap tides** are tides with the smallest daily tidal range and occur during the first and third quarters of the moon. Neap tides occur halfway between the occurrence of spring tides. When neap tides occur, the gravitational forces on the Earth by the sun and moon work against each other. **Figure 4** shows the positions of the sun, Earth, and moon during neap tides.

Figure 4 **Spring Tides and Neap Tides**

Spring Tides During spring tides, the gravitational forces of the sun and moon pull on the Earth either from the same direction (left) or from opposite directions (right).

Neap Tides During neap tides, the sun and moon are at right angles with respect to the Earth. This arrangement lessens their gravitational effect on the Earth.

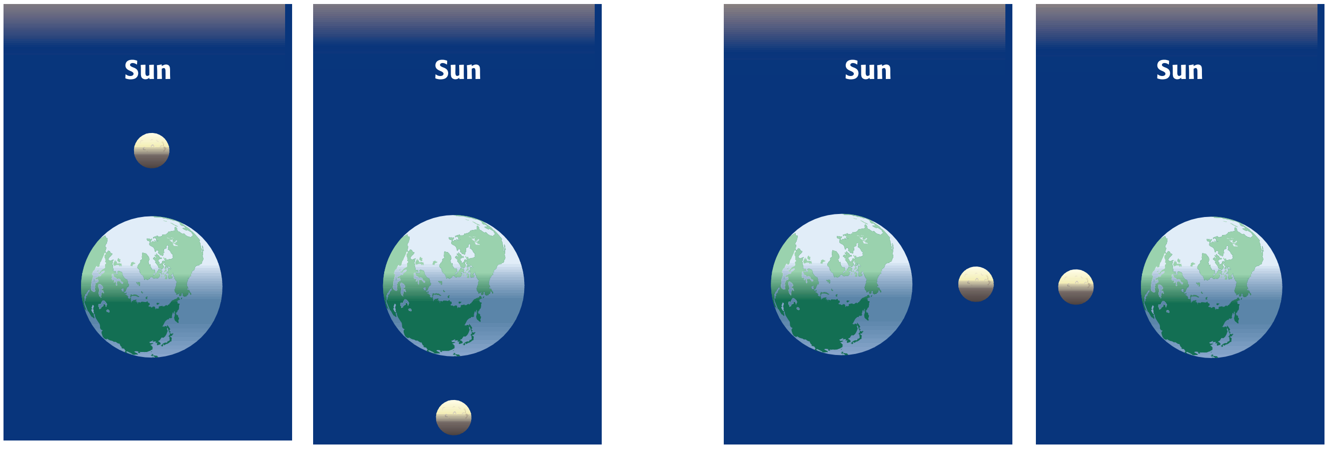


Figure 5 *It's a good thing the people on this beach (left) knew when high tide occurred (right). These photos show the Bay of Fundy, in New Brunswick, Canada. The Bay of Fundy has the greatest tidal range on Earth.*

Tides and Topography

After a tidal range has been measured, the times that tides occur can be accurately predicted. This information can be useful for people who live near or visit the coast, as shown in **Figure 5.** In some coastal areas that have narrow inlets, movements of water called tidal bores occur. A *tidal bore* is a body of water that rushes up through a narrow bay, estuary, or river channel during the rise of high tide and causes a very sudden tidal rise. Tidal bores occur in coastal areas of China, the British Isles, France, and Canada.

SECTION Review

Summary

- Tides are caused by the gravitational forces of the moon and sun on the Earth.
- The moon's gravity is the main force behind the tides.
- The positions of the sun and moon relative to the position of the Earth cause tidal ranges.
- The four different types of tides are: high tides, low tides, spring tides, and neap tides.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *spring tides* and *neap tides*.

Understanding Key Ideas

2. Tides are at their highest during
   a. spring tide.
   b. neap tide.
   c. a tidal bore.
   d. the daytime.
3. Which tides have minimum tidal range? Which tides have maximum tidal range?
4. What causes tidal ranges?

Math Skills

5. If it takes 24 h and 50 min for a spot on Earth that is facing the moon to rotate to face the moon again, how many minutes does it take?

Critical Thinking

6. **Applying Concepts** How many days pass between the minimum and the maximum of the tidal range in any given area? Explain your answer.
7. **Analyzing Processes** Explain how the position of the moon relates to the occurrence of high tides and low tides.

SCLINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Tides
SciLinks code: HSM1525

Using Scientific Methods

Skills Practice Lab

OBJECTIVES

Demonstrate the effects of temperature and salinity on the density of water.

Describe why some parts of the ocean turn over, while others do not.

MATERIALS

- beakers, 400 mL (5)
- blue and red food coloring
- bucket of ice
- gloves, heat-resistant
- hot plate
- plastic wrap, 4 pieces, approximately 30 cm × 20 cm
- salt
- spoon
- tap water
- watch or clock

SAFETY

Up from the Depths

Every year, the water in certain parts of the ocean "turns over." That is, the water at the bottom rises to the top and the water at the top falls to the bottom. This yearly change brings fresh nutrients from the bottom of the ocean to the fish living near the surface. However, the water in some parts of the ocean never turns over. By completing this activity, you will find out why not.

Keep in mind that some parts of the ocean are warmer at the bottom, and some are warmer at the top. And sometimes the saltiest water is at the bottom and sometimes not. As you complete this activity, you will investigate how these factors help determine whether the water will turn over.

Ask a Question

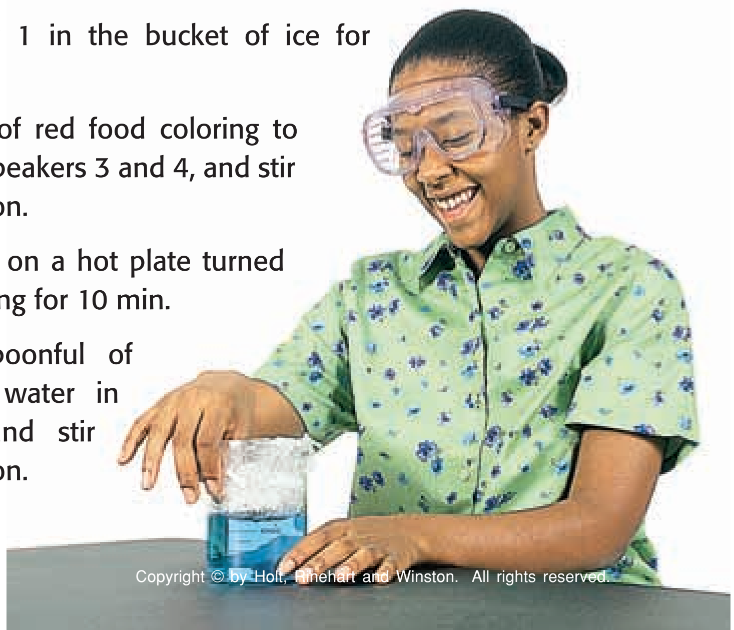
1. Why do some parts of the ocean turn over and not others?

Form a Hypothesis

2. Write a hypothesis that is a possible answer to the question above. Explain your reasoning.

Test the Hypothesis

3. Label the beakers 1 through 5. Fill beakers 1 through 4 with tap water.
4. Add a drop of blue food coloring to the water in beakers 1 and 2, and stir with the spoon.
5. Place beaker 1 in the bucket of ice for 10 min.
6. Add a drop of red food coloring to the water in beakers 3 and 4, and stir with the spoon.
7. Set beaker 3 on a hot plate turned to a low setting for 10 min.
8. Add one spoonful of salt to the water in beaker 4, and stir with the spoon.



9. While beaker 1 is cooling and beaker 3 is heating, copy the observations table below on a sheet of paper.

Observations Table	
Mixture of water	**Observations**
Warm water placed above cold water	
Cold water placed above warm water	DO NOT WRITE IN BOOK
Salty water placed above fresh water	
Fresh water placed above salty water	

10. Pour half of the water in beaker 1 into beaker 5. Return beaker 1 to the bucket of ice.
11. Tuck a sheet of plastic wrap into beaker 5 so that the plastic rests on the surface of the water and lines the upper half of the beaker.
12. Put on your gloves. Slowly pour half of the water in beaker 3 into the plastic-lined upper half of beaker 5 to form two layers of water. Return beaker 3 to the hot plate, and remove your gloves.
13. Very carefully, pull on one edge of the plastic wrap and remove it so that the warm, red water rests on the cold, blue water. **Caution:** The plastic wrap may be warm.
14. Wait about 5 minutes, and then observe the layers in beaker 5. Did one layer remain on top of the other? Was there any mixing or turning over? Record your observations in your observations table.
15. Empty beaker 5, and rinse it with clean tap water.
16. Repeat the procedure used in steps 10–15. This time, pour warm, red water from beaker 3 on the bottom and cold, blue water from beaker 1 on top. (Use gloves when pouring warm water.)
17. Again, repeat the procedure used in steps 10–15. This time, pour blue tap water from beaker 2 on the bottom and red, salty water from beaker 4 on top.
18. Repeat the procedure used in steps 10–15 a third time. This time, pour red, salty water from beaker 4 on the bottom and blue tap water from beaker 2 on top.

Analyze the Results

1. **Analyzing Data** Compare the results of all four trials. Explain why the water turned over in some of the trials but not in all of them.

Draw Conclusions

2. **Evaluating Results** What is the effect of temperature and salinity on the density of water?
3. **Drawing Conclusions** What makes the temperature of ocean water decrease? What could make the salinity of ocean water increase?
4. **Drawing Conclusions** What reasons can you give to explain why some parts of the ocean do not turn over in the spring while some do?

Applying Your Data

Suggest a method for setting up a model that tests the combined effects of temperature and salinity on the density of water. Consider using more than two water samples and dyes.

Chapter Review

USING KEY TERMS

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

1. *surface current* and *deep current*
2. *El Niño* and *La Niña*
3. *spring tide* and *neap tide*
4. *tide* and *tidal range*

UNDERSTANDING KEY IDEAS

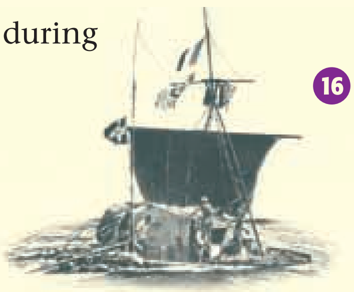
Multiple Choice

5. Deep currents form when
   a. cold air decreases water density.
   b. warm air increases water density.
   c. the ocean surface freezes and solids from the water underneath are removed.
   d. salinity increases.

6. When waves come near the shore,
   a. they speed up.
   b. they maintain their speed.
   c. their wavelength increases.
   d. their wave height increases.

7. Whitecaps break
   a. in the surf.
   b. in the breaker zone.
   c. in the open ocean.
   d. as their wavelength increases.

8. Tidal range is greatest during
   a. spring tide.
   b. neap tide.
   c. a tidal bore.
   d. the daytime.



9. Tides alternate between high and low because the moon revolves around the Earth
   a. at the same speed the Earth rotates.
   b. at a much faster speed than the Earth rotates.
   c. at a much slower speed than the Earth rotates.
   d. at different speeds.

10. El Niño can cause
   a. droughts to occur in Indonesia and Australia.
   b. upwelling to occur off the coast of South America.
   c. earthquakes.
   d. droughts to occur in the southern half of the United States.

Short Answer

11. Explain the relationship between upwelling and El Niño.
12. Describe the two parts of a wave. Describe how these two parts relate to wavelength and wave height.
13. Compare the relative positions of the Earth, moon, and sun during the spring and neap tides.
14. Explain the difference between the breaker zone and the surf.
15. Describe how warm-water currents affect the climate in the British Isles.
16. Describe the factors that form deep currents.

CRITICAL THINKING

17 **Concept Mapping** Use the following terms to create a concept map: *wind, deep currents, sun's gravity, types of ocean-water movement, surface currents, tides, increasing water density, waves,* and *moon's gravity*.

18 **Identifying Relationships** Why are tides more noticeable in Earth's oceans than on its land?

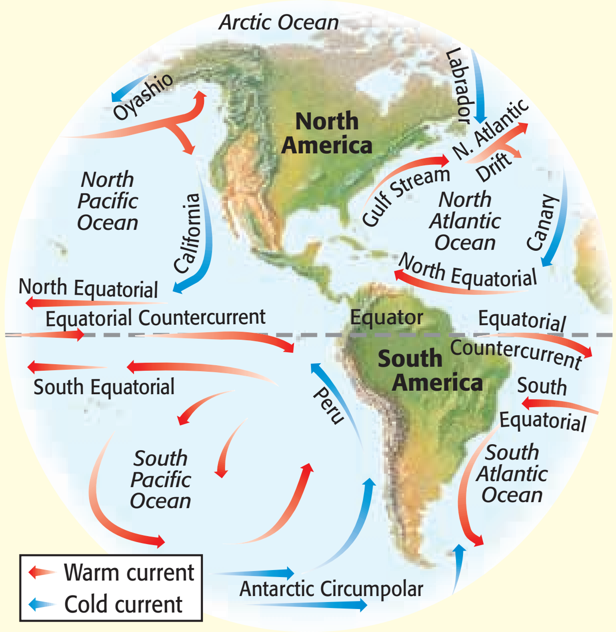
19 **Expressing Opinions** Explain why it's important to study El Niño and La Niña.

20 **Applying Concepts** Suppose you and a friend are planning a fishing trip to the ocean. Your friend tells you that the fish bite more in his secret fishing spot during low tide. If low tide occurred at the spot at 7 a.m. today and you are going to fish there in 1 week, at what time will low tide occur in that spot?

21 **Identifying Relationships** Describe how global winds, the Coriolis Effect, and continental deflections form a pattern of surface currents on Earth.

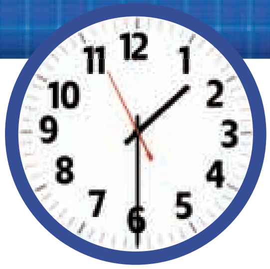
INTERPRETING GRAPHICS

The diagram below shows some of Earth's major surface currents that flow in the Western Hemisphere. Use the diagram to answer the questions that follow.



22 List two warm-water currents and two cold-water currents.

23 How do you think the Labrador Current affects the climate of Canada and Greenland?



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 When certain algae grow rapidly, they clump together on the ocean's surface in an algal bloom that changes the color of the water. Because these algal blooms often turn the water red or reddish brown and tidal conditions were believed to cause the blooms, people called these blooms *red tides*. However, algal blooms are not always red and are not directly related to tides. Scientists now call these algae clusters <u>harmful algal blooms (HABs)</u>. HABs are considered harmful because the species of algae that makes up the blooms produces toxins that can poison fish and shellfish, which in turn can poison people.

Unfortunately, seafood contamination is not noticeable without testing and is not easily eliminated. The toxins don't change the flavor of the seafood, and cooking the seafood doesn't eliminate the toxins.

1. Why did scientists start calling red tides *HABs*?

- **A** The name *HABs* is easier to remember.
- **B** The name *red tides* was not accurate in describing the phenomenon.
- **C** The algal blooms are actually green.
- **D** The term *red tides* did not reflect the danger of the blooms.

2. How can a person tell if seafood has been contaminated by HABs?

- **F** Contaminated seafood has a reddish color.
- **G** HABs change the flavor of the seafood.
- **H** Seafood contaminated by HABs has a strange smell.
- **I** Unfortunately, there is no easy way to tell.

Passage 2 Tsunamis are the most destructive waves in the ocean. Most tsunamis are caused by earthquakes on the ocean floor, but some can be caused by volcanic eruptions and underwater landslides. Tsunamis are sometimes called *tidal waves,* which is <u>misleading</u> because tsunamis have no connection with tides.

Tsunamis commonly have a wave period of about 15 min and a wave speed of about 725 km/h, which is about as fast as a jet airliner. By the time a tsunami reaches the shore, its height may be 30 to 40 m.

In 1960, a tsunami was triggered by an earthquake off the coast of South America. The tsunami was so powerful that it crossed the Pacific Ocean and hit the city of Hilo, on the coast of Hawaii, approximately 10,000 km away. The same tsunami then continued on to strike Japan.

1. The word *misleading* was used in this passage to describe the use of the term *tidal waves* because

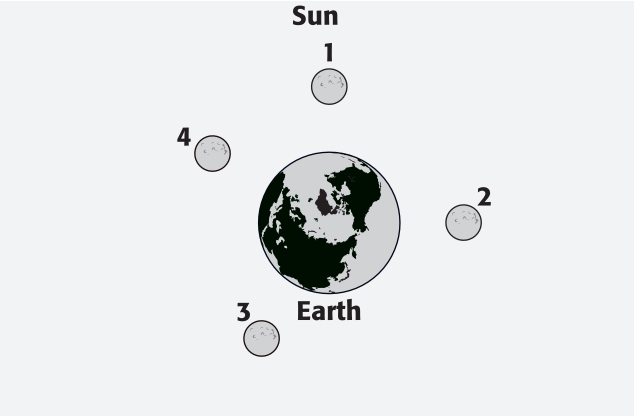
- **A** tsunamis are related to tides.
- **B** tsunamis can cause extensive damage to shores.
- **C** tsunamis are related to earthquakes.
- **D** tsunamis are not related to tides.

2. Which of the following statements is a fact from the passage?

- **F** All tsunamis are caused by earthquakes.
- **G** A tsunami can travel as fast as a jet airliner.
- **H** The tsunami of 1960 caused destruction only in Japan.
- **I** Tsunamis are caused by surface currents.

INTERPRETING GRAPHICS

The diagram below shows the possible positions of the moon relative to the Earth and sun during different tidal ranges. Use the diagram below to answer the questions that follow.



1. At which position would the moon be during a neap tide?

A 1
B 2
C 3
D 4

2. At which position would the moon be during a spring tide?

F 1
G 2
H 3
I 4

3. The tidal range would be greater when the moon is at position 3 than when the moon is at position 4 because

A position 4 forms a 90° angle with the sun and the Earth.
B position 3 is very near a neap-tide position.
C position 3 is very near a spring-tide position.
D position 4 is very near a spring-tide position.

MATH

Read each question below, and choose the best answer.

1. If a wave has a speed of 3 m/s and a wavelength of 12 m, what is its period? Use the following equation to answer the question above:

$$\frac{\text{wavelength (m)}}{\text{wave period (s)}} = \text{wave speed (m/s)}$$

A 36 s
B 4 m
C 24 s
D 4 s

2. Antarctic Bottom Water takes 750 years to move from the Antarctic coast to the equator. If the distance between the equator and the Antarctic coast is about 10,000 km, approximately how many kilometers does the bottom water move each year?

F 13 km
G 200 km
H 75 km
I 1 km

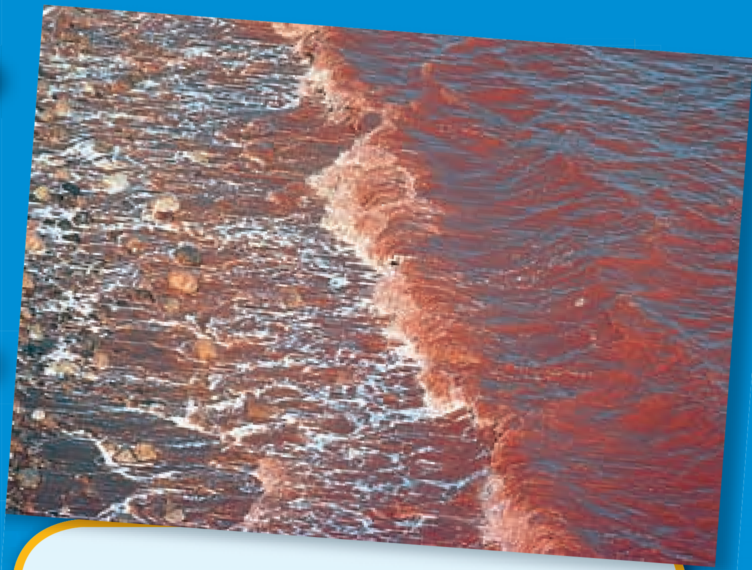
3. A boat is traveling north at 20 km/h against a current that is moving south at 12 km/h. What is the overall speed and direction of the boat?

A 8 km/h north
B 8 km/h south
C 32 km/h north
D 32 km/h south

4. Imagine that you are in a rowboat on the open ocean. You count 2 waves traveling right under your boat in 10 seconds. You estimate the wavelength to be 3 m. What is the wave speed?

F 0.6 m/s
G 6.0 m/s
H 0.3 m/s
I 3.0 m/s

Science in Action



Weird Science

Using Toy Ducks to Track Ocean Currents

Accidents can sometimes lead to scientific discovery. For example, on January 10, 1992, 29,000 plastic tub toys spilled overboard when a container ship traveling northwest of Hawaii ran into a storm. In November of that year, those toys began washing up on Alaskan beaches. When oceanographers heard about this, they placed advertisements in newspapers along the Alaskan coast asking people who found the toys to call them. Altogether, hundreds of toys were recovered. Using recovery dates and locations and computer models, oceanographers were able to re-create the toys' drift and figure out which currents carried the toys. As for the remaining toys, currents may carry them to a number of different destinations. Some may travel through the Arctic Ocean and eventually reach Europe!

Math ACTIVITY

Between January 10, 1992, and November 16, 1992, some of the toys were carried approximately 3,220 km from the cargo-spill site to the coast of Alaska. Calculate the average distance traveled by these toys per day. (Hint: The year 1992 was a leap year.)

Science, Technology, and Society

Red Tides

Imagine going to the beach only to find that the ocean water has turned red and that a lot of fish are floating belly up. What could cause such damage to the ocean? It may surprise you to find that the answer is single-celled algae. When certain algae grow rapidly, they clump together on the ocean's surface in what are known as algal blooms. These algal blooms have been commonly called *red tides* because the blooms often turn the water red or reddish-brown. The term scientists use for these sudden explosions in algae growth is *harmful algal blooms* (HABs). The blooms are harmful because certain species of algae produce toxins that can poison fish, shellfish, and people who eat poisoned fish or shellfish. Toxic blooms can be carried hundreds of miles on ocean currents. HABs can ride into an area on an ocean current and cause fish to die and people who eat the poisoned fish or shellfish to become ill.

Social Studies ACTIVITY

Some scientists think that factors related to human activities, such as agricultural runoff into the ocean, are causing more HABs than occurred in the past. Other scientists disagree. Find out more about this issue, and have a class debate about the roles humans play in creating HABs.

Careers

Cristina Castro

Marine Biologist Have you ever imagined watching whales for a living? Cristina Castro does. Castro works as a marine biologist with the Pacific Whale Foundation in Ecuador. She is studying the migratory patterns of a whale species known as the *humpback whale*. Each year, the humpback whale migrates from feeding grounds in the Antarctic to the warm waters off Ecuador, where the whales breed. Her studies take place largely in the Machalilla National Park. The park is a two-mile stretch of beach that is protected by the government of Ecuador.

In her research, Cristina Castro focuses on the connection between El Niño events and the number of humpback whales in the waters off Ecuador. Castro believes that during an El Niño event, the waters off Ecuador are too hot for the whales. When the whales get hot, they have a difficult time cooling off because they have a thick coat of blubber that provides insulation. So, Castro believes that the whales stay in colder waters during an El Niño event.

Language Arts ACTIVITY

WRITING SKILL Research the humpback whale's migratory route from Antarctica to Ecuador. Write a short story in which you tell of the migration from the point of view of a young whale.

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To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5H2OF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS14.

UNIT 2

TIMELINE

Introduction to Matter

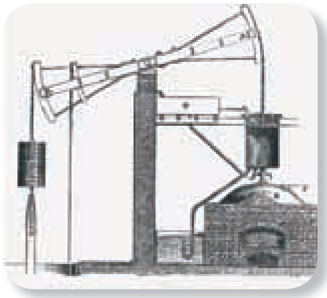
In this unit, you will explore a question that people have been pondering for centuries: What is the nature of matter? You will learn how the word *matter* is defined. You will also learn about the different states of matter and how to classify different arrangements of matter as elements, compounds, or mixtures. In addition, you will learn how the periodic table is used to classify and organize elements. This timeline shows some of the events and discoveries that have occurred throughout history as scientists have sought to understand the nature of matter.

1661

Robert Boyle, a chemist in England, determines that elements are substances that cannot be broken down into anything simpler by chemical processes.

1712

Thomas Newcomen invents the first practical steam engine.



1937

The *Hindenburg* explodes while docking in Lakehurst, New Jersey. To make it lighter than air, the airship was filled with flammable hydrogen gas.

1971

The first commercially available "pocket" calculator is introduced. It has a mass of nearly 1 kg and a price of about $400, hardly the kind of pocket calculator that exists today.

1766

English chemist Henry Cavendish discovers and describes the properties of a highly flammable substance now known as hydrogen gas.

1800

Current from an electric battery is used to separate water into the elements hydrogen and oxygen for the first time.

1920

American women win the right to vote with the ratification of the 19th Amendment to the Constitution.

1950

Silly Putty® is sold in a toy store for the first time. The soft, gooey substance quickly becomes popular because of its strange properties, including the ability to "pick up" the print from a newspaper page.

1957

The space age begins when the Soviet Union launches *Sputnik I*, the first artificial satellite to circle the Earth.

1989

An oil tanker strikes a reef in Prince William Sound, Alaska, and spills nearly 11 million gallons of oil. The floating oil injures or kills thousands of marine mammals and seabirds and damages the Alaskan coastline.

2000

The World's Fair, an international exhibition featuring exhibits and participants from around the world, is held in Hanover, Germany. The theme is "Humankind, Nature, and Technology."

2003

Sally Ride, the first American woman in space, is inducted into the Astronaut Hall of Fame.

5

The Properties of Matter

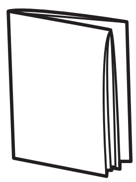
About the PHOTO

This giant ice dragon began as a 1,700 kg block of ice! Making the blocks of ice takes six weeks. Then, the ice blocks are stored at –30°C until the sculpting begins. The artist has to work at –10°C to keep the ice from melting. An ice sculptor has to be familiar with the many properties of water, including its melting point.

PRE-READING ACTIVITY

FOLDNOTES

Booklet Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.



START-UP ACTIVITY

Sack Secrets

In this activity, you will test your skills in determining an object's identity based on the object's properties.

Procedure

1. You and two or three of your classmates will receive a **sealed paper sack** containing a **mystery object.** Do not open the sack!
2. For five minutes, make as many observations about the object as you can without opening the sack. You may touch, smell, shake, or listen to the object through the sack. Record your observations.

Analysis

1. At the end of five minutes, discuss your findings with your partners.
2. List the object's properties that you can identify. Make another list of properties that you cannot identify. Make a conclusion about the object's identity.
3. Share your observations, your list of properties, and your conclusion with the class. Then, open the sack.
4. Did you properly identify the object? If so, how? If not, why not? Record your answers.

SECTION 1

What Is Matter?

What do you have in common with a toaster, a steaming bowl of soup, or a bright neon sign?

You are probably thinking that this is a trick question. It is hard to imagine that a person has anything in common with a kitchen appliance, hot soup, or a glowing neon sign.

Matter

From a scientific point of view, you have at least one characteristic in common with these things. You, the toaster, the bowl, the soup, the steam, the glass tubing of a neon sign, and the glowing gas are made of matter. But exactly what is matter? **Matter** is anything that has mass and takes up space. It's that simple! Everything in the universe that you can see is made up of some type of matter.

Matter and Volume

All matter takes up space. The amount of space taken up, or occupied, by an object is known as the object's **volume.** Your fingernails, the Statue of Liberty, the continent of Africa, and a cloud have volume. And because these things have volume, they cannot share the same space at the same time. Even the tiniest speck of dust takes up space. Another speck of dust cannot fit into that space without somehow bumping the first speck out of the way. **Figure 1** shows an example of how one object cannot share with another object the same space at the same time. Try the Quick Lab on the next page to see for yourself that matter takes up space.

READING WARM-UP

Objectives

- Describe the two properties of all matter.
- Identify the units used to measure volume and mass.
- Compare mass and weight.
- Explain the relationship between mass and inertia.

Terms to Learn

matter	mass
volume	weight
meniscus	inertia

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

matter anything that has mass and takes up space

volume a measure of the size of a body or region in three-dimensional space

Figure 1 *Because CDs are made of matter, they have volume. Once your CD storage rack is filled with CDs, you cannot fit another CD in the rack.*

Quick Lab

Space Case

1. Crumple a **piece of paper.** Fit it tightly in the bottom of a **clear plastic cup** so that it won't fall out.
2. Turn the cup upside down. Lower the cup straight down into a **bucket** half-filled with **water.** Be sure that the cup is completely underwater.
3. Lift the cup straight out of the water. Turn the cup upright, and observe the paper. Record your observations.
4. Use the point of a **pencil** to punch a small hole in the bottom of the cup. Repeat steps 2 and 3.
5. How do the results show that air has volume? Explain your answer.

Liquid Volume

Lake Erie, the smallest of the Great Lakes, has a volume of approximately 483 trillion (that's 483,000,000,000,000) liters of water. Can you imagine that much water? Think of a 2-liter bottle of soda. The water in Lake Erie could fill more than 241 trillion 2-liter soda bottles. That's a lot of water! On a smaller scale, a can of soda has a volume of only 355 milliliters, which is about one-third of a liter. You can check the volume of the soda by using a large measuring cup from your kitchen.

Liters (L) and milliliters (mL) are the units used most often to express the volume of liquids. The volume of any amount of liquid, from one raindrop to a can of soda to an entire ocean, can be expressed in these units.

Reading Check **What are two units used to express volume?** (*See the Appendix for answers to Reading Checks.*)

Measuring the Volume of Liquids

In your science class, you'll probably use a graduated cylinder instead of a measuring cup to measure the volume of liquids. Graduated cylinders are used to measure the liquid volume when accuracy is important. The surface of a liquid in any container, including a measuring cup or a large beaker, is curved. The curve at the surface of a liquid is called a **meniscus** (muh NIS kuhs). To measure the volume of most liquids, such as water, you must look at the bottom of the meniscus, as shown in **Figure 2.** Note that you may not be able to see a meniscus in a large beaker. The meniscus looks flat because the liquid is in a wide container.

Figure 2 *To measure volume correctly, read the scale at the lowest part of the meniscus (as shown) at eye level.*

meniscus the curve at a liquid's surface by which one measures the volume of the liquid

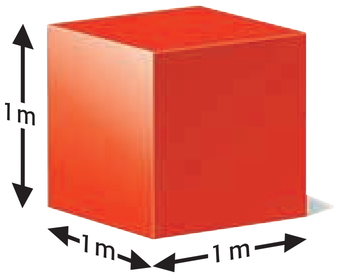


Figure 3 *A cubic meter (1 m^3) is a cube that has a length, width, and height of 1 m.*

Volume of a Regularly Shaped Solid Object

The volume of any solid object is expressed in cubic units. The word *cubic* means "having three dimensions." In science, cubic meters (m^3) and cubic centimeters (cm^3) are the units most often used to express the volume of solid things. The 3 in these unit symbols shows that three quantities, or dimensions, were multiplied to get the final result. You can see the three dimensions of a cubic meter in **Figure 3.** There are formulas to find the volume of regularly shaped objects. For example, to find the volume of a cube or a rectangular object, multiply the length, width, and height of the object, as shown in the following equation:

$$volume = length \times width \times height$$

Figure 4 *The 12-sided object displaced 15 mL of water. Because 1 mL = 1 cm^3, the volume of the object is 15 cm^3.*

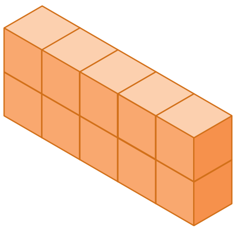
Volume of an Irregularly Shaped Solid Object

How do you find the volume of a solid that does not have a regular shape? For example, to find the volume of a 12-sided object, you cannot use the equation given above. But you can measure the volume of a solid object by measuring the volume of water that the object displaces. In **Figure 4,** when a 12-sided object is added to the water in a graduated cylinder, the water level rises. The volume of water displaced by the object is equal to its volume. Because 1 mL is equal to 1 cm^3, you can express the volume of the water displaced by the object in cubic centimeters. Although volumes of liquids can be expressed in cubic units, volumes of solids should not be expressed in liters or milliliters.

Reading Check **Explain how you would measure the volume of an apple.**

MATH FOCUS

Volume of a Rectangular Solid What is the volume of a box that has a length of 5 cm, a width of 1 cm, and a height of 2 cm?



Step 1: Write the equation for volume.

$$volume = length \times width \times height$$

Step 2: Replace the variables with the measurements given to you, and solve.

$$volume = 5 \text{ cm} \times 1 \text{ cm} \times 2 \text{ cm} = 10 \text{ cm}^3$$

Now It's Your Turn

1. A book has a length of 25 cm, a width of 18 cm, and a height of 4 cm. What is its volume?
2. What is the volume of a suitcase that has a length of 95 cm, a width of 50 cm, and a height of 20 cm?
3. A CD case is 14.2 cm long, 12.4 cm wide, and 1 cm deep. What is its volume?

Matter and Mass

Another characteristic of all matter is mass. **Mass** is the amount of matter in an object. For example, you and a peanut are made of matter. But you are made of more matter than a peanut is, so you have more mass. The mass of an object is the same no matter where in the universe the object is located. The only way to change the mass of an object is to change the amount of matter that makes up the object.

mass a measure of the amount of matter in an object

weight a measure of the gravitational force exerted on an object; its value can change with the location of the object in the universe

The Difference Between Mass and Weight

The terms *mass* and *weight* are often used as though they mean the same thing, but they don't. **Weight** is a measure of the gravitational (GRAV i TAY shuh nuhl) force exerted on an object. Gravitational force keeps objects on Earth from floating into space. The gravitational force between an object and the Earth depends partly on the object's mass. The more mass an object has, the greater the gravitational force on the object and the greater the object's weight. But an object's weight can change depending on its location in the universe. An object would weigh less on the moon than it does on Earth because the moon has less gravitational force than Earth does. **Figure 5** explains the differences between mass and weight.

Figure 5 Differences Between Mass and Weight

Mass

- Mass is a measure of the amount of matter in an object.
- Mass is always constant for an object no matter where the object is located in the universe.
- Mass is measured by using a balance (shown below).
- Mass is expressed in kilograms (kg), grams (g), and milligrams (mg).

Weight

- Weight is a measure of the gravitational force on an object.
- Weight varies depending on where the object is in relation to the Earth (or any large body in the universe).
- Weight is measured by using a spring scale (shown at right).
- Weight is expressed in newtons (N).

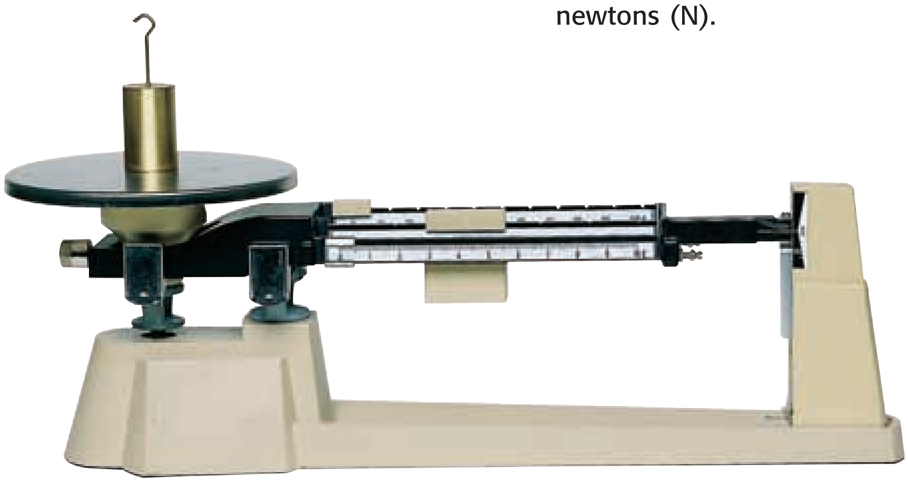


Figure 6 *The brick and the sponge take up the same amount of space. But the brick has more matter in it, so its mass—and thus its weight—is greater.*

Measuring Mass and Weight

The brick and the sponge in **Figure 6** have the same volume. But because the brick has more mass, a greater gravitational force is exerted on the brick than on the sponge. As a result, the brick weighs more than the sponge.

The SI unit of mass is the kilogram (kg), but mass is often expressed in grams (g) and milligrams (mg), too. These units can be used to express the mass of any object in the universe.

Weight is a measure of gravitational force and is expressed in the SI unit of force, the *newton* (N). One newton is about equal to the weight of an object that has a mass of 100 g on Earth. So, if you know the mass of an object, you can calculate the object's weight on Earth. Weight is a good estimate of the mass of an object because, on Earth, gravity doesn't change.

Reading Check **What units are often used to measure mass?**

Inertia

inertia the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction until an outside force acts on the object

Imagine kicking a soccer ball that has the mass of a bowling ball. It would be not only painful but also very difficult to get the ball moving in the first place! The reason is inertia (in UHR shuh). **Inertia** is the tendency of an object to resist a change in motion. So, an object at rest will remain at rest until something causes the object to move. Also, a moving object will keep moving at the same speed and in the same direction unless something acts on the object to change its speed or direction.

MATH FOCUS

Converting Mass to Weight A student has a mass of 45,000 g. How much does this student weigh in newtons?

Step 1: Write the information given to you.

45,000 g

Step 2: Write the conversion factor to change grams into newtons.

1 N = 100 g

Step 3: Write the equation so that grams will cancel.

$$45{,}000 \text{ g} \times \frac{1 \text{ N}}{100 \text{ g}} = 450 \text{ N}$$

Now It's Your Turn

1. What is the weight of a car that has a mass of 1,362,000 g?
2. Your pair of boots has a mass of 850 g. If each boot has exactly the same mass, what is the weight of each boot?

Mass: The Measure of Inertia

Mass is a measure of inertia. An object that has a large mass is harder to get moving and harder to stop than an object that has less mass. The reason is that the object with the large mass has greater inertia. For example, imagine that you are going to push a grocery cart that has only one potato in it. Pushing the cart is easy because the mass and inertia are small. But suppose the grocery cart is stacked with potatoes, as in **Figure 7.** Now the total mass—and the inertia—of the cart full of potatoes is much greater. It will be harder to get the cart moving. And once the cart is moving, stopping the cart will be harder.

Figure 7 *Because of inertia, moving a cart full of potatoes is more difficult than moving a cart that is empty.*

SECTION Review

Summary

- Two properties of matter are volume and mass.
- Volume is the amount of space taken up by an object.
- The SI unit of volume is the liter (L).
- Mass is the amount of matter in an object.
- The SI unit of mass is the kilogram (kg).
- Weight is a measure of the gravitational force on an object, usually in relation to the Earth.
- Inertia is the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction. The more massive an object is, the greater its inertia.

Using Key Terms

1. Use the following terms in the same sentence: *volume* and *meniscus*.
2. In your own words, write a definition for each of the following terms: *mass, weight,* and *inertia*.

Understanding Key Ideas

3. Which of the following is matter?
   a. dust
   b. the moon
   c. strand of hair
   d. All of the above
4. A graduated cylinder is used to measure
   a. volume.
   b. weight.
   c. mass.
   d. inertia.
5. The volume of a solid is measured in
   a. liters.
   b. grams.
   c. cubic centimeters.
   d. All of the above
6. Mass is measured in
   a. liters.
   b. centimeters.
   c. newtons.
   d. kilograms.
7. Explain the relationship between mass and inertia.

Math Skills

8. A nugget of gold is placed in a graduated cylinder that contains 80 mL of water. The water level rises to 225 mL after the nugget is added to the cylinder. What is the volume of the gold nugget?
9. One newton equals about 100 g on Earth. How many newtons would a football weigh if it had a mass of 400 g?

Critical Thinking

10. **Identifying Relationships** Do objects with large masses always have large weights? Explain.
11. **Applying Concepts** Would an elephant weigh more or less on the moon than it would weigh on Earth? Explain your answer.

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Topic: What Is Matter?
SciLinks code: HSM1662

SECTION 2

Physical Properties

Have you ever played the game 20 Questions? The goal of this game is to figure out what object another person is thinking of by asking 20 yes/no questions or less.

READING WARM-UP

Objectives

- Identify eight examples of physical properties of matter.
- Describe how properties are used to identify substances.
- List six examples of physical changes.
- Explain what happens to matter during a physical change.

Terms to Learn

physical property
density
specific heat
physical change

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember examples of physical properties.

If you can't figure out the object's identity after asking 20 questions, you may not be asking the right kinds of questions. What kinds of questions should you ask? You may want to ask questions about the physical properties of the object. Knowing the properties of an object can help you find out what it is.

Physical Properties

The questions in **Figure 1** help someone gather information about color, odor, mass, and volume. Each piece of information is a physical property of matter. A **physical property** of matter can be observed or measured without changing the matter's identity. For example, you don't have to change an apple's identity to see its color or to measure its volume.

Other physical properties, such as magnetism, the ability to conduct electric current, strength, and flexibility, can help someone identify how to use a substance. For example, think of a scooter with an electric motor. The magnetism produced by the motor is used to convert energy stored in a battery into energy that will turn the wheels.

Reading Check **List four physical properties.** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *Asking questions about the physical properties of an object can help you identify it.*

Examples of Physical Properties

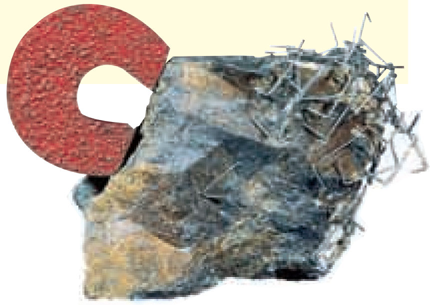
You use physical properties every day. For example, physical properties help you determine if your socks are clean (odor), if your books will fit into your backpack (volume), or if your shirt matches your pants (color). **Figure 2** gives more examples of physical properties.

physical property a characteristic of a substance that does not involve a chemical change, such as density, color, or hardness

Figure 2 **Examples of Physical Properties**

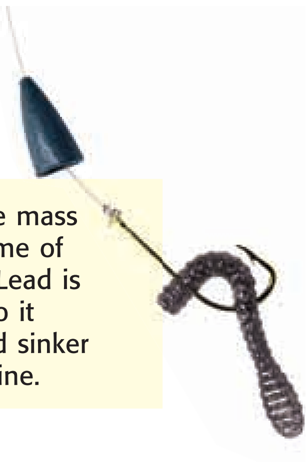
Thermal conductivity (KAHN duhk TIV uh tee) is the rate at which a substance transfers heat. Plastic foam is a poor conductor.

Magnetism is the property of some materials to attract iron or objects containing iron. Lodestone is a naturally magnetic rock.



Solubility (SAHL yoo BIL uh tee) is the ability of a substance to dissolve in another substance. Flavored drink mix dissolves in water.

State is the physical form in which a substance exists, such as a solid, liquid, or gas. Ice is water in the solid state.



Density is the mass per unit volume of a substance. Lead is very dense, so it makes a good sinker for a fishing line.

Ductility (duhk TIL uh tee) is the ability of a substance to be pulled into a wire. **Electrical conductivity** describes how freely charges can move in a material. Copper is often used to make wiring because it is ductile and it has a high electrical conductivity.

Malleability (MAL ee uh BIL uh tee) is the ability of a substance to be rolled or pounded into thin sheets. Aluminum can be rolled into sheets to make foil.

Density

density the ratio of the mass of a substance to the volume of the substance

Density is a physical property that describes the relationship between mass and volume. **Density** is the amount of matter in a given space, or in a certain volume. A golf ball and a table-tennis ball have similar volumes. But a golf ball has more mass than a table-tennis ball does. So, the golf ball has a greater density.

Liquid Layers

Figure 3 *This graduated cylinder contains six liquids. From top to bottom, they are corn oil, water, shampoo, dish detergent, antifreeze, and maple syrup.*

What do you think causes the liquid in **Figure 3** to look the way it does? Is it trick photography? No, it is differences in density! There are six liquids in the graduated cylinder. Each liquid has a different density. If the liquids are carefully poured into the cylinder, they can form six layers because of the differences in density. The densest layer is on the bottom. The least dense layer is on top. The order of the layers shows the order of increasing density. Yellow is the least dense, followed by the colorless layer, red, blue, green, and brown (the densest).

Density of Solids

Which would you rather carry around all day: a kilogram of lead or a kilogram of feathers? At first, you might say feathers. But both the feathers and the lead have the same mass, just as the cotton balls and the tomatoes have the same mass, as shown in **Figure 4.** So, the lead would be less awkward to carry around than the feathers would. The feathers are much less dense than the lead. So, it takes a lot of feathers to equal the same mass of lead.

Knowing the density of a substance can also tell you if the substance will float or sink in water. If the density of an object is less than the density of water, the object will float. Likewise, a solid object whose density is greater than the density of water will sink when the object is placed in water.

Reading Check **What will happen to an object placed in water if the object's density is less than water's density?**

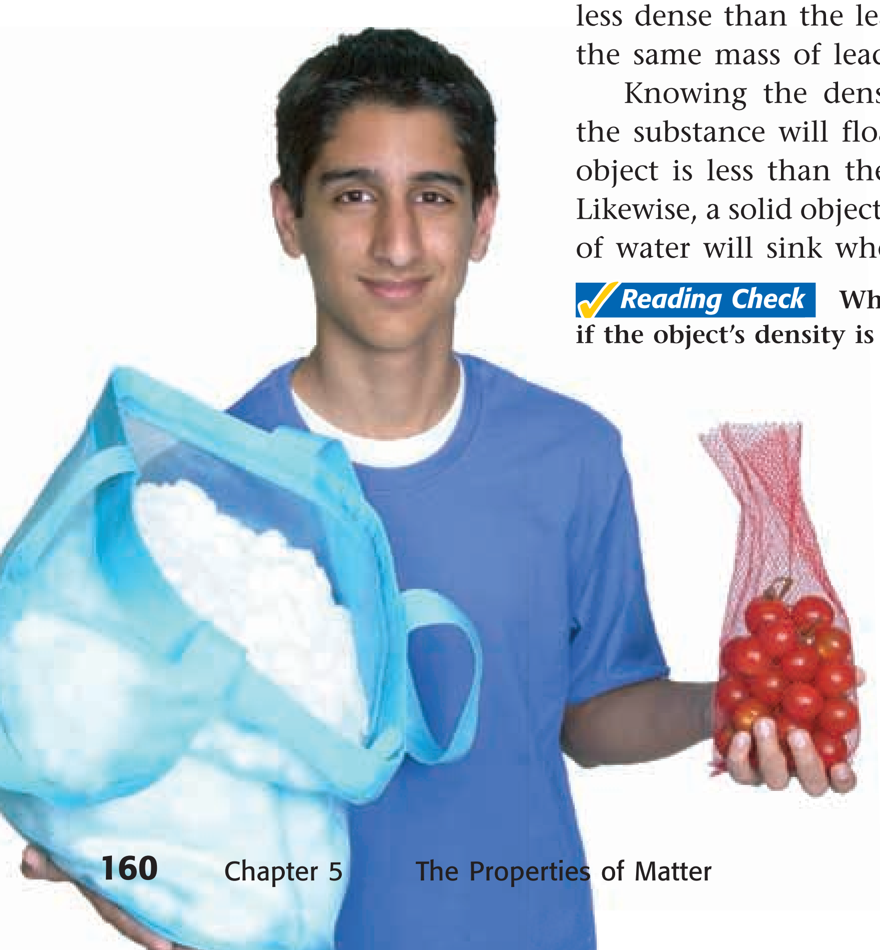


Figure 4 *The cotton balls and the tomatoes have the same mass. But cotton is much less dense than the tomatoes.*

Solving for Density

To find an object's density (D), first measure its mass (m) and volume (V). Then, use the equation below.

$$D = \frac{m}{V}$$

Units for density consist of a mass unit divided by a volume unit. Some units for density are g/cm^3, g/mL, kg/m^3, and kg/L. Remember that the volume of a solid is often given in cubic centimeters or cubic meters. So, the density of a solid should be given in units of g/cm^3 or kg/m^3.

Using Density to Identify Substances

Density is a useful physical property for identifying substances. Each substance has a density that differs from the densities of other substances. And the density of a substance is always the same at a given temperature and pressure. Look at **Table 1** to compare the densities of several common substances.

Table 1* Densities of Common Substances

Substance	Density* (g/cm^3)	Substance	Density* (g/cm^3)
Helium (gas)	0.00001663	Zinc (solid)	7.13
Oxygen (gas)	0.001331	Silver (solid)	10.50
Water (liquid)	1.00	Lead (solid)	11.35
Pyrite (solid)	5.02	Mercury (liquid)	13.55

*at 20°C and 1.0 atm

SCHOOL to HOME

Twenty Questions

Play a game of 20 Questions with a parent. One person will think of an object, and the other person will ask yes/no questions about it. Write the questions in your **science journal** as you play. Put a check mark next to the questions asked about physical properties. When the object is identified or when the 20 questions are up, switch roles.

ACTIVITY

MATH FOCUS

Calculating Density What is the density of an object whose mass is 25 g and whose volume is 10 cm^3?

Step 1: Write the equation for density.

$$D = \frac{m}{V}$$

Step 2: Replace m and V with the measurements given in the problem, and solve.

$$D = \frac{25 \text{ g}}{10 \text{ cm}^3} = 2.5 \text{ g/cm}^3$$

The equation for density can also be rearranged to find mass and volume, as shown.

$m = D \times V$ (Rearrange by multiplying by V.)

$V = \frac{m}{D}$ (Rearrange by dividing by D.)

Now It's Your Turn

1. Find the density of a substance that has a mass of 45 kg and a volume of 43 m^3. (Hint: Make sure that your answer's units are units of density.)
2. Suppose that you have a lead ball whose mass is 454 g. What is the ball's volume? (Hint: Use **Table 1** above.)
3. What is the mass of a 15 mL sample of mercury?
4. A metal object has a mass of 25 g and a volume of 2.38 cm^3. Identify the metal as silver or lead based on its density.

Quick Lab

Sweet and Salty Solubility

1. Use a **balance** to measure out 5 g of **solid A** into a **plastic cup** and 5 g of **solid B** into a second **plastic cup.**
2. Use a **graduated cylinder** to add 5 mL of **water** to each of the plastic cups.
3. Use a **spoon** to stir the contents in each cup 30 times.
4. Examine the cups. Which substance has the higher solubility?
5. The unknown solids are sugar and salt. Sugar has a higher solubility than salt has. Using this property, identify solid A and solid B as sugar and salt. Explain your reasoning.

Identifying Substances Using Properties

Imagine that your friend asked you to get her backpack as she cleaned up her lab table. What if there are several backpacks that are the same color or the same brand? To identify the backpack, your friend would need to tell you enough properties to single out her pack from all the others. In a similar way, substances can be identified using properties.

Boiling Points and Melting Points

Look at the substances shown in **Figure 5.** Each of these substances is a solid at room temperature. Each is made of crystals shaped like cubes. Each substance is partly composed of the element sodium. How can you tell the substances apart? As shown in **Figure 5,** each substance has a different melting point and boiling point than the other substances have. So, the melting point or boiling point can be used to identify the substances.

Reading Check **Is a white solid sodium bromide or sodium chloride if it melts above 700°C and boils below 1,400°C? Explain.**

Solubilities

Another property that can be used to identify substances is solubility. Some substances can be identified by whether they dissolve in another substance, such as water. However, there are many substances that dissolve in water. For example, all three solids in **Figure 5** dissolve in water. But, different amounts of substances will dissolve in the same amount of water. In 100 g of water, 36.0 g sodium chloride, 94.6 g sodium bromide, or 184 g sodium iodide can dissolve. So the amount of a substance that will dissolve can be used to identify that substance.

Figure 5 **Melting Points and Boiling Points**

Sodium chloride
Melting point: 800.7°C
Boiling point: 1,465°C

Sodium bromide
Melting point: 747°C
Boiling point: 1,390°C

Sodium iodide
Melting point: 660°C
Boiling point: 1,304°C

Figure 6 *The cloth part of a seat belt has a lower specific heat than the metal part has. So, when each part absorbs the same amount of energy, the metal part gets hotter than the cloth part does.*

Specific Heat

Another property that can be used to identify substances is how easily each changes temperature when it absorbs or loses energy. When equal amounts of energy are transferred to or from equal masses of different substances, the change in temperature for each substance will differ. **Specific heat** is the amount of energy needed to change the temperature of 1 kg of a substance by 1°C.

specific heat the quantity of heat required to raise a unit mass of homogeneous material 1 K or 1°C in a specified way given constant pressure and volume

The specific heat of the cloth of the seat belt in **Figure 6** is more than twice that of the metal buckle. So, for equal masses of metal and cloth, the same thermal energy will increase the temperature of the metal twice as much as the cloth. The higher the specific heat of something is, the more energy it takes to increase its temperature. **Table 2** shows that most metals have very low specific heats. On the other hand, the specific heat of water is very high. This is why swimming-pool water usually feels cool, even on a hot day. The same energy heats up the air more than it heats up the water.

Reading Check **You find that a piece of metal has a specific heat of 448 J/kg•°C. Identify the metal based on its specific heat.**

Table 2 Specific Heat of Some Common Substances

Substance	Specific heat (J/kg•°C)	Substance	Specific heat (J/kg•°C)
Lead	128	Glass	837
Gold	129	Aluminum	899
Copper	387	Cloth of seat belt	1,340
Iron	448	Ice	2,090
Metal of seat belt	500	Water	4,184

Figure 7 **Examples of Physical Changes**

Melting butter for popcorn involves a physical change.

This aluminum can has gone through the physical change of being crushed. The properties of the can are the same.

physical change a change of matter from one form to another without a change in chemical properties

Physical Changes Do Not Form New Substances

A **physical change** is a change that affects one or more physical properties of a substance. Imagine that a piece of silver is pounded and molded into a heart-shaped pendant. This change is a physical one because only the shape of the silver has changed. The piece of silver is still silver. Its properties are the same. **Figure 7** shows more examples of physical changes.

Reading Check **What is a physical change?**

Examples of Physical Changes

Freezing water to make ice cubes and sanding a piece of wood are examples of physical changes. These changes do not change the identities of the substances. Ice is still water. And sawdust is still wood. Another interesting physical change takes place when certain substances dissolve in other substances. For example, when you dissolve sugar in water, the sugar seems to disappear. But if you heat the mixture, the water evaporates. Then, you will see that the sugar is still there. The sugar went through a physical change when it dissolved.

CONNECTION TO Geology

WRITING SKILL **Erosion** Erosion of soil is a physical change. Soil erodes when wind and water move soil from one place to another. Research the history of the Grand Canyon. Write a one-page report about how erosion formed the Grand Canyon.

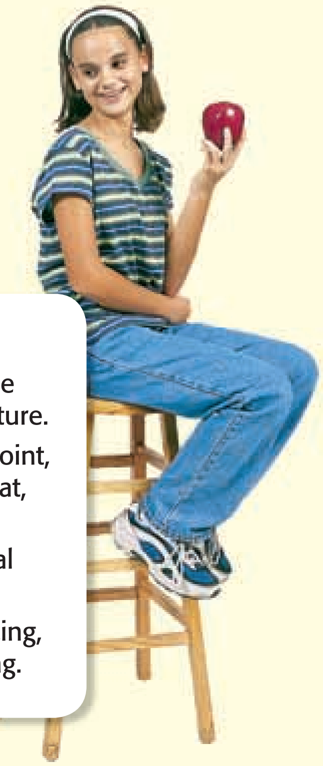
ACTIVITY

Matter and Physical Changes

Physical changes do not change the identity of the matter involved. A stick of butter can be melted and poured over a bowl of popcorn, as shown in **Figure 7.** Although the shape of the butter has changed, the butter is still butter, so a physical change has occurred. In the same way, if you make a figure from a lump of clay, you change the clay's shape and cause a physical change. But the identity of the clay does not change. The properties of the figure are the same as those of the lump of clay.

SECTION

Review



Summary

- Physical properties of matter can be observed without changing the identity of the matter.
- Examples of physical properties are thermal conductivity, state, malleability, ductility, electrical conductivity, solubility, density, and specific heat.
- Density is the amount of matter in a given space.
- The density of a substance is always the same at a given pressure and temperature.
- Properties, including density, melting point, boiling point, solubility, and specific heat, can be used to identify substances.
- When a substance undergoes a physical change, its identity stays the same.
- Examples of physical changes are freezing, cutting, bending, dissolving, and melting.

Using Key Terms

1. Use each of the following terms in a separate sentence: *physical property* and *physical change*.

Understanding Key Ideas

2. The units of density for a rectangular piece of wood are
   - **a.** grams per milliliter.
   - **b.** cubic centimeters.
   - **c.** kilograms per liter.
   - **d.** grams per cubic centimeter.
3. Explain why a golf ball is heavier than a table-tennis ball even though the balls are the same size.
4. Describe what happens to a substance when it goes through a physical change.
5. Identify eight examples of physical properties.
6. List six physical changes that matter can go through.

Math Skills

7. What is the density of an object that has a mass of 350 g and a volume of 95 cm^3? Would this object float in water? Explain.
8. The density of an object is 5 g/cm^3, and the volume of the object is 10 cm^3. What is the mass of the object?

Critical Thinking

9. **Applying Concepts** How can you determine that a coin is not pure silver if you know the mass and volume of the coin?
10. **Analyzing Processes** Explain how you would find the density of an unknown liquid if you have all of the laboratory equipment that you need.

Interpreting Graphics

11. Describe the change taking place in the image at right. What evidence can you present to support the conclusion that this change is a physical change?

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Topic: Describing Matter; Physical Changes

SciLinks code: HSM0391; HSM1142

SECTION 3

Chemical Properties

How would you describe a piece of wood before and after it is burned? Has it changed color? Does it have the same texture? The original piece of wood changed, and physical properties alone can't describe what happened to it.

READING WARM-UP

Objectives

- Describe two examples of chemical properties.
- Explain what happens during a chemical change.
- Distinguish between physical and chemical changes.

Terms to Learn

chemical property
chemical change

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Chemical Properties

Physical properties are not the only properties that describe matter. **Chemical properties** describe matter based on its ability to change into new matter that has different properties. For example, when wood is burned, ash and smoke are created. These new substances have very different properties than the original piece of wood had. Wood has the chemical property of flammability. *Flammability* is the ability of a substance to burn. Ash and smoke cannot burn, so they have the chemical property of nonflammability.

Another chemical property is reactivity. *Reactivity* is the ability of two or more substances to combine and form one or more new substances. The photo of the old car in **Figure 1** illustrates reactivity and nonreactivity.

Reading Check **What does the term *reactivity* mean?** (*See the Appendix for answers to Reading Checks.*)

chemical property a property of matter that describes a substance's ability to participate in chemical reactions

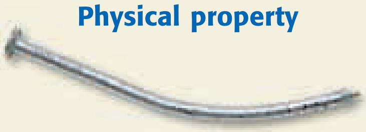
Figure 1 **Reactivity with Oxygen**

The iron used in this old car has the chemical property of **reactivity with oxygen**. When iron is exposed to oxygen, it rusts.

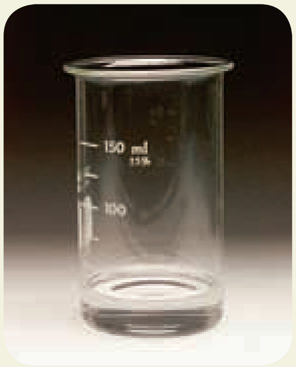
The bumper on this car still looks new because it is coated with chromium. Chromium has the chemical property of **nonreactivity with oxygen.**

Figure 2 **Physical Versus Chemical Properties**

Physical property

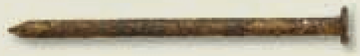


Shape Bending an iron nail will change its shape.



State Rubbing alcohol is a clear liquid at room temperature.

Chemical property



Reactivity with Oxygen An iron nail can react with oxygen in the air to form iron oxide, or rust.

Flammability Rubbing alcohol is able to burn easily.

Comparing Physical and Chemical Properties

How do you tell a physical property from a chemical property? You can observe physical properties without changing the identity of the substance. For example, you can find the density and hardness of wood without changing anything about the wood.

Chemical properties, however, aren't as easy to observe. For example, you can see that wood is flammable only while it is burning. And you can observe that gold is nonflammable only when it won't burn. But a substance always has chemical properties. A piece of wood is flammable even when it's not burning. **Figure 2** shows examples of physical and chemical properties.

Characteristic Properties

The properties that are most useful in identifying a substance are *characteristic properties*. These properties are always the same no matter what size the sample is. Characteristic properties can be physical properties, such as density and solubility, as well as chemical properties, such as flammability and reactivity. Scientists rely on characteristic properties to identify and classify substances.

CONNECTION TO Social Studies

WRITING SKILL **The Right Stuff** When choosing materials to use in manufacturing, you must make sure their properties are suitable for their uses. For example, false teeth can be made from acrylic plastic, porcelain, or gold. According to legend, George Washington wore false teeth made of wood. Do research and find what Washington's false teeth were really made of. In your **science journal,** write a paragraph about what you have learned. Include information about the advantages of the materials used in modern false teeth.

Quick Lab

Changing Change

1. Place a folded **paper towel** in a small **pie plate.**
2. Pour **vinegar** into the pie plate until the entire paper towel is damp.
3. Place three shiny **pennies** on top of the paper towel.
4. Put the pie plate in a safe place. Wait 24 hours.
5. Describe and explain the change that took place.

Chemical Changes and New Substances

A **chemical change** happens when one or more substances are changed into new substances that have new and different properties. Chemical changes and chemical properties are not the same. Chemical properties of a substance describe which chemical changes will occur and which chemical changes will not occur. But chemical changes are the process by which substances actually change into new substances. You can learn about the chemical properties of a substance by looking at the chemical changes that take place.

You see chemical changes more often than you may think. For example, a chemical reaction happens every time a battery is used. Chemicals failing to react results in a dead battery. Chemical changes also take place within your body when the food you eat is digested. **Figure 3** describes other examples of chemical changes.

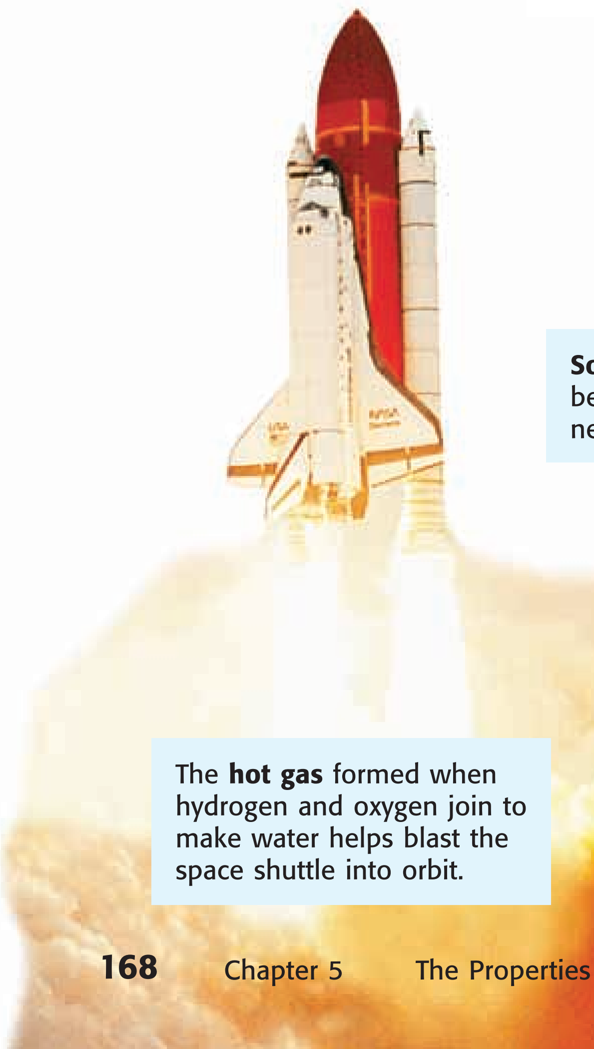
Reading Check How does a chemical change differ from a chemical property?

Figure 3 Examples of Chemical Changes

Soured milk smells bad because bacteria have formed new substances in the milk.

Effervescent tablets bubble when the citric acid and baking soda in them react in water.

The **Statue of Liberty** is made of orange-brown copper but it looks green from the metal's interaction with moist air. New copper compounds formed and these chemical changes made the statue turn green over time.



The **hot gas** formed when hydrogen and oxygen join to make water helps blast the space shuttle into orbit.

Figure 4 *Each of the original ingredients has different physical and chemical properties than the final product, the cake, does!*

What Happens During a Chemical Change?

A fun way to see what happens during chemical changes is to bake a cake. You combine eggs, flour, sugar, and other ingredients, as shown in **Figure 4.** When you bake the batter, the heat of the oven and the interaction of the ingredients cause a chemical change. The result is a cake that has properties that differ from the properties of the ingredients.

chemical change a change that occurs when one or more substances change into entirely new substances with different properties

Signs of Chemical Changes

Look back at **Figure 3.** In each picture, at least one sign indicates a chemical change. Signs that indicate a chemical change include a change in color or odor, the release of energy in the form of sound, heat, or light, and bubbling or clouding of the mixture. When two substances that are dissolved in water combine to form a cloudy solid, that solid is called a *precipitate*.

In the cake example, you would smell the cake as it baked. You would also see the batter rise and begin to brown. When you cut the finished cake, you would see the air pockets made by gas bubbles that formed in the batter. These signs show that chemical changes have happened.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in keyword **HP5MATW.**

Matter and Chemical Changes

In chemical changes, the identity of the matter changes. So, most of these changes that happen in your daily life, such as a cake baking, would be hard to reverse. But, some chemical changes can be reversed by more chemical changes. For example, the water formed in the space shuttle's engines could be split into hydrogen and oxygen by using an electric current.

Figure 5 **Physical and Chemical Changes**

Change in Texture Grinding baking soda into a fine, powdery substance is a physical change.

Reactivity with Vinegar Gas bubbles are produced when vinegar is poured into baking soda.

Physical Versus Chemical Changes

The most important question to ask when trying to decide if a physical or chemical change has happened is, Did the composition change? The *composition* of an object is the type of matter that makes up the object and the way that the matter is arranged in the object. **Figure 5** shows both a physical and a chemical change.

A Change in Composition

Physical changes do not change the composition of a substance. For example, water is made of two hydrogen atoms and one oxygen atom. Whether water is a solid, liquid, or gas, its composition is the same. But chemical changes do alter the composition of a substance. For example, through a process called *electrolysis,* water is broken down into hydrogen and oxygen gases. The composition of water has changed, so you know that a chemical change has taken place.

CONNECTION TO Environmental Science

Acid Rain When fossil fuels are burned, a chemical change takes place. Sulfur from fossil fuels and oxygen from the air combine to produce sulfur dioxide, a gas. When sulfur dioxide enters the atmosphere, it undergoes another chemical change by interacting with water and oxygen. Research this chemical reaction. Make a poster describing the reaction and showing how the final product affects the environment.

ACTIVITY

QUICK LAB

Physical or Chemical Change?

1. Watch as your teacher places a burning **wooden stick** into a **test tube.** Record your observations.
2. Place a mixture of **powdered sulfur** and **iron filings** on a **sheet of paper.** Place a **bar magnet** underneath the paper, and try to separate the iron from the sulfur.
3. Drop an **effervescent tablet** into a **beaker of water.** Record your observations.
4. Identify whether each change is a physical change or a chemical change. Explain your answers.

Reversing Changes

Can physical and chemical changes be reversed? Many physical changes are easily reversed. They do not change the composition of a substance. For example, if an ice cube melts, you could freeze the liquid water to make another ice cube. But composition does change in a chemical change. So, most chemical changes are not easily reversed. Look at **Figure 6.** The chemical changes that happen when a firework explodes would be almost impossible to reverse, even if you collected all of the materials made in the chemical changes.

Figure 6 *This display of fireworks represents many chemical changes happening at the same time.*

SECTION Review

Summary

- Chemical properties describe a substance based on its ability to change into a new substance that has different properties.
- Chemical properties can be observed only when a chemical change might happen.
- Examples of chemical properties are flammability and reactivity.
- New substances form as a result of a chemical change.
- Unlike a chemical change, a physical change does not alter the identity of a substance.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *chemical property* and *chemical change*.

Understanding Key Ideas

2. Rusting is an example of a

a. physical property.
b. physical change.
c. chemical property.
d. chemical change.

3. Which of the following is a characteristic property that can be used to identify substances?

a. density
b. chemical reactivity
c. solubility in water
d. All of the above

4. Write two examples of chemical properties and explain what they are.

5. The Statue of Liberty was originally a copper color. After being exposed to the air, she turned a greenish color. What kind of change happened? Explain your answer.

6. Explain how to tell the difference between a physical and a chemical property.

Critical Thinking

7. Making Comparisons Compare physical and chemical changes in terms of what happens to the matter involved in each.

8. Applying Concepts Identify two physical properties and two chemical properties of a bag of microwave popcorn before popping and after.

Interpreting Graphics

9. Describe a sign related to the chemical change happening within the system shown below.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Chemical Changes
SciLinks code: HSM0266

SECTION 4

Using the Properties of Matter

READING WARM-UP

Objectives

- Describe the use of materials in technological design based on density or magnetism.
- Describe the use of materials in technological design based on electrical conductivity or malleability.
- Describe the use of materials in technological design based on solubility.

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

You can describe substances by the physical and chemical properties they have. You can even use those properties to distinguish one substance from another. But one of the most important uses of the properties of matter is in selecting materials for technological design.

Density

Think of a child holding the string of a helium-filled balloon. Believe it or not, this is an example of how properties are used in technological design. Because helium's density is lower than the density of air, the balloon floats. Helium's density is a property that makes helium useful in blimps and in weather balloons.

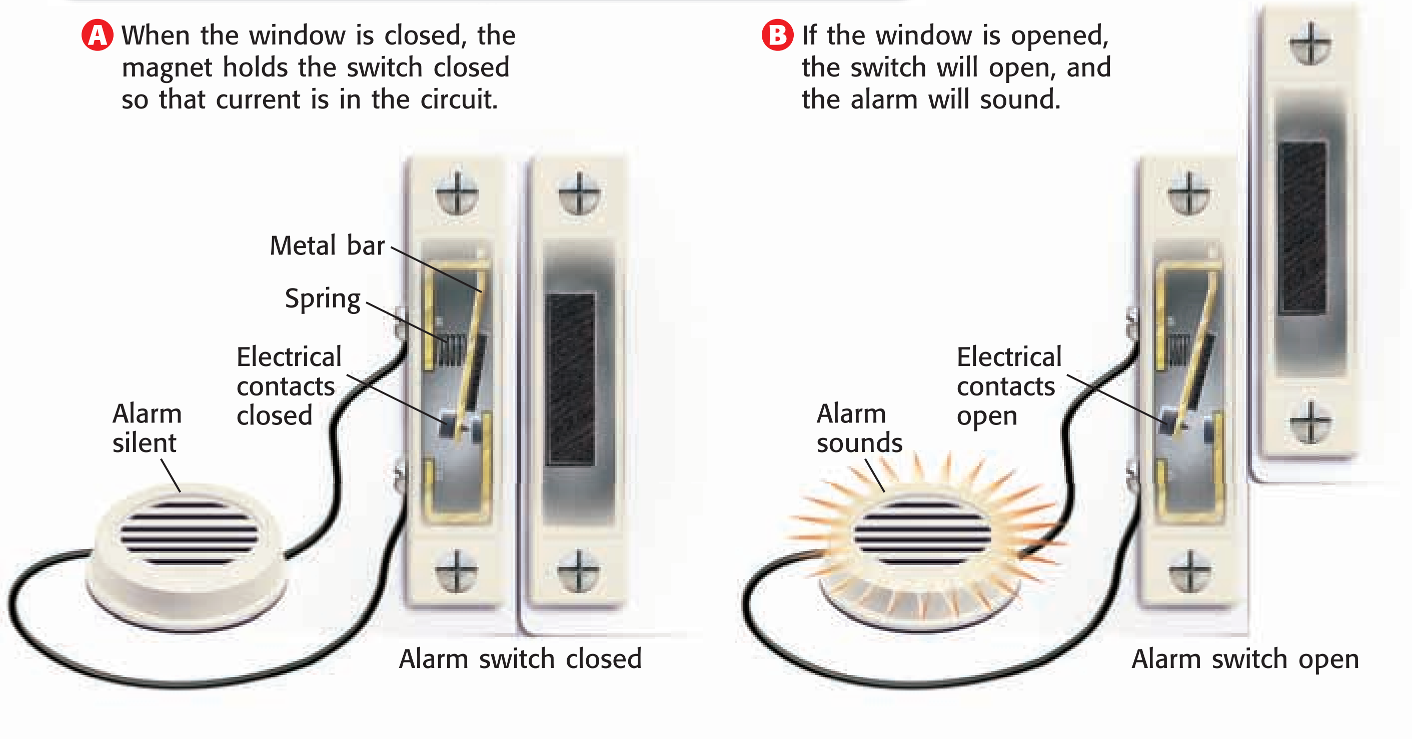
Density and Fishing

If you have ever gone fishing, you probably made use of the densities of materials. To get the hook as deep as the fish are, you would use a lead sinker. The density of lead helps drag the hook and line underwater. To avoid the problem of the hook sinking all the way to the bottom and snagging on something, you could attach a float, such as the one in **Figure 1.**

The float has a density that is less than the density of water, so it will float at the water's surface. If a fish grabs the hook, the float is pulled under water. When you see the float dip into the water, you know that it is time to hold tightly to the fishing rod! The combination of the high density of lead and the low density of the float allows you to design a system that gives you a better chance of catching your dinner!

Figure 1 *The colorful float is less dense than water. It is used to keep the hook from sinking all the way to the bottom and snagging.*

Figure 2 **Using Magnetism in an Alarm**



Magnetism

You may think of magnets as devices used to attach papers or photos to a refrigerator door. But magnets are involved in many different devices. The property of magnetism is very important in technological design. For example, some hand tools, such as hammers and screwdrivers, are made from materials that have been magnetized. These tools can be a big help in tight spaces because they attract and hold onto the nail or screw while you work with it.

Magnetism and Alarms

The magnetic properties of materials are also very important in some alarm systems. The alarm shown in **Figure 2** uses the simple magnetic attraction between a piece of iron and a magnet to alert homeowners that a window or door has been opened. When the window is closed, the iron switch is attracted to the magnet. The switch completes an electric circuit, and electric charges flow through the system. When the window slides open, as shown in **Figure 2,** the magnet is no longer near enough to the iron to attract it strongly. The spring pulls the switch open, and the circuit is broken. When this happens, the alarm sounds.

Reading Check **Describe one way in which magnetism is used in a technological design.** (*See the Appendix for answers to Reading Checks.*)

Electrical Conductivity

Another property that is important in technological design is electrical conductivity. This property describes how well charges move through a material. Metals tend to have high electrical conductivities. So, metals are used when you want charges to move. If you do not want charges to move, you can use a material that has a low electrical conductivity, such as rubber or plastic. An electrical cord is made up of metal wires covered in rubber or plastic. Charges can move in the wires but charges cannot move through the rubber or plastic.

Conductivity and Coins

On January 27, 2000, the first Golden Dollars, like the one shown in **Figure 3,** were put into circulation. A law passed in 1997 called for a new dollar coin to be minted. The new coin was replacing a dollar coin that was minted in 1979 and 1980. The new coin had to be gold in color, so the metals used in the old silver-colored coin could not be used. The new coin had to be the same size as the old coin. That wasn't difficult. But in addition to size, vending machines use electrical conductivity to recognize coins. So, the new coin had to have the same conductivity as the previous coin. Otherwise, the machines would need to be adjusted to accept the new coins.

Just three months before minting of the coins was scheduled to begin, a mixture, or alloy, of copper, zinc, manganese, and nickel was developed that worked. Coins made by sandwiching a copper core between two layers of this alloy had the proper electrical conductivity. A new coin was born!

CONNECTION TO Social Studies

WRITING SKILL **Edison and the Light Bulb**

Thomas Alva Edison invented or made improvements to many devices. He conducted many experiments using different materials to find a material that had the right electrical conductivity to use in an incandescent light bulb. Research Edison's work on the light bulb. Make a poster that shows some of the materials Edison used in his research and which material finally worked.

Figure 3 *The technological design of the Golden Dollar had to overcome many problems. The biggest problem was finding a material that had the right electrical conductivity so that vending machines would recognize the coin as a dollar!*

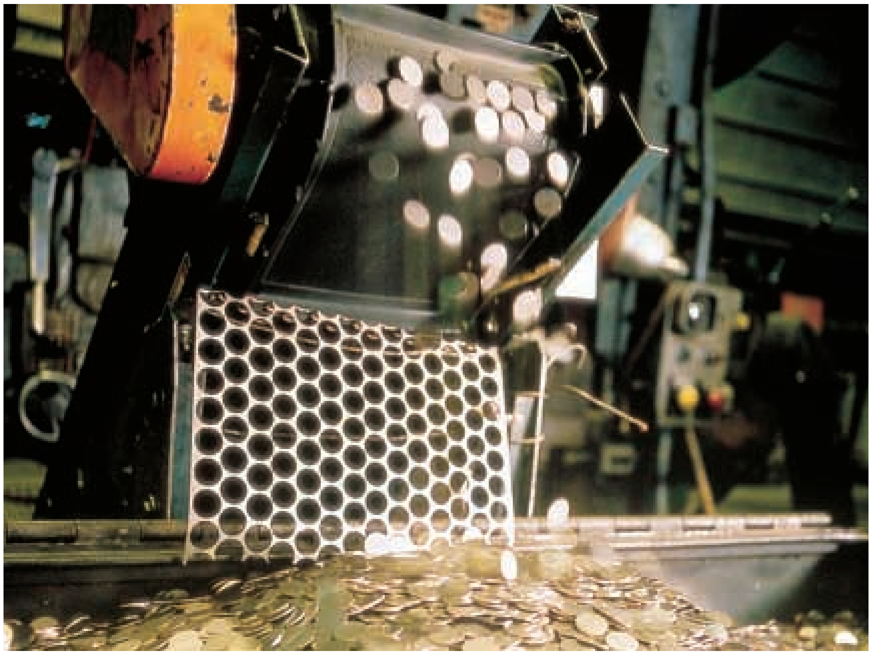


Figure 4 *These metal blanks will be made into coins. The metal must be malleable so that it can be squeezed to the correct thickness for the coins.*

Malleability

A material commonly used to demonstrate the property of malleability is aluminum. Aluminum is a material which is rolled out to make cans and foil. Aluminum foil is even available in various thicknesses. Another example of the use of malleability is in making coins.

Each coin must be the same thickness as all other coins of that type. To make the thickness uniform, the metal is squeezed between rollers and cut into blanks, like those shown in **Figure 4.** The materials chosen to be made into coins must have the proper malleability so that they can be squeezed without breaking.

Reading Check **Is wood a suitable material for use in a design that requires a material to be flattened into sheets? Explain your reasoning.**

Quick Lab

Identifying Change

1. Get a **set of coins** from your teacher. Make a table to organize your observations of each coin in your set.
2. Examine each coin. Record your observations in your table.
3. Use a **balance** to determine the mass of each coin. Record the mass in your table.
4. What characteristics allow you to identify each coin?
5. Using only your sense of touch, try to identify each coin. Was identifying the coins difficult? Explain your answer.
6. Why is it important that coins are recognizable by touch as well as by sight?

Solubility

It is safe to say that you wouldn't want your coins to dissolve if they were to get wet. But are there times when you do want a material that can dissolve in water? As they develop new materials that have unique properties, scientists are finding creative ways to use solubility in technological design.

Starch-Based Packing Material

Imagine that the package shown in **Figure 5** was delivered to your home. After you take out the radio, what do you do with the box and the packing peanuts? You could reuse or recycle the cardboard box. But would you think to get rid of the packing peanuts by washing them down the drain?

For years, packing peanuts were made of a plastic foam. These peanuts would often be thrown into the trash and end up in landfills. Because the plastic did not break down, the peanuts would remain in the landfill for many years. An interesting problem in technological design was to develop a packing material that would break down easily and would not be harmful to the environment.

Figure 5 *The radio is protected by starch-based peanuts. In just a few minutes, these peanuts dissolve in a bowl of water. The plastic-foam peanuts do not.*

Benefits of Starch-Based Packing Material

Packing peanuts that are made from starch dissolve quickly in water, as shown in **Figure 5.** They do not need to be thrown away. They can even be composted. Because they break down quickly into natural materials, they do not fill up landfills. And they are made from plant material, such as corn, which is a renewable resource. The chemicals used to make plastic-foam peanuts are made from petroleum, which is a nonrenewable resource.

Reading Check **Why is solubility an important property in the design of packing peanuts?**

Water-Soluble Films

The strips shown in **Figure 6** are designed to kill germs and freshen breath as they dissolve. The film that is used must dissolve quickly to release the ingredients contained in the film. Films dissolve at different rates depending on their chemical makeup and thickness, on the water temperature, and on the volume of water. In industry, water-soluble films are used to package fertilizer, cleaners, and even foodstuffs. The films protect people from coming into contact with the material. The films also protect the environment by not leaving behind packaging waste that might have chemicals on it.

Figure 6 *This strip, a water-soluble film, is designed to dissolve quickly on your tongue to give your breath a burst of freshness!*

SECTION Review

Summary

- Properties of materials make them suitable for use in different technological designs.
- Designs that need things to float or sink might be based on density.
- Designs that need to hold things together might be based on magnetism.
- Designs of coins might be based on electrical conductivity and malleability.
- Designs that need things to dissolve or not to dissolve might be based on solubility.

Understanding Key Ideas

1. Flattening metal to make coins demonstrates which property?
   - a. electrical conductivity
   - b. density
   - c. solubility
   - d. malleability
2. Which property would be important to consider if you were designing a hot-air balloon?
   - a. density
   - b. electrical conductivity
   - c. malleability
   - d. magnetism
3. Describe how magnetism can be used in the design of earrings that look as though they are made for pierced ears.
4. Many data-storage devices, such as computer hard drives, record information magnetically. Explain why materials that are strongly magnetized would not be suitable in the construction of the hard drive's case.
5. Why is the metal copper a better choice than plastic for use in a lightning rod?

Critical Thinking

6. **Applying Concepts** A company wants to develop a new product that contains laundry detergent and softener in a single packet. The detergent should be released within the first 2 min of the wash cycle, and the softener should be released 5 min later. Describe the suitability of films for use in this design based on solubility.
7. **Applying Concepts** Describe the suitability of concrete in terms of its density and solubility for use in making a boat.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Properties of Metals

SciLinks code: HSM1231

Skills Practice Lab

White Before Your Eyes

OBJECTIVES

Describe the physical properties of four substances.

Identify physical and chemical changes.

Classify four substances by their chemical properties.

MATERIALS

- baking powder
- baking soda
- carton, egg, plastic-foam
- cornstarch
- eyedroppers (3)
- iodine solution
- spatulas (4)
- stirring rod
- sugar
- vinegar
- water

SAFETY

You have learned how to describe matter based on its physical and chemical properties. You have also learned some signs that can help you determine whether a change in matter is a physical change or a chemical change. In this lab, you'll use what you have learned to describe four substances based on their properties and the changes that they undergo.

Procedure

1. Copy Table 1 and Table 2 shown on the next page. Be sure to leave plenty of room in each box to write down your observations.
2. Using a spatula, place a small amount of baking powder into three cups of your egg carton. Use just enough baking powder to cover the bottom of each cup. Record your observations about the baking powder's appearance, such as color and texture, in the "Unmixed" column of Table 1.

3. Use an eyedropper to add 60 drops of water to the baking powder in the first cup. Stir with the stirring rod. Record your observations in Table 1 in the column labeled "Mixed with water." Clean your stirring rod.

4. Use a clean dropper to add 20 drops of vinegar to the second cup of baking powder. Stir. Record your observations in Table 1 in the column labeled "Mixed with vinegar." Clean your stirring rod.

5. Use a clean dropper to add five drops of iodine solution to the third cup of baking powder. Stir. Record your observations in Table 1 in the column labeled "Mixed with iodine solution." Clean your stirring rod. **Caution:** Be careful when using iodine. Iodine will stain your skin and clothes.

6. Repeat steps 2–5 for each of the other substances (baking soda, cornstarch, and sugar). Use a clean spatula for each substance.

Analyze the Results

1. **Examining Data** What physical properties do all four substances share?

2. **Analyzing Data** In Table 2, write the type of change—physical or chemical—that you observed for each substance. State the property that the change demonstrates.

Draw Conclusions

3. **Evaluating Results** Classify the four substances by the chemical property of reactivity. For example, which substances are reactive with vinegar (acid)?

Table 1 Observations

Substance	Unmixed	Mixed with water	Mixed with vinegar	Mixed with iodine solution
Baking powder				
Baking soda				
Cornstarch				
Sugar				

Table 2 Changes and Properties

	Mixed with water		Mixed with vinegar		Mixed with iodine solution	
Substance	Change	Property	Change	Property	Change	Property
Baking powder						
Baking soda						
Cornstarch						
Sugar						

Chapter Review

USING KEY TERMS

1 Use each of the following terms in a separate sentence: *physical property, chemical property, physical change,* and *chemical change.*

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

2 *mass* and *weight*

3 *inertia* and *mass*

4 *volume* and *density*

UNDERSTANDING KEY IDEAS

Multiple Choice

5 Which of the following properties is NOT a chemical property?

a. reactivity with oxygen
b. malleability
c. flammability
d. reactivity with acid

6 The volume of a liquid can be expressed in all of the following units EXCEPT

a. grams.
b. liters.
c. milliliters.
d. cubic centimeters.

7 The SI unit for the mass of a substance is the

a. gram.
b. liter.
c. milliliter.
d. kilogram.

8 The best way to measure the volume of an irregularly shaped solid is to

a. use a ruler to measure the length of each side of the object.
b. weigh the solid on a balance.
c. use the water displacement method.
d. use a spring scale.

9 Which of the following statements about weight is true?

a. Weight is a measure of the gravitational force on an object.
b. Weight varies depending on where the object is located in relation to the Earth.
c. Weight is measured by using a spring scale.
d. All of the above

10 Which of the following statements does NOT describe a physical property of a piece of chalk?

a. Chalk is a solid.
b. Chalk can be broken into pieces.
c. Chalk is white.
d. Chalk will bubble in vinegar.

11 Which of the following statements about density is true?

a. Density is expressed in grams.
b. Density is mass per unit volume.
c. Density is expressed in milliliters.
d. Density is a chemical property.

Short Answer

12 In one or two sentences, explain how the process of measuring the volume of a liquid differs from the process of measuring the volume of a solid.

13. What is the formula for calculating density?

14. List three characteristic properties of matter.

Math Skills

15. What is the volume of a book that has a width of 10 cm, a length that is 2 times the width, and a height that is half the width? Remember to express your answer in cubic units.

16. A jar contains 30 mL of glycerin (whose mass is 37.8 g) and 60 mL of corn syrup (whose mass is 82.8 g). Which liquid is on top? Show your work, and explain your answer.

CRITICAL THINKING

17. **Concept Mapping** Use the following terms to create a concept map: *matter, mass, inertia, volume, milliliters, cubic centimeters, weight,* and *gravity.*

18. **Applying Concepts** You hear an advertisement for a medicine that is available in a time-release formula. What property might be important in the design of this product? As an informed consumer, under what conditions would you most likely choose this product? Explain your reasoning.

19. **Analyzing Processes** You are making breakfast for your friend Filbert. When you take the scrambled eggs to the table, he asks, "Would you please poach these eggs instead?" What scientific reason do you give Filbert for not changing his eggs?

20. **Identifying Relationships** You look out your bedroom window and see your new neighbor moving in. Your neighbor bends over to pick up a small cardboard box, but he cannot lift it. What can you conclude about the item(s) in the box? Use the terms *mass* and *inertia* to explain how you came to your conclusion.

21. **Analyzing Ideas** You may sometimes hear on the radio or on TV that astronauts are weightless in space. Explain why this statement is not true.

INTERPRETING GRAPHICS

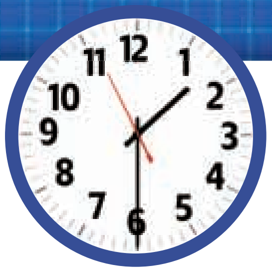
Use the photograph below to answer the questions that follow.

22. Why is aluminum suitable for use in the technological design of this can?

23. When this can was crushed, did it undergo a physical change or a chemical change?

24. How does the density of the metal in the crushed can compare with the density of the metal before the can was crushed?

25. Can you tell what the chemical properties of the can are by looking at the picture? Explain your answer.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Astronomers were studying the motions of galaxies in space when they noticed something odd. They thought that the large gravitational force, which causes the galaxies to rotate rapidly, was due to a large amount of mass in the galaxies. Then, they discovered that the mass of the galaxies was not great enough to explain this large gravitational force. So, what was causing the additional gravitational force? One theory is that the universe contains matter that we cannot see with our eyes or our telescopes. Astronomers call this invisible matter <u>dark matter</u>.

1. According to this passage, what did astronomers originally think caused the rotation of the galaxies?

A a lack of inertia
B a large gravitational force
C a small amount of mass in the galaxies
D a small gravitational force

2. Why do you think astronomers use the term *dark matter*?

F Dark matter refers to dark objects.
G Dark matter refers to matter that we can't see.
H You need a telescope to see dark matter.
I All large objects are dark.

3. Which statement is the best summary of the passage?

A The enormous amount of mass in the galaxies explains why the galaxies rotate.
B Dark matter may be responsible for the gravitational force that causes the rotation of galaxies.
C Invisible matter is called dark matter.
D Galaxies rotate as they move through the universe.

Passage 2 Blimps and dirigibles are types of airships. An airship consists of an engine, a large balloon that contains gas, and a gondola that carries passengers and crew. Airships float in air because the gases that the airships contain are less dense than air. In the early 1900s, airships were commonly used for travel, including transatlantic flights. Airships were less frequently used after the 1937 explosion and crash of the *Hindenburg* in New Jersey. The *Hindenburg* was filled with <u>flammable</u> hydrogen gas instead of helium gas, which is nonflammable.

1. In this passage, what does *flammable* mean?

A able to burn
B able to float
C able to sink
D not able to burn

2. Which of the following statements is true according to the passage?

F Hydrogen gas is nonflammable.
G Airships float because they contain gases that are less dense than air.
H Helium gas was used in the *Hindenburg*.
I The gondola contains gas.

3. Which of the following statements about airships is true?

A Airships are still a major mode of transportation.
B Airships now contain nonflammable, hydrogen gas.
C Airships consist of an engine, a gondola, and a large balloon.
D Airships traveled only in the United States.

INTERPRETING GRAPHICS

The table below shows the properties of different substances. Use the table below to answer the questions that follow.

Properties of Some Substances*		
Substance	**State**	**Density (g/cm^3)**
Helium	Gas	0.0001663
Pyrite	Solid	5.02
Mercury	Liquid	13.55
Gold	Solid	19.32

* at room temperature and pressure

1. What could you use to tell pyrite (fool's gold) and gold apart?

A volume
B density
C mass
D state

2. What do you think would happen if you placed a nugget of pyrite into a beaker of mercury?

F The pyrite would sink.
G The pyrite would dissolve.
H The mercury and the pyrite would react.
I The pyrite would float.

3. If a nugget of pyrite and a nugget of gold each have a mass of 50 g, what can you conclude about the volume of each nugget?

A The volume of pyrite is greater than the volume of gold.
B The volume of pyrite is less than the volume of gold.
C The volumes of the substances are equal.
D There is not enough information to determine the answer.

4. Which substance has the **lowest** density?

F helium
G pyrite
H mercury
I gold

MATH

Read each question below, and choose the best answer.

1. Imagine that you have discovered a new element, and you want to find its density. It has a mass of 78.8 g and a volume of 8 cm^3. To find the density of the element, you must divide the element's mass by its volume. What is the density of the element?

A 0.102 g/cm^3
B 0.98 g/cm^3
C 9.85 g/cm^3
D 630.4 g/cm^3

2. Many soft drinks come in bottles that contain about 590 mL. If the density of a soft drink is 1.05 g/mL, what is the mass of the drink?

F 0.0018 g
G 498.2 g
H 561.9 g
I 619.5 g

3. If you have 150 g of pure gold and the density of gold is 19.32 g/cm^3, what is the volume of your gold nugget?

A 2,898 cm^3
B 7.76 cm^3
C 0.98 cm^3
D 0.13 cm^3

4. Three objects have a mass of 16 g each. But their volumes differ. Object A, a liquid, has a volume of 1.2 mL. Object B, a solid, has a volume of 3.2 cm^3. Object C, another solid, has a volume of 1.9 cm^3. Which object is the least dense?

F object A
G object B
H object C
I There is not enough information to determine the answer.

Science in Action

Scientific Debate

Paper or Plastic?
Which do you choose at the grocery store, paper or plastic bags? Plastic bags are waterproof and take up less space. You can use them to line waste cans and to pack lunches. Some places will recycle plastic bags. But making 1 ton of plastic bags uses 11 barrels of oil, which can't be replaced, and produces polluting chemicals. On the other hand, making 1 ton of paper bags destroys 13 to 17 trees, which take years to replace. Paper bags, too, can be used for lining waste cans and packing lunches. Recycling paper pollutes less than recycling plastic does. What is the answer? Maybe we should reuse both!

Language Arts ACTIVITY

WRITING SKILL Evaluate the risks and benefits and the constraints of the technological design of each kind of bag. Write a one-page essay defending your position on this subject.

Science, Technology, and Society

Building a Better Body
If you break a bone, you will probably wear a cast while the bone heals. But if a bone is too damaged to heal, doctors can use technology—a false bone made from titanium—to replace it. Titanium appears to be a great bone-replacement material. It is a lightweight but strong metal. It attaches to existing bone and resists chemical changes. But, friction can wear away titanium bones. Research has found that implanting a form of nitrogen on the titanium makes the metal last longer.

Social Studies ACTIVITY

Use information systems to locate resources to identify scientific needs, human needs, and problems that are subject to the technological solution of bone-replacement therapy. Make a timeline of events leading up to current technology.

Careers

Mimi So

Gemologist and Jewelry Designer A typical day for gemologist and jewelry designer Mimi So involves deciding what materials to work with. When she chooses a gemstone for a piece of jewelry, she must consider the size, hardness, color, grade, and cut of the stone. When choosing a metal to use as a setting for a stone, she must look at the hardness, melting point, color, and malleability of the metal. She needs to choose a metal that not only looks good with a particular stone but also has physical properties that will work with that stone. For example, Mimi So says emeralds are soft and fragile. A platinum setting would be too hard and could damage the emerald. So, emeralds are usually set in a softer metal, such as 18-karat gold.

The chemical properties of stones must also be considered. Heating can burn or discolor some gemstones. Mimi So says, "If you are using pearls in a design that requires heating the metal, the pearl is not a stone, so you cannot heat the pearl, because it would destroy the pearl."

Math Activity

Pure gold is 24-karat (24K). Gold that contains 18 parts gold and 6 parts other metals is 18-karat gold. The percentage of gold in 18K gold is found by dividing the amount of gold by the total amount of the material and then multiplying by 100%. For example, (18 parts gold)/(24 parts total) equals $0.75 \times 100\% = 75\%$ gold. Find the percentage of gold in 10K and 14K gold.

go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HP5MATF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS02.

6

States of Matter

About the PHOTO

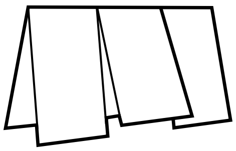
This beautiful glass creation by artist Dale Chihuly is entitled "Mille Fiori" (A Thousand Flowers). The pieces that form the sculpture were not always solid and unchanging. Each individual piece started as a blob of melted glass on the end of a hollow pipe. The artist worked with his assistants to quickly form each shape before the molten glass cooled and became a solid again.

PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "Solid," "Liquid," and "Gas." As you read the chapter, write information you learn about each category under the appropriate flap.



START-UP ACTIVITY

Vanishing Act

In this activity, you will use isopropyl alcohol (rubbing alcohol) to investigate a change of state.

Procedure

1. Pour **rubbing alcohol** into a **small plastic cup** until the alcohol just covers the bottom of the cup.
2. Moisten the tip of a **cotton swab** by dipping it into the alcohol in the cup.
3. Rub the cotton swab on the palm of your hand. Make sure there are no cuts or abrasions on your hands.
4. Record your observations.
5. Wash your hands thoroughly.

Analysis

1. Explain what happened to the alcohol after you rubbed the swab on your hand.
2. Did you feel a sensation of hot or cold? If so, how do you explain what you observed?
3. Record your answers.

SECTION 1

Three States of Matter

You've just walked home on one of the coldest days of the year. A fire is blazing in the fireplace. And there is a pot of water on the stove to make hot chocolate.

READING WARM-UP

Objectives

- Describe the properties shared by particles of all matter.
- Describe three states of matter.
- Explain the differences between the states of matter.

Terms to Learn

states of matter
solid
liquid
surface tension
viscosity
gas

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

The water begins to bubble. Steam rises from the pot. You make your hot chocolate, but it is too hot to drink. You don't want to wait for it to cool down. So, you add an ice cube. You watch the ice melt in the hot liquid until the drink is at just the right temperature. Then, you enjoy your hot drink while warming yourself by the fire.

The scene described above has examples of the three most familiar states of matter: solid, liquid, and gas. The **states of matter** are the physical forms in which a substance can exist. For example, water commonly exists in three states of matter: solid (ice), liquid (water), and gas (steam).

Particles of Matter

Matter is made up of tiny particles called *atoms* and *molecules* (MAHL i kyoolz). These particles are too small to see without a very powerful microscope. Atoms and molecules are always in motion and are always bumping into one another. The particles interact with each other, and the way they interact with each other helps determine the state of the matter. **Figure 1** describes three states of matter—solid, liquid, and gas—in terms of the speed and attraction of the particles.

Figure 1 **Models of a Solid, a Liquid, and a Gas**

Particles of a solid do not move fast enough to overcome the strong attraction between them. So, they are close together and vibrate in place.

Particles of a liquid move fast enough to overcome some of the attraction between them. The particles are close together but can slide past one another.

Particles of a gas move fast enough to overcome almost all of the attraction between them. The particles are far apart and move independently of one another.

Solids

Imagine dropping a marble into a bottle. Would anything happen to the shape or size of the marble? Would the shape or size of the marble change if you put it in a larger bottle?

states of matter the physical forms of matter, which include solid, liquid, and gas

solid the state of matter in which the volume and shape of a substance are fixed

Solids Have Definite Shape and Volume

Even in a bottle, a marble keeps its original shape and volume. The marble's shape and volume stay the same no matter what size bottle you drop it into because the marble is a solid. A **solid** is the state of matter that has a definite shape and volume.

The particles of a substance in a solid state are very close together. The attraction between them is stronger than the attraction between the particles of the same substance in the liquid or gaseous state. The particles in a solid move, but they do not move fast enough to overcome the attraction between them. Each particle vibrates in place. Therefore, each particle is locked in place by the particles around it.

CONNECTION TO Physics

Is Glass a Liquid? At one time, there was a theory that glass was a liquid. This theory came about because of the observation that ancient windowpanes were often thicker at the bottom than at the top. People thought that the glass had flowed to the bottom of the pane, so glass must be a liquid. Research this theory. Present your research to your class in an oral presentation.

ACTIVITY

There Are Two Kinds of Solids

There are two kinds of solids—*crystalline* (KRIS tuhl in) and *amorphous* (uh MAWR fuhs). Crystalline solids have a very orderly, three-dimensional arrangement of particles. The particles of crystalline solids are in a repeating pattern of rows. Iron, diamond, and ice are examples of crystalline solids.

Amorphous solids are made of particles that do not have a special arrangement. So, each particle is in one place, but the particles are not arranged in a pattern. Examples of amorphous solids are glass, rubber, and wax. **Figure 2** shows a photo of quartz (a crystalline solid) and glass (an amorphous solid).

Reading Check **How are the particles in a crystalline solid arranged?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 **Crystalline and Amorphous Solids**

The particles of crystalline solids, such as this quartz crystal, have an orderly three-dimensional pattern.

Glass, an amorphous solid, is made of particles that are not arranged in any particular pattern.

Figure 3 *Although their shapes are different, the beaker and the graduated cylinder each contain 350 mL of juice.*

liquid the state of matter that has a definite volume but not a definite shape

surface tension the force that acts on the surface of a liquid and that tends to minimize the area of the surface

viscosity the resistance of a gas or liquid to flow

gas a form of matter that does not have a definite volume or shape

Liquids

What do you think would change about orange juice if you poured the juice from a can into a glass? Would the volume of juice be different? Would the taste of the juice change?

Liquids Change Shape but Not Volume

The only thing that would change when the juice is poured into the glass is the shape of the juice. The shape changes because juice is a liquid. **Liquid** is the state of matter that has a definite volume but takes the shape of its container. The particles in liquids move fast enough to overcome some of the attractions between them. The particles slide past each other until the liquid takes the shape of its container.

Although liquids change shape, they do not easily change volume. A can of juice contains a certain volume of liquid. That volume stays the same if you pour the juice into a large container or a small one. **Figure 3** shows the same volume of liquid in two different containers.

Figure 4 *Water forms spherical drops as a result of surface tension.*

Liquids Have Unique Characteristics

A special property of liquids is surface tension. **Surface tension** is a force that acts on the particles at the surface of a liquid. Surface tension causes some liquids to form spherical drops, like the beads of water shown in **Figure 4.** Different liquids have different surface tensions. For example, gasoline has a very low surface tension and forms flat drops.

Another important property of liquids is viscosity. **Viscosity** is a liquid's resistance to flow. Usually, the stronger the attractions between the molecules of a liquid, the more viscous the liquid is. For example, honey flows more slowly than water. So, honey has a higher viscosity than water.

Reading Check **What is viscosity?**

Gases

Would you believe that one small tank of helium can fill almost 700 balloons? How is this possible? After all, the volume of a tank is equal to the volume of only about five filled balloons. The answer has to do with helium's state of matter.

Gases Change in Both Shape and Volume

Helium is a gas. **Gas** is the state of matter that has no definite shape or volume. The particles of a gas move quickly. So, they can break away completely from one another. The particles of a gas have less attraction between them than do particles of the same substance in the solid or liquid state.

The amount of empty space between gas particles can change. Look at **Figure 5.** The particles of helium in the balloons are farther apart than the particles of helium in the tank. The particles spread out as helium fills the balloon. So, the amount of empty space among the gas particles increases.

Figure 5 *Many balloons can be filled from one tank of helium because the particles of helium gas in a balloon are far apart.*

SECTION Review

Summary

- The three most familiar states of matter are solid, liquid, and gas.
- All matter is made of tiny particles called atoms and molecules that attract each other and move constantly.
- A solid has a definite shape and volume.
- A liquid has a definite volume but not a definite shape.
- A gas does not have a definite shape or volume.

Using Key Terms

1. Use each of the following terms in a separate sentence: *viscosity* and *surface tension.*

Understanding Key Ideas

2. One property that all particles of matter have in common is they
   a. never move in solids.
   b. only move in gases.
   c. move constantly.
   d. None of the above
3. Describe solids, liquids, and gases in terms of shape and volume.

Critical Thinking

4. **Applying Concepts** Classify each substance according to its state of matter: apple juice, bread, a textbook, and steam.
5. **Identifying Relationships** The volume of a gas can change, but the volume of a solid cannot. Explain why this is true.

Interpreting Graphics

Use the image below to answer the questions that follow.

6. Identify the state of matter shown in the jar.
7. Discuss how the particles in the jar are attracted to each other.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Solids, Liquids, and Gases
SciLinks code: HSM1420

SECTION 2

Matter and Temperature

You probably put on a sweater or a jacket when it's cold. Likewise, you probably wear shorts in the summer when it gets hot. But how hot is hot, and how cold is cold?

READING WARM-UP

Objectives

- Describe how temperature relates to kinetic energy.
- Compare temperatures on different temperature scales.

Terms to Learn

temperature
thermal expansion
absolute zero

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Think about the knobs on a water faucet: they are labeled "H" for hot and "C" for cold. But does only hot water come out when the hot-water knob is on? You may have noticed that when you first turn on the hot water, the water is warm or even cool. Is the label on the knob wrong? The terms *hot* and *cold* are not scientific terms. If you really want to specify how hot or cold something is, you must use temperature.

What Is Temperature?

You probably think of temperature as a measure of how hot or cold something is. But using the terms *hot* and *cold* can be confusing. Using the word *temperature* avoids confusion. Scientifically, **temperature** is a measure of the average kinetic energy of the particles in an object. *Kinetic energy* is the energy of motion. All moving objects have kinetic energy. The amount of kinetic energy that an object has depends on the object's mass and speed. The greater the mass or speed of an object, the greater the object's kinetic energy is.

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

Temperature and Kinetic Energy

All matter is made of atoms or molecules that are always moving, even if it doesn't look like they are. Because the particles are in motion, they have kinetic energy. The faster the particles are moving, the more kinetic energy they have. Look at **Figure 1.** The more kinetic energy that the particles of an object have, the higher the temperature of the object is.

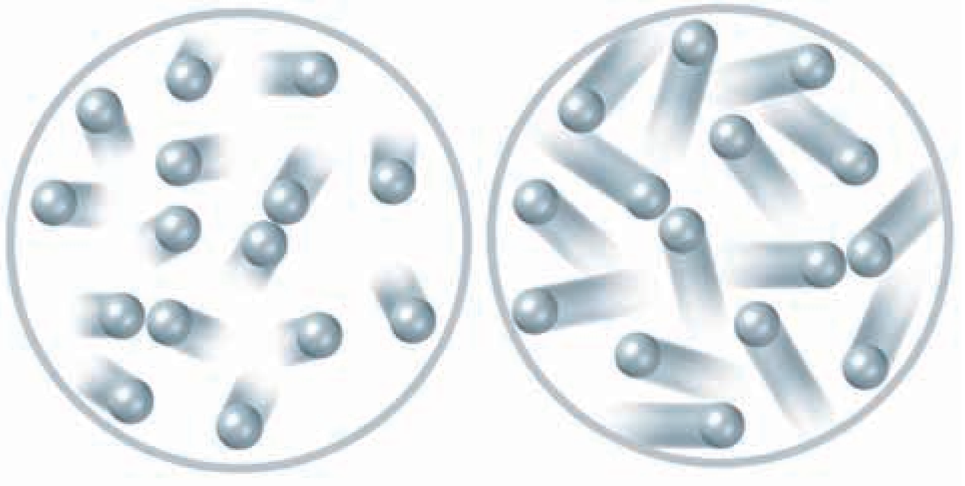


Figure 1 *The gas particles on the right have a higher average kinetic energy than those on the left. So, the gas on the right is at a higher temperature.*

Quick Lab

Hot or Cold?

1. Put both your hands into a **bucket of warm water,** and note how the water feels.
2. Now, put one hand into a **bucket of cold water** and the other into a **bucket of hot water.**
3. After a minute, take your hands out of the hot and cold water and put them back in the warm water. Note how the water feels to each hand.
4. Can you rely on your hands to determine temperature? Explain your observations.

Internet Activity

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5STAW.**

Average Kinetic Energy of Particles

Particles of matter are always moving. But they move in different directions and at different speeds. The motion of particles is random. Because particles are moving at different speeds, individual particles have different amounts of kinetic energy. But the *average* kinetic energy of all of the particles in an object can be measured. When you measure an object's temperature, you measure the average kinetic energy of all of the particles in the object.

A substance's temperature depends on the average kinetic energy of all of its particles. Its temperature does not depend on how much of the substance you have. Look at **Figure 2.** A pot of tea and a cup of tea each have a different amount of tea. But their atoms have the same average kinetic energy. So, the pot of tea and the cup of tea are at the same temperature.

Reading Check **How is temperature related to kinetic energy?** (*See the Appendix for answers to Reading Checks.*)

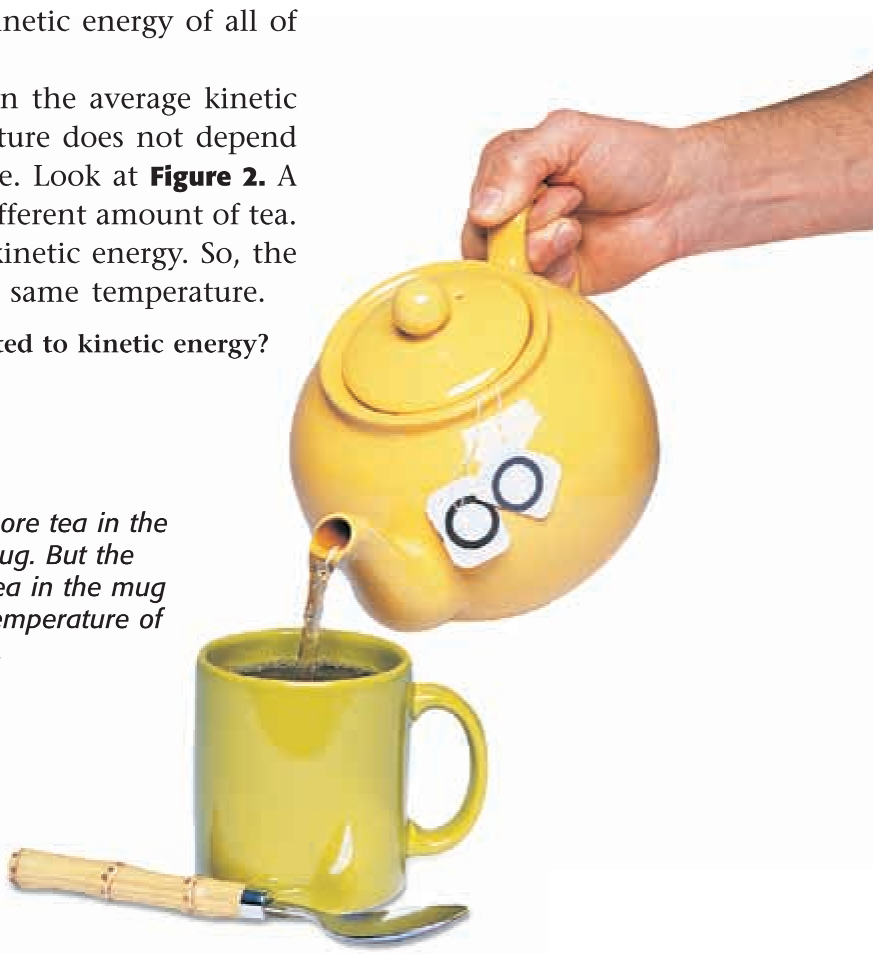


Figure 2 *There is more tea in the teapot than in the mug. But the temperature of the tea in the mug is the same as the temperature of the tea in the teapot.*

Measuring Temperature

How would you measure the temperature of a steaming cup of hot chocolate? Would you take a sip of it or stick your finger in it? You probably would not. You would use a thermometer.

Using a Thermometer

Many thermometers are thin glass tubes filled with a liquid. Mercury and alcohol are often used in thermometers because they remain in liquid form over a large temperature range.

Thermometers can measure temperature because of a property called thermal expansion. **Thermal expansion** is the increase in volume of a substance in response to an increase in temperature. As a substance's temperature increases, its particles move faster and spread out. As the space between the particles increases, the substance expands. Mercury and alcohol expand by constant amounts for a given change in temperature.

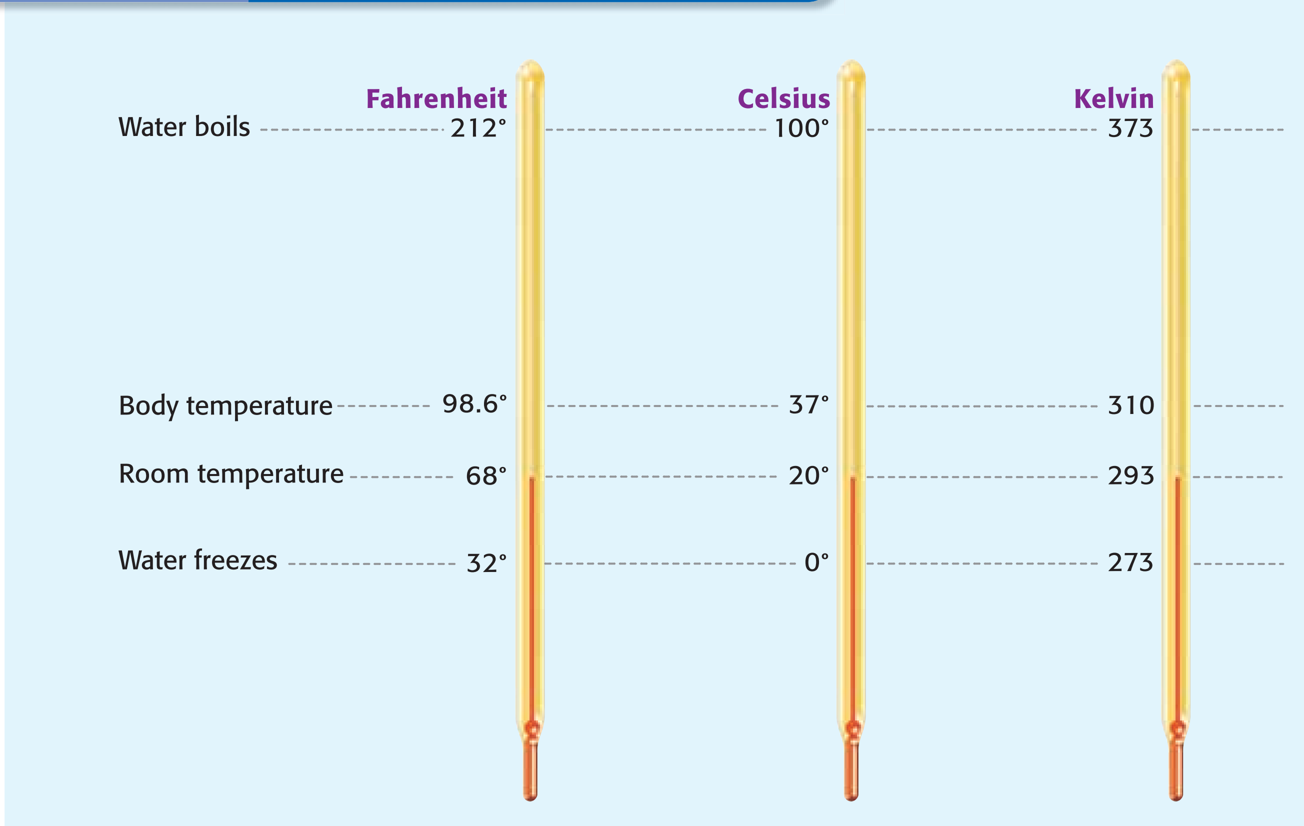
Look at the thermometers in **Figure 3.** They are at the same temperature. So, the alcohol in each thermometer has expanded the same amount. But the number for each thermometer is different because a different temperature scale is marked on each one.

Reading Check **What property makes thermometers work?**

thermal expansion an increase in the size of a substance in response to an increase in the temperature of the substance

absolute zero the temperature at which molecular energy is at a minimum (0 K on the Kelvin scale or −273.16°C on the Celsius scale)

Figure 3 **Three Temperature Scales**



Temperature Scales

Look at **Figure 4.** When a weather report is given, you will probably hear the temperature given in degrees Fahrenheit (°F). However, scientists and people in some other countries often use the Celsius scale. In the Celsius scale, the temperature range between the freezing point and boiling point of water is divided into 100 equal parts, called degrees Celsius (°C). A third scale, the Kelvin (or absolute) scale, is the official SI temperature scale. The Kelvin scale is divided into units called *kelvins* (K)—not *degrees kelvin*.

The lowest temperature on the Kelvin scale is 0 K, which is called **absolute zero.** Absolute zero (about –459°F) is the temperature at which all molecular motion stops. It is not possible to reach absolute zero, although temperatures very close to 0 K have been reached in laboratories.

As the thermometers on the previous page show, a given temperature is represented by different numbers on the three temperature scales. For example, the freezing point of water is 32°F, 0°C, or 273 K.

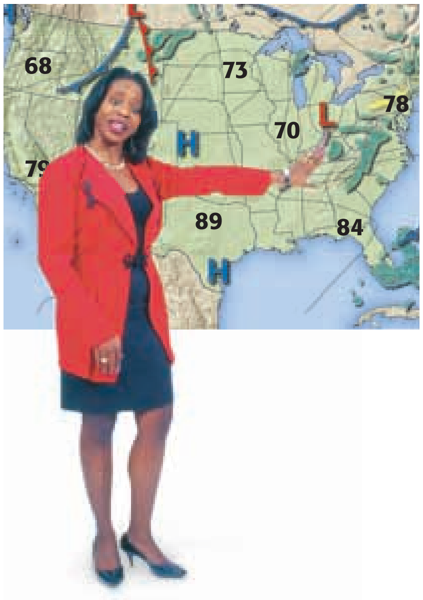


Figure 4 *Weather reports that you see on the news usually give temperatures in degrees Fahrenheit (°F).*

SECTION Review

Summary

- Temperature is a measure of the average kinetic energy of the particles of a substance.
- Three temperature scales are the Fahrenheit, Celsius, and Kelvin scales.
- Thermal expansion is the increase in volume of a substance due to an increase in temperature.
- Absolute zero (0 K, or −273°C) is the lowest possible temperature.

Using Key Terms

1. In your own words, write a definition for the term *temperature*.
2. Use each of the following terms in a separate sentence: *thermal expansion* and *absolute zero*.

Understanding Key Ideas

3. Which of the following is the coldest temperature possible?
   - **a.** 0 K
   - **b.** 0°C
   - **c.** 0°F
   - **d.** −273°F
4. How is temperature related to kinetic energy?
5. Describe the process of thermal expansion.

Math Skills

6. Use **Figure 3** to find whether a degree Fahrenheit is larger or smaller than a degree Celsius. Explain with calculations.

Critical Thinking

7. **Predicting Consequences** Why do you think heating a full pot of soup on the stove could cause the soup to overflow?
8. **Forming Hypotheses** A glass of cold water was placed on a table. The average kinetic energy in the cold water increased, while the average kinetic energy of the part of the table under the glass decreased. What do you think happened?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Temperature?
SciLinks code: HSM1664

SECTION 3

Changes of State

It can be tricky to eat a frozen juice bar outside on a hot day. In just minutes, the juice bar will start to melt. Soon the solid juice bar becomes a liquid mess.

READING WARM-UP

Objectives

- Describe how energy is involved in changes of state.
- Describe what happens during melting and freezing.
- Compare evaporation and condensation.
- Explain what happens during sublimation.
- Identify the two changes that can happen when a substance loses or gains energy.

Terms to Learn

change of state
melting
evaporation
boiling
condensation
sublimation

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the five changes of state.

As the juice bar melts, it goes through a change of state. In this section, you will learn about the four changes of state shown in **Figure 1** as well as a fifth change of state called *sublimation* (SUHB luh MAY shuhn).

Energy and Changes of State

A **change of state** is the change of a substance from one physical form to another. All changes of state are physical changes. In a physical change, the identity of a substance does not change. In **Figure 1,** the ice, liquid water, and steam are all the same substance—water.

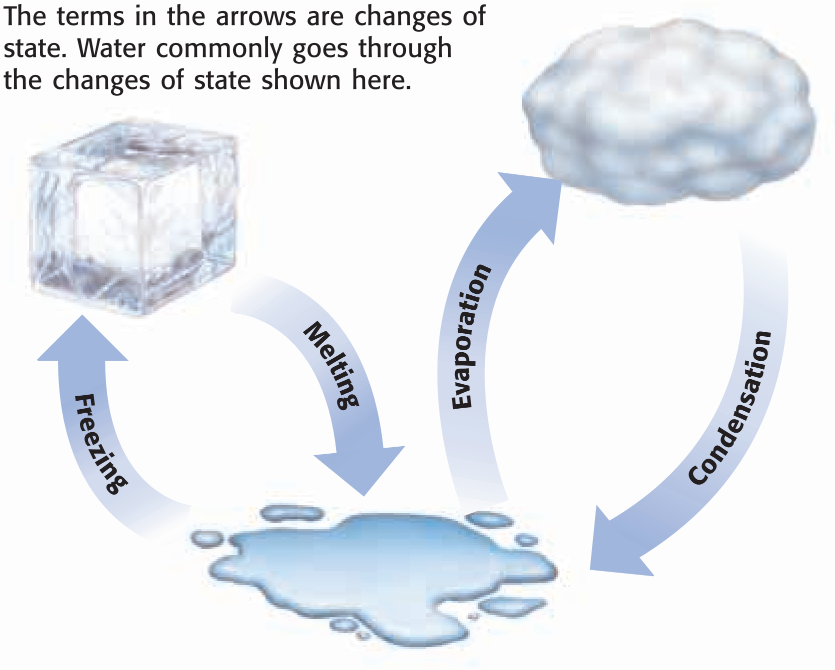
The particles of a substance move differently depending on the state of the substance. The particles also have different amounts of energy when the substance is in different states. For example, particles in liquid water have more energy than particles in ice. But particles of steam have more energy than particles in liquid water. So, to change a substance from one state to another, you must add or remove energy.

Reading Check **What is a change of state?** (*See the Appendix for answers to Reading Checks.*)

change of state the change of a substance from one physical state to another

Figure 1 Changes of State

The terms in the arrows are changes of state. Water commonly goes through the changes of state shown here.



Melting: Solid to Liquid

One change of state that happens when you add energy to a substance is melting. **Melting** is the change of state from a solid to a liquid. This change of state is what happens when ice melts. Adding energy to a solid increases the temperature of the solid. As the temperature increases, the particles of the solid move faster. When a certain temperature is reached, the solid will melt. The temperature at which a substance changes from a solid to a liquid is the *melting point* of the substance. Melting point is a physical property. Different substances have different melting points. For example, gallium melts at about 30°C. Because your normal body temperature is about 37°C, gallium will melt in your hand! This is shown in **Figure 2.** Table salt, however, has a melting point of 801°C, so it will not melt in your hand.

Figure 2 *Even though gallium is a metal, it would not be very useful as jewelry!*

Adding Energy

For a solid to melt, particles must overcome some of their attractions to each other. When a solid is at its melting point, any energy added to it is used to overcome the attractions that hold the particles in place. Melting is an *endothermic* (EN doh THUHR mik) change because energy is gained by the substance as it changes state.

melting the change of state in which a solid becomes a liquid by adding energy

Freezing: Liquid to Solid

The change of state from a liquid to a solid is called *freezing*. The temperature at which a liquid changes into a solid is the liquid's *freezing point*. Freezing is the reverse process of melting. Thus, freezing and melting occur at the same temperature, as shown in **Figure 3.**

Removing Energy

For a liquid to freeze, the attractions between the particles must overcome the motion of the particles. Imagine that a liquid is at its freezing point. Removing energy will cause the particles to begin locking into place. Freezing is an *exothermic* (EK so THUHR mik) change because energy is removed from the substance as it changes state.

Figure 3 *Liquid water freezes at the same temperature at which ice melts—0°C.*

If energy is added at 0°C, the ice will melt.

If energy is removed at 0°C, the liquid water will freeze.

Evaporation: Liquid to Gas

One way to experience evaporation is to iron a shirt using a steam iron. You will notice steam coming up from the iron as the wrinkles disappear. This steam forms when the liquid water in the iron becomes hot and changes to gas.

Boiling and Evaporation

evaporation the change of a substance from a liquid to a gas

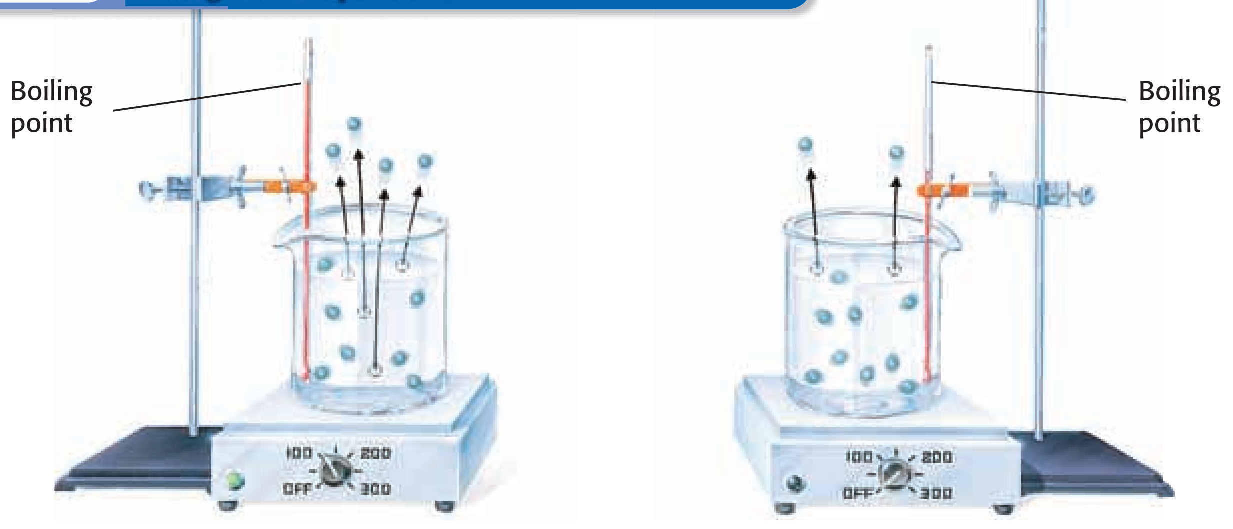
boiling the conversion of a liquid to a vapor when the vapor pressure of the liquid equals the atmospheric pressure

Evaporation (ee VAP uh RAY shuhn) is the change of a substance from a liquid to a gas. Evaporation can occur at the surface of a liquid that is below its boiling point. For example, when you sweat, your body is cooled through evaporation. Your sweat is mostly water. Water absorbs energy from your skin as the water evaporates. You feel cooler because your body transfers energy to the water. Evaporation also explains why water in a glass on a table disappears after several days.

Figure 4 explains the difference between boiling and evaporation. **Boiling** is the change of a liquid to a vapor, or gas, throughout the liquid. Boiling occurs when the pressure inside the bubbles, which is called *vapor pressure*, equals the outside pressure on the bubbles, or atmospheric pressure. The temperature at which a liquid boils is called its *boiling point*. No matter how much of a substance is present, neither the boiling point nor the melting point of a substance change. For example, 5 mL and 5 L of water both boil at 100°C.

Reading Check **What is evaporation?**

Figure 4 **Boiling and Evaporation**



Boiling occurs in a liquid at its boiling point. As energy is added to the liquid, particles throughout the liquid move faster. When they move fast enough to break away from other particles, they evaporate and become a gas.

Evaporation can also occur in a liquid below its boiling point. Some particles at the surface of the liquid move fast enough to break away from the particles around them and become a gas.

Effects of Pressure on Boiling Point

Earlier, you learned that water boils at 100°C. In fact, water boils at 100°C only at sea level, because of atmospheric pressure. Atmospheric pressure is caused by the weight of the gases that make up the atmosphere.

Atmospheric pressure varies depending on where you are in relation to sea level. Atmospheric pressure is lower at higher elevations. The higher you go above sea level, the fewer air particles there are above you. So, the atmospheric pressure is lower. Imagine boiling water at the top of a mountain. The boiling point would be lower than 100°C. For example, Denver, Colorado, is 1.6 km above sea level. In Denver, water boils at about 95°C.

CONNECTION TO Language Arts

WRITING SKILL **Cooking at High Altitudes** Many times, cake mixes and other prepared foods will have special instructions for baking and cooking at high altitudes. Even poaching an egg at a high attitude requires a different amount of cooking time. Imagine that you got a letter from a cousin in Denver. He is upset that a cake he made turned out poorly, even though he followed the recipe. Do research on cooking at high altitudes. Write a letter to your cousin explaining why he may have had problems baking the cake.

Condensation: Gas to Liquid

Look at the dragonfly in **Figure 5.** Notice the beads of water that have formed on the wings. They form because of condensation of gaseous water in the air. **Condensation** is the change of state from a gas to a liquid. Condensation and evaporation are the reverse of each other. The *condensation point* of a substance is the temperature at which the gas becomes a liquid. And the condensation point is the same temperature as the boiling point at a given pressure.

For a gas to become a liquid, large numbers of particles must clump together. Particles clump together when the attraction between them overcomes their motion. For this to happen, energy must be removed from the gas to slow the movement of the particles. Because energy is removed, condensation is an exothermic change.

condensation the change of state from a gas to a liquid

Figure 5 *Beads of water form when water vapor in the air contacts a cool surface, such as the wings of this dragonfly.*

Figure 6 *Dry ice changes directly from a solid to a gas. This change of state is called* sublimation.

Sublimation: Solid to Gas

The solid in **Figure 6** is dry ice. Dry ice is carbon dioxide in a solid state. It is called *dry ice* because instead of melting into a liquid, it goes through sublimation. **Sublimation** is the change of state in which a solid changes directly into a gas. Dry ice is much colder than ice made from water.

For a solid to change directly into a gas, the particles of the substance must move from being very tightly packed to being spread far apart. So, the attractions between the particles must be completely overcome. The substance must gain energy for the particles to overcome their attractions. Thus, sublimation is an endothermic change because energy is gained by the substance as it changes state.

sublimation the process in which a solid changes directly into a gas

Change of Temperature Vs. Change of State

When most substances lose or gain energy, one of two things happens to the substance: its temperature changes or its state changes. The temperature of a substance is related to the speed of the substance's particles. So, when the temperature of a substance changes, the speed of the particles also changes. But the temperature of a substance does not change until the change of state is complete. For example, the temperature of boiling water stays at 100°C until it has all evaporated. In **Figure 7,** you can see what happens to ice as energy is added to the ice.

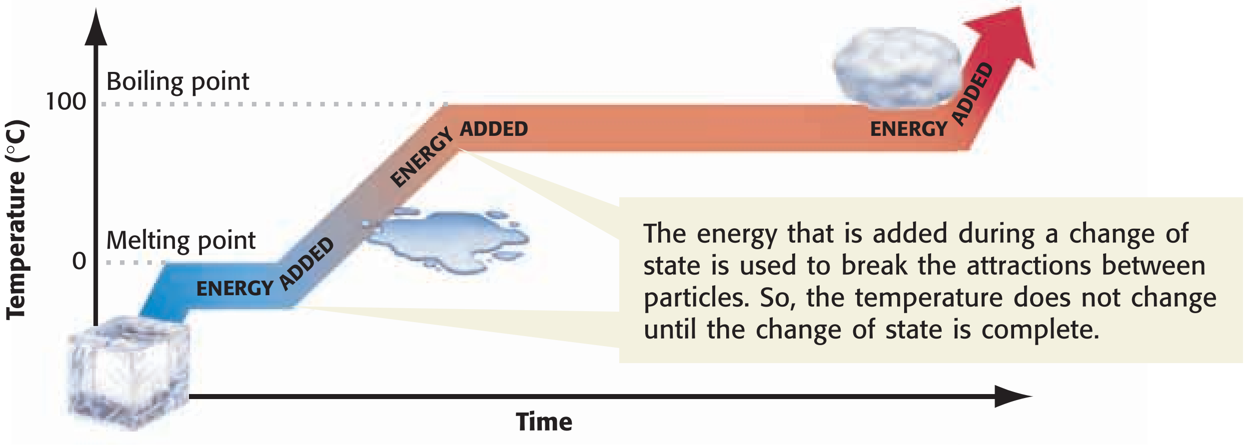
✓ *Reading Check* **What happens to the temperature of a substance as it changes state?**

Quick Lab

Boiling Water Is Cool

1. Remove the cap from a **syringe.**
2. Place the tip of the syringe in the **warm water** that is provided by your teacher. Pull the plunger out until you have 10 mL of water in the syringe.
3. Tighten the cap on the syringe.
4. Hold the syringe, and slowly pull the plunger out.
5. Observe any changes you see in the water. Record your observations.
6. Why are you not burned by the water in the syringe?

Figure 7 **Changing the State of Water**



SECTION Review

Summary

- A change of state is the conversion of a substance from one physical form to another.
- Energy is added during endothermic changes. Energy is removed during exothermic changes.
- The freezing point and the melting point of a substance are the same temperature.
- Both boiling and evaporation result in a liquid changing to a gas.
- Condensation is the change of a gas to a liquid. It is the reverse of evaporation.
- Sublimation changes a solid directly to a gas.
- The temperature of a substance does not change during a change of state.

Using Key Terms

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

1. *melting* and *freezing*
2. *condensation* and *evaporation*

Understanding Key Ideas

3. The change from a solid directly to a gas is called
   a. evaporation.
   b. boiling.
   c. melting.
   d. sublimation.
4. Describe how the motion and arrangement of particles in a substance change as the substance freezes.
5. Explain what happens to the temperature of an ice cube as it melts.
6. How are evaporation and boiling different? How are they similar?

Math Skills

7. The volume of a substance in the gaseous state is about 1,000 times the volume of the same substance in the liquid state. How much space would 18 mL of water take up if it evaporated?

Critical Thinking

8. **Evaluating Data** The temperature of water in a beaker is 25°C. After adding a piece of magnesium to the water, the temperature increases to 28°C. Is this an exothermic or endothermic reaction? Explain your answer.
9. **Applying Concepts** Solid crystals of iodine were placed in a flask. The top of the flask was covered with aluminum foil. The flask was gently heated. Soon, the flask was filled with a reddish gas. What change of state took place? Explain your answer.
10. **Predicting Consequences** Would using dry ice in your holiday punch cause it to become watery after several hours? Why or why not?

Skills Practice Lab

A Hot and Cool Lab

When you add energy to a substance through heating, does the substance's temperature always go up? When you remove energy from a substance through cooling, does the substance's temperature always go down? In this lab you'll investigate these important questions with a very common substance—water.

OBJECTIVES

Measure and record time and temperature accurately.

Graph the temperature change of water as it changes state.

Analyze and interpret graphs of changes of state.

MATERIALS

- beaker, 250 or 400 mL
- coffee can, large
- gloves, heat-resistant
- graduated cylinder, 100 mL
- graph paper
- hot plate
- ice, crushed
- rock salt
- stopwatch
- thermometer
- water
- wire-loop stirring device

SAFETY

Procedure

1. Fill the beaker about one-third to one-half full with water.
2. Put on heat-resistant gloves. Turn on the hot plate, and put the beaker on it. Put the thermometer in the beaker. **Caution:** Be careful not to touch the hot plate.
3. Make a copy of Table 1. Record the temperature of the water every 30 seconds. Continue doing this until about one-fourth of the water boils away. Note the first temperature reading at which the water is steadily boiling.

Table 1

Time (s)	30	60	90	120	150	180	210	etc.
Temperature (°C)		DO NOT WRITE IN BOOK						

4. Turn off the hot plate.
5. While the beaker is cooling, make a graph of temperature (y-axis) versus time (x-axis). Draw an arrow pointing to the first temperature at which the water was steadily boiling.

6. After you finish the graph, use heat-resistant gloves to pick up the beaker. Pour the warm water out, and rinse the warm beaker with cool water. **Caution:** Even after cooling, the beaker is still too warm to handle without gloves.

7. Put approximately 20 mL of water in the graduated cylinder.

8. Put the graduated cylinder in the coffee can, and fill in around the graduated cylinder with crushed ice. Pour rock salt on the ice around the graduated cylinder. Place the thermometer and the wire-loop stirring device in the graduated cylinder.

9. As the ice melts and mixes with the rock salt, the level of ice will decrease. Add ice and rock salt to the can as needed.

10. Make another copy of Table I. Record the temperature of the water in the graduated cylinder every 30 seconds. Stir the water with the stirring device. **Caution:** Do not stir with the thermometer.

11. Once the water begins to freeze, stop stirring. Do not try to pull the thermometer out of the solid ice in the cylinder.

12. Note the temperature when you first notice ice crystals forming in the water. Continue taking readings until the water in the graduated cylinder is completely frozen.

13. Make a graph of temperature (*y*-axis) versus time (*x*-axis). Draw an arrow to the temperature reading at which the first ice crystals form in the water in the graduated cylinder.

Analyze the Results

1. **Describing Events** What happens to the temperature of boiling water when you continue to add energy through heating?

2. **Describing Events** What happens to the temperature of freezing water when you continue to remove energy through cooling?

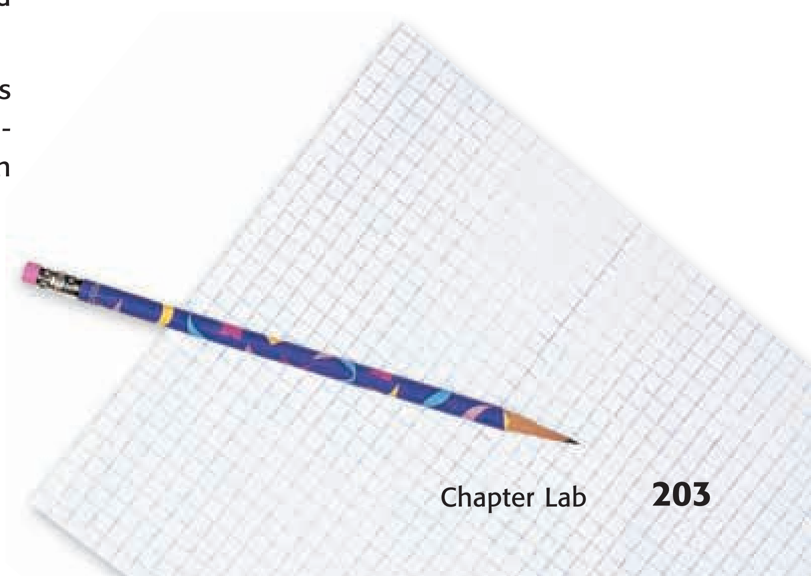
3. **Analyzing Data** What does the slope of each graph represent?

4. **Analyzing Results** How does the slope of the graph that shows water boiling compare with the slope of the graph before the water starts to boil? Why is the slope different for the two periods?

5. **Analyzing Results** How does the slope of the graph showing water freezing compare with the slope of the graph before the water starts to freeze? Why is the slope different for the two periods?

Draw Conclusions

6. **Evaluating Data** The particles that make up solids, liquids, and gases are in constant motion. Adding or removing energy causes changes in the movement of these particles. Using this idea, explain why the temperature graphs of the two experiments look the way they do.



Chapter Review

USING KEY TERMS

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

1. *solid* and *liquid*
2. *temperature* and *thermal expansion*
3. *evaporation* and *boiling*
4. *condensation* and *sublimation*

UNDERSTANDING KEY IDEAS

Multiple Choice

5. Which of the following statements best describes the particles of a liquid?
   - a. The particles are far apart and moving fast.
   - b. The particles are close together but moving past each other.
   - c. The particles are far apart and moving slowly.
   - d. The particles are closely packed and vibrating in place.

6. Which of the following temperatures is the lowest?
   - a. 100°C
   - b. 100°F
   - c. 100 K
   - d. None of the above

7. Boiling points and freezing points are examples of
   - a. chemical properties.
   - b. physical properties.
   - c. energy.
   - d. matter.

8. Dew collecting on a spider web in the early morning is an example of
   - a. condensation.
   - b. evaporation.
   - c. sublimation.
   - d. melting.

9. During which change of state do atoms or molecules become more ordered?
   - a. boiling
   - b. condensation
   - c. melting
   - d. sublimation

10. Which of the following changes of state is exothermic?
    - a. evaporation
    - b. melting
    - c. freezing
    - d. All of the above

11. Which statement below describes an example of thermal expansion?
    - a. The volume of liquid in a thermometer changes with temperature.
    - b. Drops of water form on the outside of a glass of ice water.
    - c. A puddle of water disappears in the sunshine.
    - d. Frost forms on a window.

12. The atoms and molecules in matter
    - a. are attracted to one another.
    - b. are constantly moving.
    - c. move faster at higher temperatures.
    - d. All of the above

Short Answer

13. Explain why liquid water takes the shape of its container but an ice cube does not.

14. Rank solids, liquids, and gases in order of particle speed from the highest speed to the lowest speed.

Math Skills

15 Kate placed 100 mL of water in five different pans, placed the pans on a windowsill for a week, and measured how much water evaporated from each pan. Draw a graph of her data, which is shown below. Place surface area on the *x*-axis and volume evaporated on the *y*-axis. Is the graph linear or nonlinear? What does this information tell you?

Pan number	1	2	3	4	5
Surface area (cm^2)	44	82	20	30	65
Volume evaporated (mL)	42	79	19	29	62

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *states of matter, solid, liquid, gas, changes of state, freezing, vaporization, condensation,* and *melting.*

17 **Analyzing Ideas** In the photo below, water is being split to form two new substances, hydrogen and oxygen. Is this a change of state? Explain your answer.

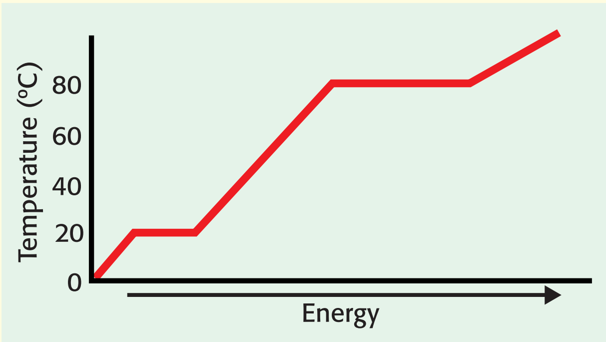
18 **Applying Concepts** After taking a shower, you notice that small droplets of water cover the mirror. Explain how this happens. Be sure to describe where the water comes from and the changes it goes through.

19 **Analyzing Methods** To protect their crops during freezing temperatures, orange growers spray water onto the trees and allow it to freeze. In terms of energy lost and energy gained, explain why this practice protects the oranges from damage.

20 **Making Inferences** At sea level, water boils at 100°C, while methane boils at –161°C. Which of these substances has a stronger force of attraction between its particles? Explain your reasoning.

INTERPRETING GRAPHICS

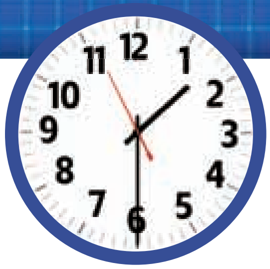
Use the graph below to answer the questions that follow.



21 What is the boiling point of the substance? What is the melting point?

22 Which state is present at 30°C?

23 How will the substance change if energy is added to the liquid at 20°C?



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Did you know that lightning can turn sand into glass? If lightning strikes sand, the sand can reach temperatures of up to 33,000°C. That temperature is as hot as the surface of the sun! This <u>intense</u> heat melts the sand into a liquid. The liquid quickly cools and hardens into glass. This glass is a rare and beautiful type of natural glass called *fulgurite*.

The same basic process is used to make light bulbs, windows, and bottles. But instead of lightning, glassmakers use hot ovens to melt solid silica (the main ingredient of sand) and other ingredients into liquid glass. Then, before the glass cools and solidifies, the glassmaker forms the glass into the desired shape.

1. In the glassmaking process, what happens after the glassmaker forms the material into the desired shape?

- **A** Solid silica melts in a hot oven.
- **B** Solid silica is struck by lightning.
- **C** The glass melts and becomes a liquid.
- **D** The glass cools and solidifies.

2. Which statement is an opinion from the passage?

- **F** Lightning can form fulgurites.
- **G** Fulgurites are beautiful.
- **H** Lightning heats the sand to 33,000°C.
- **I** Glassmakers use very hot ovens.

3. In the passage, what does <u>intense</u> mean?

- **A** a small amount
- **B** gaseous
- **C** a great amount
- **D** causing something to melt

Passage 2 For thousands of years, people used wind, water, gravity, dogs, horses, and cattle to do work. But until about 300 years ago, people had little success finding other things to help them do work. Then in 1690, Denis Papin, a French mathematician and physicist, noticed that steam <u>expanding</u> in a cylinder pushed a piston up. As the steam then cooled and contracted, the piston fell. Watching the motion of the piston, Papin had an idea. He connected a water-pump handle to the piston. As the pump handle rose and fell with the piston, water was pumped.

Throughout the next hundred years, other scientists and inventors improved upon Papin's design. In 1764, James Watt turned the steam pump into a true steam engine that could drive a locomotive. Watt's engine helped start the Industrial Revolution.

1. In the passage, what does <u>expanding</u> mean?

- **A** enlarging
- **B** enhancing
- **C** enforcing
- **D** disappearing

2. According to the passage, how was steam used?

- **F** as a source of power for thousands of years
- **G** by Denis Papin only in France
- **H** to pump water in the late 1600s
- **I** in the steam engine first

3. Which of the following statements is a fact from the passage?

- **A** Steam expands and causes a piston to fall.
- **B** When steam cools, it expands.
- **C** The invention of the water pump started the Industrial Revolution.
- **D** People began using steam as a source of power 300 years ago.

INTERPRETING GRAPHICS

Use the chart below to answer the questions that follow.

Freezing Points of 50:50 Mixtures of Antifreeze and Water	
Brand	**Freezing Point (°C)**
Ice-B-Gone	–5
Freeze Free	–7
Liqui-Freeze	–9
Auntie Freeze	–11

1. Phillip wants to purchase antifreeze for his car. Antifreeze is added to the water in a car's radiator to lower the water's freezing point. The temperature in his area never falls below –10°C. Given the information in the chart above, which of the following brands of antifreeze would be the best for Phillip's car?

A Ice-B-Gone
B Freeze-Free
C Liqui-Freeze
D Auntie Freeze

2. Phillip wants to make a bar graph that compares the brands of antifreeze. If he puts the brand name of each antifreeze on the *x*-axis, what variable belongs on the *y*-axis?

F Freezing point of water
G Freezing point of water with antifreeze in it
H Freezing point of the antifreeze only
I Freezing point of the radiator

3. Phillip's cousin lives in an area where it rarely freezes. The record low temperature for winter is –2°C. Which brand should Phillip's cousin purchase?

A Ice-B-Gone
B Freeze-Free
C Liqui-Freeze
D Auntie Freeze

MATH

Read each question below, and choose the best answer.

1. Gerard and three of his friends each want to buy a kite. The kites regularly cost \$7.95, but they are on sale for \$4.50. How much will their total savings be if they all purchase their kites on sale?

A \$13.80
B \$18.00
C \$10.35
D \$23.85

2. Francis bought a 2 L bottle of juice. How many milliliters of juice does this bottle hold?

F 0.002 mL
G 0.2 mL
H 200 mL
I 2,000 mL

3. Which of the following lists contains ratios that are all equivalent to 3/4?

A 3/4, 6/8, 15/22
B 6/10, 15/20, 20/25
C 3/4, 15/20, 20/25
D 3/4, 6/8, 15/20

4. The Liu family went to the state fair in their home state. They purchased five tickets, which cost \$6.50 each. Tickets for the rides cost \$1.25 each, and all five family members rode six rides. Two daughters bought souvenirs that cost \$5.25 each. Snacks cost a total of \$12.00. What is the total amount of money the family spent on their outing?

F \$61.25
G \$140.50
H \$62.50
I \$92.50

Standardized Test Preparation

Science in Action

Science, Technology, and Society

Deep-sea Diving with Helium

Divers who breathe air while deep in the ocean run the risk of suffering from nitrogen narcosis. Nitrogen narcosis produces an alcohol-like effect, which can cause a diver to become disoriented and to use poor judgment. This toxic effect can lead to dangerous behavior. To avoid nitrogen narcosis, divers who work at depths of more than 60 m breathe heliox. *Heliox* is a mixture of helium and oxygen, instead of air. The main disadvantage of heliox is that helium conducts heat about six times faster than nitrogen does, so a diver using heliox will feel cold sooner than a diver who is breathing air.

Math ACTIVITY

There are 2.54 centimeters in one inch. How many feet deep could a diver go before he or she started experiencing nitrogen narcosis?

Scientific Discoveries

The Fourth State of Matter

If you heat water, it will eventually turn into a gas. But what would happen if you kept on heating the gas? Scientists only had to look to the sun for the answer. The sun, like other stars, is made of the fourth state of matter—plasma. Plasma is a superheated gas. Once a gas's temperature rises above 10,000°C to 20,000°C, its particles start to break apart and it becomes plasma. Unlike gas, plasma can create, and be affected by, electrical and magnetic fields. More than 99% of the known universe is made of plasma! Even Earth has some naturally occurring plasma. Plasma can be found in auroras, flames, and lightning.

Social Studies ACTIVITY

Research plasma. Find out how plasma is used in today's technology, such as plasma TVs. How will this new technology affect you and society in general? Describe your findings in a poster.

People in Science

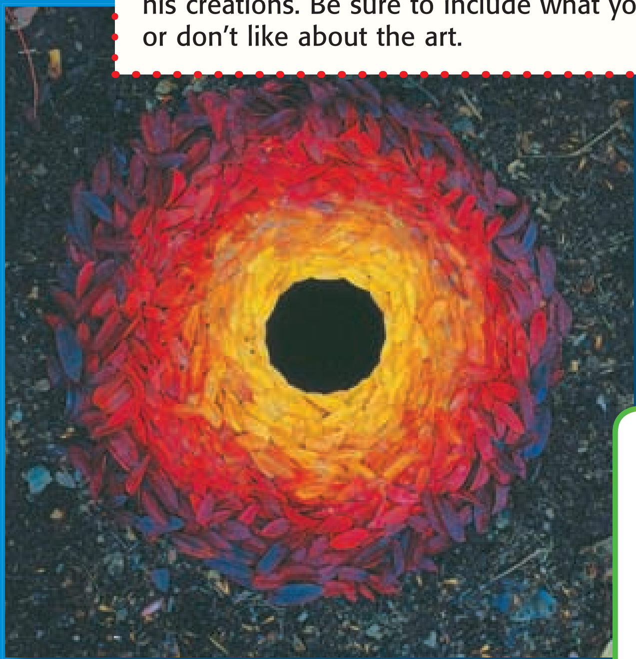
Andy Goldsworthy

Nature Artist Most of the art that Andy Goldsworthy creates will melt, decay, evaporate, or just blow away. He uses leaves, water, sticks, rocks, ice, and snow to create art. Goldsworthy observes how nature works and how it changes over time, and uses what he learns to create his art. For example, on cold, sunny mornings, Goldsworthy makes frost shadows. He stands with his back to the sun, which creates a shadow on the ground. The rising sun warms the ground and melts the frost around his shadow. When he steps away, he can see the shape of his body in the frost that is left on the ground.

In his art, Goldsworthy sometimes shows water in the process of changing states. For example, he made huge snowballs filled with branches, pebbles, and flowers. He then stored these snowballs in a freezer until summer, when they were displayed in a museum. As they melted, the snowballs slowly revealed their contents. Goldsworthy says his art reflects nature, because nature is constantly changing. Fortunately, he takes pictures of his art so we can enjoy it even after it disappears!

Language Arts ACTIVITY

WRITING SKILL Research Andy Goldsworthy's art. Write a one-page review of one of his creations. Be sure to include what you like or don't like about the art.



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Current Science

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7

Elements, Compounds, and Mixtures

About the PHOTO

Within these liquid-filled glass lamps, colored globs slowly rise and fall. But what are these liquids, and what keeps them from mixing together? The liquid inside these lamps is a mixture. This mixture is composed of four compounds, which include mineral oil, wax, water, and alcohol. The water and alcohol mix, but they remain separated from the globs of wax and oil.

PRE-READING ACTIVITY

FOLDNOTES **Key-Term Fold** Before you read the chapter, create the FoldNote entitled "Key-Term Fold" described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.

START-UP ACTIVITY

Mystery Mixture

In this activity, you will separate the different dyes found in an ink mixture.

Procedure

1. Place a **pencil** on top of a **clear plastic cup.** Tear a strip of paper (3 cm × 15 cm) from a **coffee filter.** Wrap one end of the strip around a pencil so that the other end will touch the bottom of the plastic cup. Use **tape** to attach the paper to the pencil.
2. Take the paper out of the cup. Using a **water-soluble black marker,** make a small dot in the center of the strip about 2 cm from the bottom.
3. Pour **water** in the cup to a depth of 1 cm. Lower the paper into the cup. Keep the dot above water.
4. Remove the paper when the water is 1 cm from the top. Record your observations.

Analysis

1. What happened as the paper soaked up the water?
2. Which colors make up the marker's black ink?
3. Compare your results with those of your classmates. Record your observations.
4. Is the process used to make the ink separate a physical or a chemical change? Explain.

SECTION 1

Elements

Imagine that you work for the Break-It-Down Company. Your job is to break down materials into simpler substances.

READING WARM-UP

Objectives

- Describe pure substances.
- Describe the characteristics of elements, and give examples.
- Explain how elements can be identified.
- Classify elements according to their properties.

Terms to Learn

element
pure substance
metal
nonmetal
metalloid

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

You haven't had any trouble breaking down materials so far. But one rainy Monday morning, you get a material that seems very hard to break down. First, you try physical changes, such as crushing and melting. But these do not change the material into something simpler. Next, you try some chemical changes, such as passing an electric current through the material. These do not change it either. What's going on?

Elements, the Simplest Substances

You couldn't break down the material described above because it is an element. An **element** is a pure substance that cannot be separated into simpler substances by physical or chemical means. In this section, you'll learn about elements and the properties that help you classify them.

Only One Type of Particle

Elements are pure substances. A **pure substance** is a substance in which there is only one type of particle. So, each element contains only one type of particle. These particles, called *atoms*, are much too small for us to see. For example, every atom in a 5 g nugget of the element gold is like every other atom of gold. The particles of a pure substance are alike no matter where they are found, as shown in **Figure 1.**

Reading Check **Explain why an element is a pure substance.** (*See the Appendix for answers to Reading Checks.*)

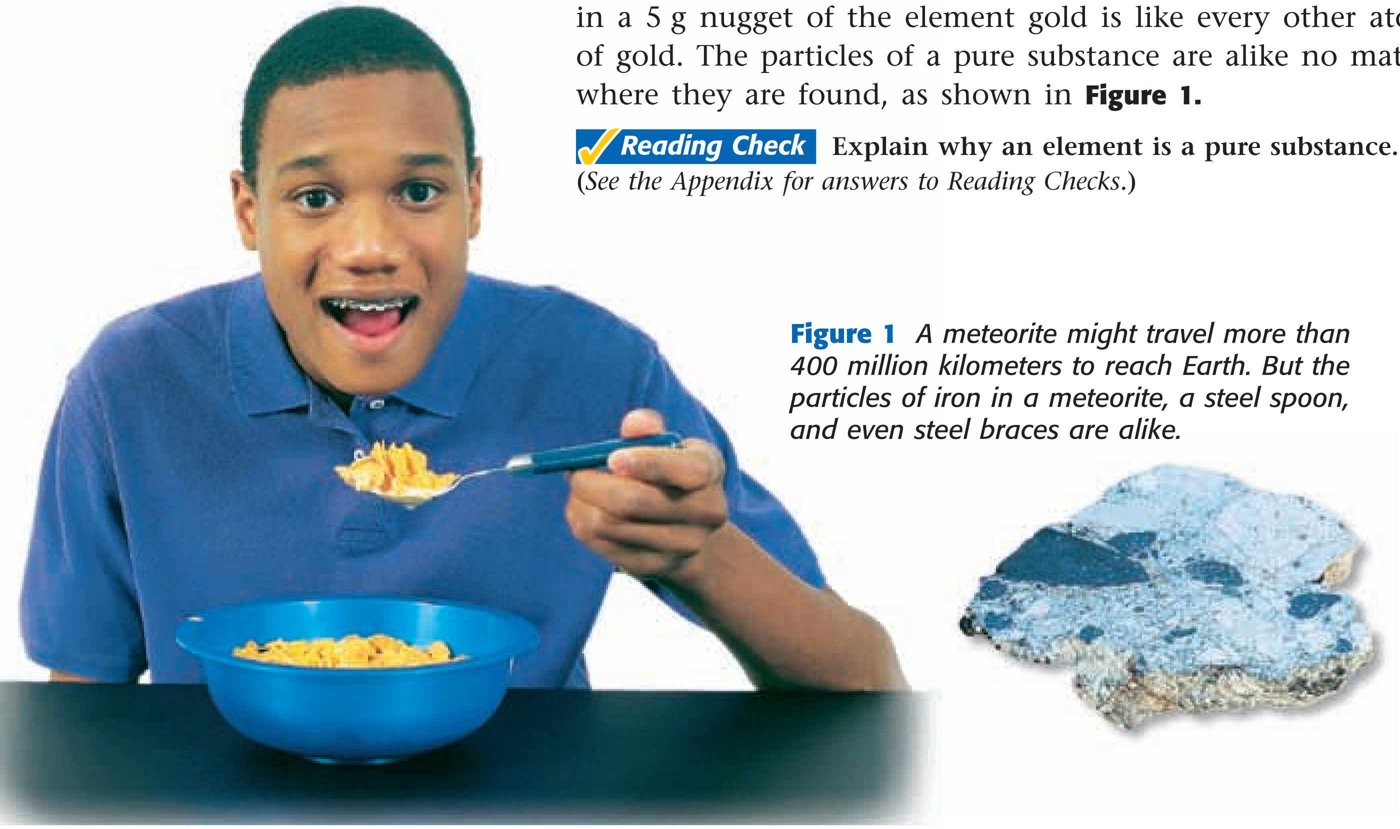


Figure 1 *A meteorite might travel more than 400 million kilometers to reach Earth. But the particles of iron in a meteorite, a steel spoon, and even steel braces are alike.*

Properties of Elements

Each element can be identified by its unique set of properties. For example, each element has its own *characteristic properties*. These properties do not depend on the amount of the element present. Characteristic properties include some physical properties, such as boiling point, melting point, and density. Chemical properties, such as reactivity with acid, are also characteristic properties.

An element may share a property with another element, but other properties can help you tell the elements apart. For example, the elements helium and krypton are both unreactive gases. However, the densities (mass per unit volume) of these elements are different. Helium is less dense than air. A helium-filled balloon will float up if it is released. Krypton is denser than air. A krypton-filled balloon will sink to the ground if it is released.

Identifying Elements by Their Properties

Look at the elements shown in **Figure 2.** These three elements have some similar properties. But each element can be identified by its unique set of properties.

Notice that the physical properties shown in **Figure 2** include melting point and density. Other physical properties, such as color, hardness, and texture, could be added to the list. Chemical properties might also be useful. For example, some elements, such as hydrogen and carbon, are flammable. Other elements, such as sodium, react with oxygen at room temperature. Still other elements, including zinc, are reactive with acid.

Quick Lab

Separating Elements

1. Examine a sample of nails provided by your teacher.
2. Your sample has **aluminum nails** and **iron nails.** Try to separate the two kinds of nails. Group similar nails into piles.
3. Pass a **bar magnet** over each pile of nails. Record your results.
4. Were you successful in completely separating the two types of nails? Explain.
5. Based on your observations, explain how the properties of aluminum and iron could be used to separate cans in a recycling plant.

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

pure substance a sample of matter, either a single element or a single compound, that has definite chemical and physical properties

Figure 2 **The Unique Properties of Elements**

Cobalt

- Melting point: 1,495°C
- Density: 8.9 g/cm^3
- Conducts electric current and heat energy
- Unreactive with oxygen in the air

Iron

- Melting point: 1,535°C
- Density: 7.9 g/cm^3
- Conducts electric current and heat energy
- Combines slowly with oxygen in the air to form rust

Nickel

- Melting point: 1,455°C
- Density: 8.9 g/cm^3
- Conducts electric current and heat energy
- Unreactive with oxygen in the air

Figure 3 *Even though these dogs are different breeds, they have enough in common to be classified as terriers.*

Classifying Elements by Their Properties

Think about how many different breeds of dogs there are. Now, think about how you tell one breed from another. Most often, you can tell just by their appearance, or the physical properties, of the dogs. **Figure 3** shows several breeds of terriers. Many terriers are fairly small in size and have short hair. Not all terriers are alike, but they share enough properties to be classified in the same group.

Categories of Elements

Elements are also grouped into categories by the properties they share. There are three major categories of elements: metals, nonmetals, and metalloids. The elements iron, nickel, and cobalt are all metals. Not all metals are exactly alike, but they do have some properties in common. **Metals** are shiny, and they conduct heat energy and electric current. **Nonmetals** make up the second category of elements. They do not conduct heat or electric current, and solid nonmetals are dull in appearance. **Metalloids,** which have properties of both metals and nonmetals, make up the last category.

metal an element that is shiny and that conducts heat and electricity well

nonmetal an element that conducts heat and electricity poorly

metalloid an element that has properties of both metals and nonmetals

Reading Check **What are three characteristics of metals?**

Categories Are Similar

Imagine being in a music store. The CDs are categorized by type of music. If you like rock-and-roll, you would go to the rock-and-roll section. You might not know every CD, but you know that a CD has the characteristics of rock-and-roll for it to be in this section.

By knowing the category to which an unfamiliar element belongs, you can predict some of its properties. **Figure 4** shows examples of each category and describes the properties that identify elements in each category.

Figure 4 The Three Major Categories of Elements

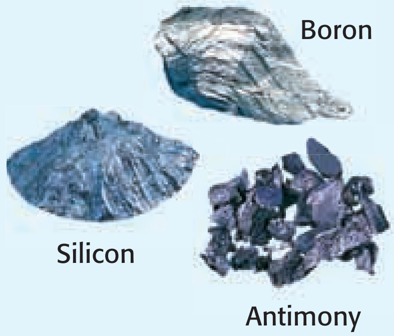
Metals

Metals are elements that are shiny and are good conductors of heat and electric current. They are *malleable.* (They can be hammered into thin sheets.) They are also *ductile.* (They can be drawn into thin wires.)

Nonmetals

Nonmetals are elements that are dull (not shiny) and that are poor conductors of heat and electric current. Solids tend to be brittle and unmalleable. Few familiar objects are made of only nonmetals.

Metalloids



Metalloids are also called semiconductors. They have properties of both metals and nonmetals. Some metalloids are shiny. Some are dull. Metalloids are somewhat malleable and ductile. Some metalloids conduct heat and electric current as well.

SECTION Review

Summary

- A substance in which all of the particles are alike is a pure substance.
- An element is a pure substance that cannot be broken down into anything simpler by physical or chemical means.
- Each element has a unique set of physical and chemical properties.
- Elements are classified as metals, nonmetals, or metalloids, based on their properties.

Using Key Terms

1. Use the following terms in the same sentence: *element* and *pure substance*.

Understanding Key Ideas

2. A metalloid
   a. may conduct electric current.
   b. can be ductile.
   c. is also called a semiconductor.
   d. All of the above
3. What is a pure substance?

Math Skills

4. There are eight elements that make up 98.5% of the Earth's crust: 46.6% oxygen, 8.1% aluminum, 5.0% iron, 3.6% calcium, 2.8% sodium, 2.6% potassium, and 2.1% magnesium. The rest is silicon. What percentage of the Earth's crust is silicon?

Critical Thinking

5. **Applying Concepts** From which category of elements would you choose to make a container that wouldn't shatter if dropped? Explain your answer.
6. **Making Comparisons** Compare the properties of metals, nonmetals, and metalloids.
7. **Evaluating Assumptions** Your friend tells you that a shiny element has to be a metal. Do you agree? Explain.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Elements
SciLinks code: HSM0496

SECTION 2

Compounds

What do salt, sugar, baking soda, and water have in common? You might use all of these to bake bread. Is there anything else similar about them?

Salt, sugar, baking soda, and water are all compounds. Because most elements take part in chemical changes fairly easily, they are rarely found alone in nature. Instead, they are found combined with other elements as compounds.

READING WARM-UP

Objectives

- Explain how elements make up compounds.
- Describe the properties of compounds.
- Analyze the unique properties of water.
- Explain how a compound can be broken down into its elements.
- Give examples of common compounds.

Terms to Learn

compound

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Compounds: Made of Elements

A **compound** is a pure substance composed of two or more elements that are chemically combined. Elements combine by reacting, or undergoing a chemical change, with one another. A particle of a compound is a molecule. Molecules of compounds are formed when atoms of two or more elements join together. Most of the substances that you see are compounds. Some examples are shown in **Table 1.**

In **Figure 1,** you see magnesium reacting with oxygen. A compound called *magnesium oxide* is forming. The compound is a pure substance. It is different from the elements that form it. Most elements can combine with one another in a variety of ways to make different compounds. Look at **Table 1** again. Although water, vinegar, and baking soda contain some of the same elements, these compounds have different properties.

The Ratio of Elements in a Compound

Elements do not randomly join to form compounds. Elements join in a specific ratio according to their masses to form a compound. For example, the ratio of the mass of hydrogen to the mass of oxygen in water is 1 to 8. This mass ratio can be written as 1:8. Every sample of water has a 1:8 mass ratio of hydrogen to oxygen. If a sample of a compound has a mass ratio that is not 1:8, the compound cannot be water.

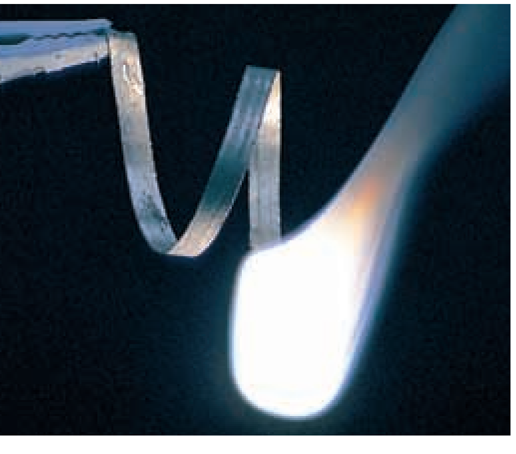


Figure 1 *As magnesium burns, it reacts with oxygen and forms the compound magnesium oxide.*

Table 1 **Familiar Compounds**

Compound	Elements combined
Table salt	sodium and chlorine
Water	hydrogen and oxygen
Vinegar	hydrogen, carbon, and oxygen
Carbon dioxide	carbon and oxygen
Baking soda	sodium, hydrogen, carbon, and oxygen

Quick Lab

Compound Confusion

1. Measure **4 g of compound A,** and place it in a **clear plastic cup.**
2. Measure **4 g of compound B**, and place it in a **second clear plastic cup.**
3. Observe the color and texture of each compound. Record your observations.
4. Add **5 mL of vinegar** to each cup. Record your observations.
5. Baking soda reacts with vinegar. Powdered sugar does not react with vinegar. Which compound is baking soda, and which compound is powdered sugar? Explain your answer.

Properties of Compounds

Each compound has its own physical properties. Physical properties include melting point, density, and color. Compounds can also be identified by their different chemical properties. Some compounds react with acid. For example, calcium carbonate, found in chalk, reacts with acid. Other compounds, such as hydrogen peroxide, react when exposed to light.

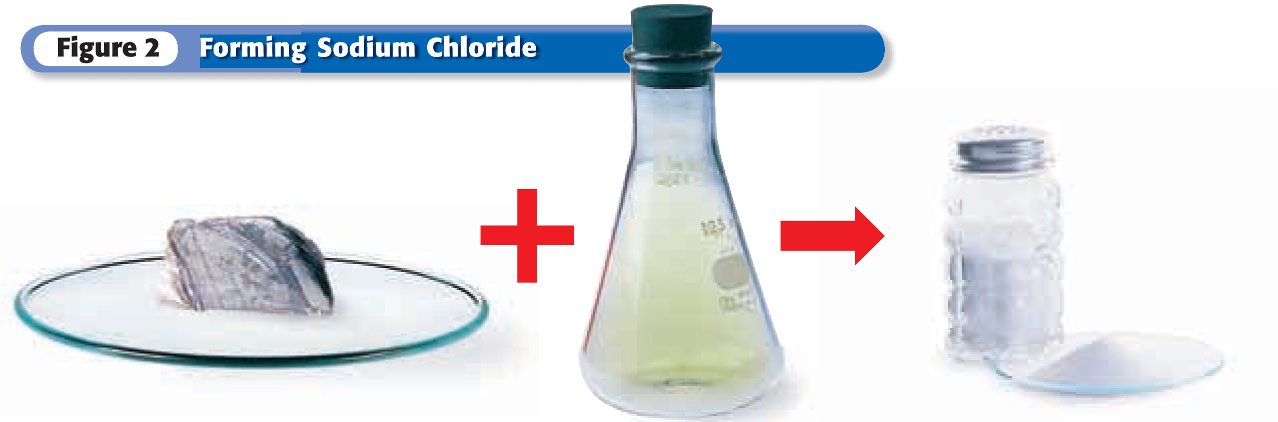
compound a substance made up of atoms of two or more different elements joined by chemical bonds

Reading Check **What are three physical properties used to identify compounds?** (*See the Appendix for answers to Reading Checks.*)

Properties: Compounds Versus Elements

A compound has properties that differ from those of the elements that form it. Look at **Figure 2.** Sodium chloride, or table salt, is made of two very dangerous elements—sodium and chlorine. Sodium reacts violently with water. Chlorine is a poisonous gas. But when combined, these elements form a harmless compound with unique properties. Sodium chloride is safe to eat. It also dissolves (without exploding!) in water.

Figure 2 **Forming Sodium Chloride**



Sodium is a soft, silvery white metal that reacts violently with water.

Chlorine is a poisonous, greenish yellow gas.

Sodium chloride, or table salt, is a white solid. It dissolves easily in water and is safe to eat.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5MIXW.**

Water: A Unique Compound

What is the most important compound on the planet? You may find it hard to believe, but no living thing can survive without tasteless, odorless water! The organisms in **Figure 3** rely on water for many reasons. What makes water so important?

The elements hydrogen and oxygen combine to form water. Every molecule of water has two parts hydrogen for every one part oxygen. This arrangement makes it possible for water to have properties unlike any other substance on Earth.

Sticking to Things

When hydrogen and oxygen combine to form water, the shape of the new compound gives water unique properties. Water molecules are attracted to one another because of their shape. This kind of attraction is called cohesion. *Cohesion* is the force that holds molecules of a single material together. Water forms drops because of cohesion.

Because of their shape, water molecules are attracted to other substances, too. This kind of attraction is called adhesion and is responsible for the drops of water left on your skin after a swim. *Adhesion* is the attractive force between two different substances that are in contact with each other.

Dissolving Substances

The shape of water molecules also makes the compound a great solvent. A *solvent* is a substance in which other substances dissolve. Water is called the *universal solvent* because most substances dissolve in it. Many substances can dissolve in water because it is *polar*. Polar substances have two areas that have opposite charges. Water molecules are slightly positive in one area and slightly negative in another area.

Figure 3 *Fish aren't the only organisms that rely on water for life. No living thing can survive without water.*

Figure 4 *Ice floats on water. While the surface of this lake is frozen, fish are able to live in the water beneath. The high specific heat capacity of water and the buoyancy of ice make this possible.*

Heating and Cooling

Have you ever wondered why the water in a swimming pool feels cold even on the hottest summer day? Water has a high specific heat capacity. Thus, water is able to absorb a large amount of energy before its temperature increases.

The specific heat capacity of water makes life on Earth possible in a few very important ways. The Earth's oceans absorb and slowly release energy from the sun, which helps to regulate temperature and seasonal changes. In much the same way, the water in your body regulates your body temperature.

Floating and Sinking

Imagine using a straw to push an ice cube underwater. What happens when you release the ice cube? A force pushes the ice back to the surface! The force that pushes the ice back to the water's surface is called buoyant force. *Buoyant force* is the upward force that fluids exert on all matter. Buoyant force is related to the density of an object. For example, a rock sinks when placed in water because the rock has a higher density than water. Look at **Figure 4.** Unlike a rock, ice floats on water. Ice floats on water because ice has a lower density than water.

Reading Check **Identify three unique properties of water.**

SCHOOL to HOME

Universal Solvent?

Almost anything will dissolve in water. With a parent, explore what kitchen substances, such as flour, sugar, and oil, dissolve in water. Discuss the similar properties of these substances.

ACTIVITY

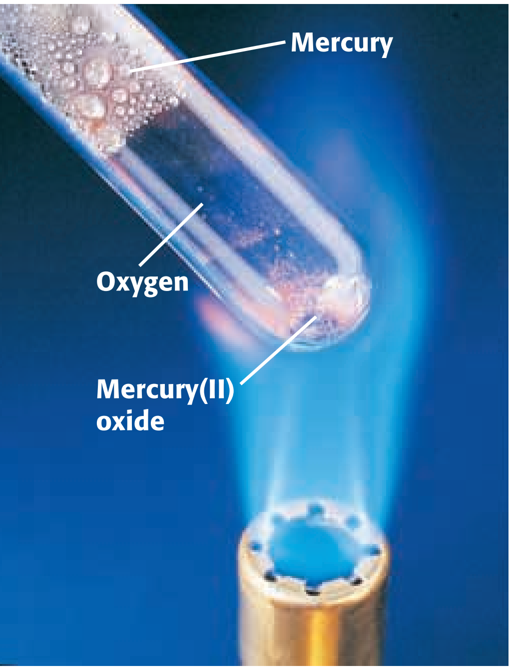


Figure 5 *Heating mercury(II) oxide causes a chemical change that separates it into the elements mercury and oxygen.*

Breaking Down Compounds

Some compounds can be broken down into their elements by chemical changes. Other compounds break down to form simpler compounds instead of elements. These simpler compounds can then be broken down into elements through more chemical changes. For example, carbonic acid is a compound that helps give carbonated beverages their "fizz." When you open a carbonated beverage, carbonic acid breaks down into carbon dioxide and water. Carbon dioxide and water can then be broken down into the elements carbon, oxygen, and hydrogen through chemical changes.

Reading Check **Compounds can be broken down into what two types of substances?**

Methods of Breaking Down Compounds

The only way to break down a compound is through a chemical change. Sometimes, energy is needed for a chemical change to happen. Two ways to add energy to break down a compound are to apply heat and to apply an electric current. For example, heating the compound mercury(II) oxide breaks it down into the elements mercury and oxygen, as shown in **Figure 5.**

Compounds in Your World

You are surrounded by compounds. Compounds make up the food you eat, the school supplies you use, and the clothes you wear—even you!

Compounds in Nature

Proteins are compounds found in all living things. The element nitrogen is one of the elements needed to make proteins. **Figure 6** shows how some plants get the nitrogen they need. Other plants use nitrogen compounds that are in the soil. Animals get the nitrogen they need by eating plants or by eating animals that have eaten plants. The proteins in the food are broken down as an animal digests the food. The simpler compounds that form are used by the animal's cells to make new proteins.

Another compound that plays an important role in life is carbon dioxide. You exhale carbon dioxide that was made in your body. Plants take in carbon dioxide, which is used in photosynthesis. Plants use photosynthesis to make compounds called *carbohydrates*. These carbohydrates can then be broken down for energy through other chemical changes by plants or animals.

Figure 6 *The bumps on the roots of this pea plant are home to bacteria that form compounds from nitrogen in the air. The pea plant makes proteins from these compounds.*

Compounds in Industry

The compounds found in nature are not usually the raw materials needed by industry. Often, these compounds must be broken down to provide elements or other compounds that can be used as raw material. For example, aluminum is used in cans and airplanes. But aluminum is not found alone in nature. Aluminum is produced by breaking down the compound aluminum oxide. Ammonia is another important compound used in industry. It is used to make fertilizers. Ammonia is made by combining the elements nitrogen and hydrogen. Plants can use ammonia as a source of nitrogen for making proteins. Other manufactured compounds are used in medicines, food preservatives, and synthetic fabrics.

CONNECTION TO Physics

Electrolysis The process of using electric current to break down compounds is known as *electrolysis*. For example, electrolysis can be used to separate water into hydrogen and oxygen. Research ways that electrolysis is used in industry. Make a poster of what you learn, and present a report to your class. ACTIVITY

SECTION Review

Summary

- A compound is a pure substance composed of two or more elements.
- The elements that form a compound always combine in a specific ratio according to their masses.
- Each compound has a unique set of physical and chemical properties that differ from those of the elements that make up the compound.
- Water is a compound with unique properties. All living things rely on water for life.
- Compounds can be broken down into simpler substances only by chemical changes.

Using Key Terms

1. In your own words, write a definition for the term *compound*.

Understanding Key Ideas

2. The elements in a compound
   a. join in a specific ratio according to their masses.
   b. combine by reacting with one another.
   c. can be separated by chemical changes.
   d. All of the above
3. What type of change is needed to break down a compound?
4. Why is water called the *universal solvent*?

Math Skills

5. Table sugar is a compound made of carbon, hydrogen, and oxygen. If sugar contains 41.86% carbon and 6.98% hydrogen, what percentage of sugar is oxygen?

Critical Thinking

6. **Applying Concepts** Iron is a solid, gray metal. Oxygen is a colorless gas. When oxygen and iron chemically combine, rust is made. Rust has a reddish brown color. Why is rust different from the iron and oxygen that it is made of?
7. **Analyzing Ideas** A jar contains samples of the elements carbon and oxygen. Does the jar contain a compound? Explain your answer.
8. **Comparing and Contrasting** Explain the different roles cohesion and adhesion have in the following situation. After a rainstorm, water drops cling to the windshield of a car.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Compounds

SciLinks code: HSM0332

SECTION 3

Mixtures

Imagine that you roll out some dough, add tomato sauce, and sprinkle some cheese on top. Then, you add green peppers, mushrooms, olives, and pepperoni! What have you just made?

A pizza, of course! But that's not all. You have also created a mixture—and a delicious one at that! In this section, you will learn about mixtures and their properties.

READING WARM-UP

Objectives

- Describe three properties of mixtures.
- Describe four methods of separating the parts of a mixture.
- Analyze a solution in terms of its solute and solvent.
- Explain how concentration affects a solution.
- Describe the particles in a suspension.
- Explain how a colloid differs from a solution and a suspension.

Terms to Learn

mixture	concentration
solution	solubility
solute	suspension
solvent	colloid

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Properties of Mixtures

All mixtures—even pizza—share certain properties. A **mixture** is a combination of two or more substances that are not chemically combined. When two or more materials are put together, they form a mixture if they do not react to form a compound. For example, cheese and tomato sauce do not react when they are used to make a pizza. So, a pizza is a mixture.

mixture a combination of two or more substances that are not chemically combined

No Chemical Changes in a Mixture

No chemical change happens when a mixture is made. So, each substance in a mixture has the same chemical makeup it had before the mixture formed. That is, each substance in a mixture keeps its identity. In some mixtures, such as the pizza in **Figure 1,** you can see each of the components. In other mixtures, such as salt water, you cannot see all the components.

Reading Check Why do substances in a mixture keep their identities? (*See the Appendix for answers to Reading Checks.*)

Separating Mixtures Through Physical Methods

You don't like mushrooms on your pizza? Just pick them off. This change is a physical change of the mixture. The identities of the substances do not change. But not all mixtures are as easy to separate as a pizza. You cannot just pick salt out of a saltwater mixture. One way to separate the salt from the water is to heat the mixture until the water evaporates. The salt is left behind. Other ways to separate mixtures are shown in **Figure 2.**

Figure 1 *You can see each topping on this mixture, which is better known as a pizza.*

Figure 2 Common Ways to Separate Mixtures

Distillation (DIS tuh LAY shuhn) is a process that separates a mixture based on the boiling points of the components. Here, pure water (at right) is being distilled from a salt-water mixture (at left). Distillation is also used to separate crude oil into components, such as gasoline and kerosene.

A **magnet** can be used to separate a mixture of the elements iron and aluminum. Iron is attracted to the magnet, but aluminum is not.

The different parts of blood are separated using a machine called a **centrifuge** (SEN truh FYOOJ). In the test tube at left, a layer of plasma rests above a layer of red blood cells. A centrifuge separates mixtures by the densities of the components.

Separating a mixture of sodium chloride (table salt) and sulfur takes more than one step.

1 In the first step, water is added, and the mixture is stirred. Salt dissolves in water. Sulfur does not.

2 In the second step, the mixture is poured through a filter. The filter traps the solid sulfur.

3 In the third step, the water is evaporated. The sodium chloride is left behind.

Table 1 Mixtures and Compounds	
Mixtures	**Compounds**
Made of elements, compounds, or both	Made of elements
No change in original properties of components	Change in original properties of components
Separated by physical means	Separated by chemical means
Formed using any ratio of components	Formed using a set ratio of components

Figure 3 *These paperweights are made of granite. They are different colors because the granite used in each has different ratios of minerals.*

The Ratio of Components in a Mixture

A compound is made of elements in a specific mass ratio. However, the components of a mixture do not need to be mixed in a definite ratio. For example, granite is a mixture made of three minerals: feldspar, mica, and quartz. Feldspar is pink in color. Mica is black. Quartz is colorless. Look at the egg-shaped paperweights in **Figure 3.** The pink one is made from granite that has more feldspar than mica or quartz. That is why it is pink. The black one is made from granite that has more mica than the other minerals. The gray one is made from granite that has more quartz than the other minerals. Even though the proportions of the minerals change, this combination of minerals is always a mixture called *granite*. **Table 1** above summarizes the differences between mixtures and compounds.

Solutions

solution a homogeneous mixture of two or more substances uniformly dispersed throughout a single phase

solute in a solution, the substance that dissolves in the solvent

solvent in a solution, the substance in which the solute dissolves

A **solution** is a mixture that appears to be a single substance. A solution is composed of particles of two or more substances that are distributed evenly among each other. Solutions have the same appearance and properties throughout the mixture.

The process in which particles of substances separate and spread evenly throughout a mixture is known as *dissolving*. In solutions, the **solute** is the substance that is dissolved. The **solvent** is the substance in which the solute is dissolved. A solute must be *soluble,* or able to dissolve, in the solvent. A substance that is *insoluble,* or unable to dissolve, forms a mixture that is not a solution.

Salt water is a solution. Salt is soluble in water, meaning that salt dissolves in water. Therefore, salt is the solute, and water is the solvent. When two liquids or two gases form a solution, the substance with the greater amount is the solvent.

Table 2 Examples of Different States in Solutions

States	Examples
Gas in gas	dry air (oxygen in nitrogen)
Gas in liquid	soft drinks (carbon dioxide in water)
Liquid in liquid	antifreeze (alcohol in water)
Solid in liquid	salt water (salt in water)
Solid in solid	brass (zinc in copper)

Examples of Solutions

You may think that all solutions are liquids. And in fact, tap water, soft drinks, gasoline, and many cleaning supplies are liquid solutions. However, solutions may also be gases, such as air. Solutions may even be solids, such as steel. *Alloys* are solid solutions of metals or nonmetals dissolved in metals. Brass is an alloy of the metal zinc dissolved in copper. Steel is an alloy made of the nonmetal carbon and other elements dissolved in iron. **Table 2** lists more examples of solutions.

Reading Check **What is an alloy?**

Particles in Solutions

The particles in solutions are so small that they never settle out. They also cannot be removed by filtering. In fact, the particles are so small that they don't even scatter light. Both of the jars in **Figure 4** contain mixtures. The mixture in the jar on the left is a solution of table salt in water. The jar on the right holds a mixture—but not a solution—of gelatin in water.

CONNECTION TO Language Arts

WRITING SKILL **Alloys** Research an alloy. Find out what the alloy is made of and the amount of each substance in the alloy. Also, identify different ways that the alloy is used. Then, write a song or poem about the alloy to recite in class.

Figure 4 *Both of these jars contain mixtures. The mixture in the jar on the left, however, is a solution. The particles in solutions are so small that they don't scatter light. Therefore, you can't see the path of light through the solution.*

Figure 5 *The dilute solution* (left) *contains less solute than the concentrated solution* (right).

Concentration of Solutions

A measure of the amount of solute dissolved in a solvent is **concentration.** Concentration can be expressed in grams of solute per milliliter of solvent (g/mL).

concentration the amount of a particular substance in a given quantity of a mixture, solution, or ore

solubility the ability of one substance to dissolve in another at a given temperature and pressure

Concentrated or Dilute?

Solutions can be described as being concentrated or dilute. In **Figure 5,** both solutions have the same amount of solvent. However, the solution on the left contains less solute than the solution on the right. The solution on the left is dilute. The solution on the right is concentrated. Keep in mind that the terms *dilute* and *concentrated* do not tell you the amount of solute that is dissolved.

Solubility

If you add too much sugar to a glass of lemonade, not all of the sugar can dissolve. Some of it sinks to the bottom. To find the maximum amount of sugar that can dissolve, you would need to know the solubility of sugar. The **solubility** of a solute is the ability of the solute to dissolve in a solvent at a certain temperature. **Figure 6** shows how the solubility of several different solid substances changes with temperature.

MATH FOCUS

Calculating Concentration What is the concentration of a solution that has 35 g of salt dissolved in 175 mL of water?

Step 1: One equation for finding concentration is the following:

$$concentration = \frac{grams\ of\ solute}{milliliters\ of\ solvent}$$

Step 2: Replace grams of solute and milliliters of solvent with the values given, and solve.

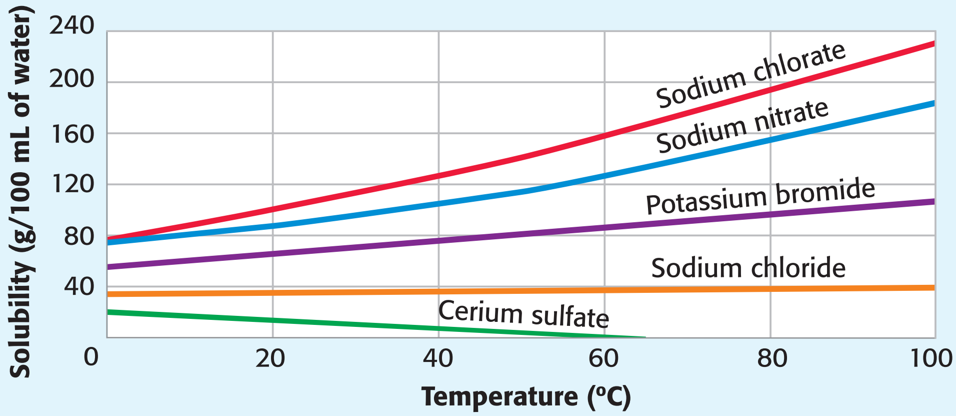
$$\frac{35\text{ g salt}}{175\text{ mL water}} = 0.2\text{ g/mL}$$

Now It's Your Turn

1. What is the concentration of solution A if it has 55 g of sugar dissolved in 500 mL of water?
2. What is the concentration of solution B if it has 36 g of sugar dissolved in 144 mL of water?
3. Which solution is more concentrated?

Figure 6 **Solubility of Different Solids In Water**

The solubility of most solids increases as the temperature gets higher. So, more solute can dissolve at higher temperatures. However, some solids, such as cerium sulfate, are less soluble at higher temperatures.



Dissolving Gases in Liquids

Most solids are more soluble in liquids at higher temperatures. But gases become less soluble in liquids as the temperature is raised. A soft drink goes flat faster when warm. The gas that is dissolved in the soft drink cannot stay dissolved when the temperature increases. So, the gas escapes, and the soft drink becomes "flat."

Reading Check **How does the solubility of gases change with temperature?**

Dissolving Solids Faster in Liquids

Several things affect how fast a solid will dissolve. Look at **Figure 7** to see three ways to make a solute dissolve faster. You can see why you will enjoy a glass of lemonade sooner if you stir granulated sugar into the lemonade before adding ice!

Figure 7 **How to Dissolve Solids Faster**

Mixing by stirring or shaking causes the solute particles to separate from one another and spread out more quickly among the solvent particles.

Heating causes particles to move more quickly. The solvent particles can separate the solute particles and spread them out more quickly.

Crushing the solute increases the amount of contact it has with the solvent. The particles of the crushed solute mix with the solvent more quickly.

Suspensions

Have you ever shaken a snow globe? If so, you have seen the solid snow particles mix with the water, as shown in **Figure 8.** When you stop shaking the globe, the snow settles to the bottom. This mixture is called a suspension. A **suspension** is a mixture in which particles of a material are dispersed throughout a liquid or gas but are large enough that they settle out.

The particles in a suspension are large enough to scatter or block light. The particles are also too large to stay mixed without being stirred or shaken. If a suspension is allowed to sit, the particles will settle out, as they do in a snow globe.

A suspension can be separated by passing it through a filter. So, the liquid or gas passes through the filter, but the solid particles are large enough to be trapped by the filter.

Reading Check **How can the particles of a suspension be separated?**

SCHOOL to HOME

Suspensions

Many household items, such as paints, salad dressings, and medicines, are suspensions. With a parent, find several items that have directions that tell you to shake the bottle before use. Discuss what problems could arise if you do not shake the container before use.

ACTIVITY

Colloids

Some mixtures have properties between those of solutions and suspensions. These mixtures are known as colloids (KAHL OYDZ). A **colloid** is a mixture in which the particles are dispersed throughout but are not heavy enough to settle out. The particles in a colloid are relatively small and are fairly well mixed. You might be surprised at the number of colloids you see each day. Milk, mayonnaise, and stick deodorant—even the gelatin and whipped cream in **Figure 8**—are colloids.

The particles in a colloid are much smaller than the particles in a suspension. However, the particles are large enough to scatter light. A colloid cannot be separated by filtration. The particles are small enough to pass through a filter.

suspension a mixture in which particles of a material are more or less evenly dispersed throughout a liquid or gas

colloid a mixture consisting of tiny particles that are intermediate in size between those in solutions and those in suspensions and that are suspended in a liquid, solid, or gas

Figure 8 **Properties of Suspensions and Colloids**

Suspension This snow globe contains solid particles that will mix with the clear liquid when you shake it up. But the particles will soon fall to the bottom when the globe is at rest.

Colloid This dessert includes two tasty examples of colloids—fruity gelatin and whipped cream.

SECTION Review

Summary

- A mixture is a combination of two or more substances, each of which keeps its own characteristics.
- Mixtures can be separated by physical means, such as filtration and evaporation.
- A solution is a mixture that appears to be a single substance but is composed of a solute dissolved in a solvent.
- Concentration is a measure of the amount of solute dissolved in a solvent.
- The solubility of a solute is the ability of the solute to dissolve in a solvent at a certain temperature.
- Suspensions are mixtures that contain particles large enough to settle out or be filtered and to block or scatter light.
- Colloids are mixtures that contain particles that are too small to settle out or be filtered but are large enough to scatter light.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. The <u>solvent</u> is the substance that is dissolved.
2. A <u>suspension</u> is composed of substances that are spread evenly among each other.
3. A measure of the amount of solute dissolved in a solvent is <u>solubility</u>.
4. A <u>colloid</u> contains particles that will settle out of the mixture if left sitting.

Understanding Key Ideas

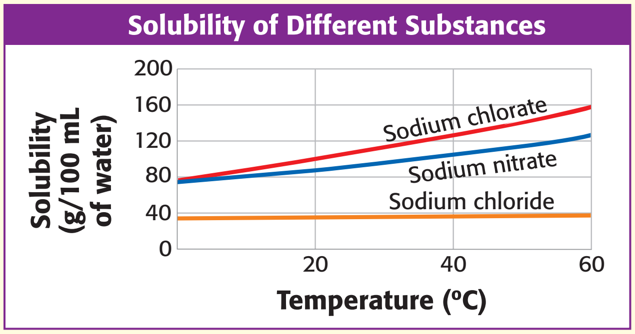
5. A mixture
   a. has substances in it that are chemically combined.
   b. can always be separated using filtration.
   c. contains substances that are not mixed in a definite ratio.
   d. All of the above
6. List three ways to dissolve a solid faster.

Critical Thinking

7. **Making Comparisons** How do solutions, suspensions, and colloids differ?
8. **Applying Concepts** Suggest a procedure to separate iron filings from sawdust. Explain why this procedure works.
9. **Analyzing Ideas** Identify the solute and solvent in a solution made of 15 mL of oxygen and 5 mL of helium.

Interpreting Graphics

Use the graph below to answer the questions that follow.



10. At what temperature is 120 g of sodium nitrate solution soluble in 100 mL of water?
11. At 60°C, how much more sodium chlorate than sodium chloride dissolves in 100 mL of water?

SCILINKS. NSTA
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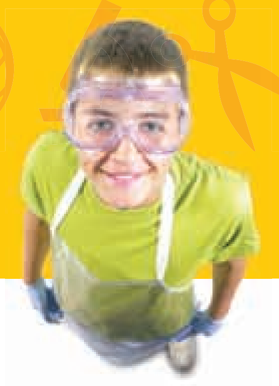
For a variety of links related to this chapter, go to www.scilinks.org

Topic: Mixtures
SciLinks code: HSM0974

Using Scientific Methods

Skills Practice Lab



OBJECTIVES

Observe flame colors emitted by various compounds.

Determine the composition of an unknown compound.

MATERIALS

- Bunsen burner
- chloride test solutions (4)
- hydrochloric acid, dilute, in a small beaker
- spark igniter
- tape, masking
- test tubes, small (4)
- test-tube rack
- water, distilled, in a small beaker
- wire and holder

SAFETY

Flame Tests

Fireworks produce fantastic combinations of color when they are ignited. The different colors are the results of burning different compounds. Imagine that you are the head chemist for a fireworks company. The label has fallen off one box, and you must identify the unknown compound inside so that the fireworks may be used in the correct fireworks display. To identify the compound, you will use your knowledge that every compound has a unique set of properties.

Ask a Question

1. How can you identify an unknown compound by heating it in a flame?

Form a Hypothesis

2. Write a hypothesis that is a possible answer to the question above. Explain your reasoning.

Test the Hypothesis

3. Arrange the test tubes in the test-tube rack. Use masking tape to label each tube with one of the following names: calcium chloride, potassium chloride, sodium chloride, and unknown.

4. Copy the table below. Then, ask your teacher for your portions of the solutions. **Caution:** Be very careful in handling all chemicals. Tell your teacher immediately if you spill a chemical.

Test Results

Compound	Color of flame
Calcium chloride	
Potassium chloride	DO NOT WRITE IN BOOK
Sodium chloride	
Unknown	

5. Light the burner. Clean the wire by dipping it into the dilute hydrochloric acid and then into distilled water. Holding the wooden handle, heat the wire in the blue flame of the burner until the wire is glowing and it no longer colors the flame. **Caution:** Use extreme care around an open flame.

6. Dip the clean wire into the first test solution. Hold the wire at the tip of the inner cone of the burner flame. Record in the table the color given to the flame.

7. Clean the wire by repeating step 5. Then, repeat steps 5 and 6 for the other solutions.

8. Follow your teacher's instructions for cleanup and disposal.

Analyze the Results

1. **Identifying Patterns** Is the flame color a test for the metal or for the chloride in each compound? Explain your answer.

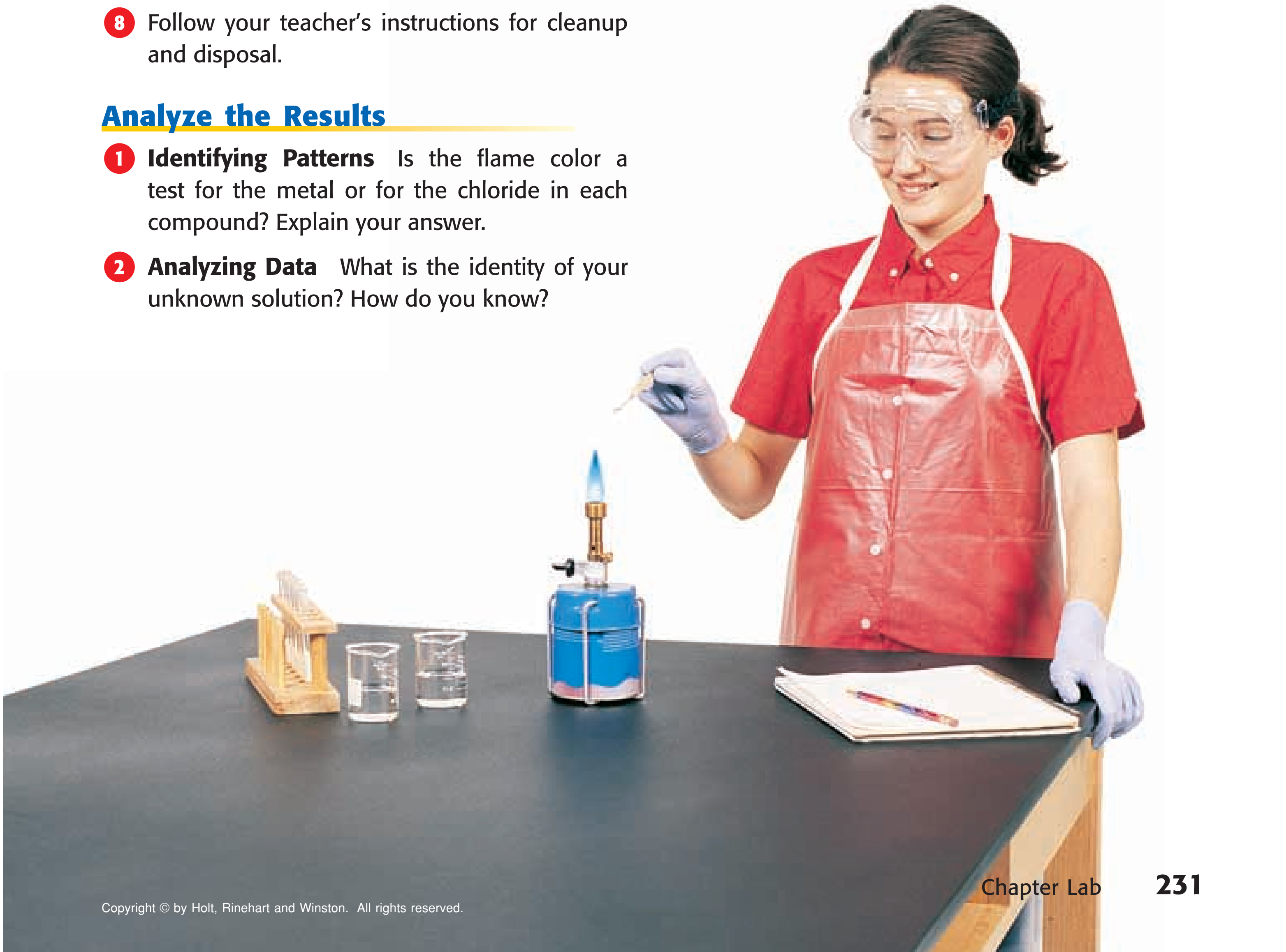
2. **Analyzing Data** What is the identity of your unknown solution? How do you know?

Draw Conclusions

3. **Evaluating Methods** Why is it necessary to carefully clean the wire before testing each solution?

4. **Making Predictions** Would you expect the compound sodium fluoride to produce the same color as sodium chloride in a flame test? Why or why not?

5. **Interpreting Information** Each of the compounds you tested is made from chlorine, which is a poisonous gas at room temperature. Why is it safe to use these compounds without a gas mask?



Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

compound	element
suspension	solubility
solution	metal
nonmetal	solute

1. A(n) ___ has a definite ratio of components.
2. The ability of one substance to dissolve in another substance is the ___ of the solute.
3. A(n) ___ can be separated by filtration.
4. A(n) ___ is a pure substance that cannot be broken down into simpler substances by chemical means.
5. A(n) ___ is an element that is brittle and dull.
6. The ___ is the substance that dissolves to form a solution.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Which of the following increases the solubility of a gas in a liquid?
   - **a.** increasing the temperature of the liquid
   - **b.** increasing the amount of gas in the liquid
   - **c.** decreasing the temperature of the liquid
   - **d.** decreasing the amount of liquid

8. Which of the following best describes chicken noodle soup?
   - **a.** element
   - **b.** mixture
   - **c.** compound
   - **d.** solution

9. Which of the following statements describes elements?
   - **a.** All of the particles in the same element are different.
   - **b.** Elements can be broken down into simpler substances.
   - **c.** Elements have unique sets of properties.
   - **d.** Elements cannot be joined together in chemical reactions.

10. A solution that contains a large amount of solute is best described as
    - **a.** insoluble.
    - **b.** concentrated.
    - **c.** dilute.
    - **d.** weak.

11. Certain objects float in water while others sink. What property of water causes this?
    - **a.** cohesion
    - **b.** adhesion
    - **c.** buoyant force
    - **d.** unique shape

12. Which of the following would not increase the rate at which a solid dissolves?
    - **a.** decreasing the temperature
    - **b.** crushing the solid
    - **c.** stirring
    - **d.** increasing the temperature

13. In which classification of matter are components chemically combined?
    - a. a solution
    - b. a colloid
    - c. a compound
    - d. a suspension

14. An element that conducts thermal energy well and is easily shaped is a
    - a. metal.
    - b. metalloid.
    - c. nonmetal.
    - d. None of the above

Short Answer

15. What is the difference between an element and a compound?

16. When nail polish is dissolved in acetone, which substance is the solute, and which is the solvent?

Math Skills

17. What is the concentration of a solution prepared by mixing 50 g of salt with 200 mL of water?

18. How many grams of sugar must be dissolved in 150 mL of water to make a solution that has a concentration of 0.6 g/mL?

CRITICAL THINKING

19. **Concept Mapping** Use the following terms to create a concept map: *matter, element, compound, mixture, solution, suspension,* and *colloid.*

20. **Forming Hypotheses** To keep the "fizz" in carbonated beverages after they have been opened, should you store them in a refrigerator or in a cabinet? Explain.

21. **Making Inferences** A light green powder is heated in a test tube. A gas is given off, and the solid becomes black. In which classification of matter does the green powder belong? Explain your reasoning.

22. **Predicting Consequences** Why is it desirable to know the exact concentration of solutions rather than whether they are concentrated or dilute?

23. **Applying Concepts** Describe a procedure to separate a mixture of salt, finely ground pepper, and pebbles.

INTERPRETING GRAPHICS

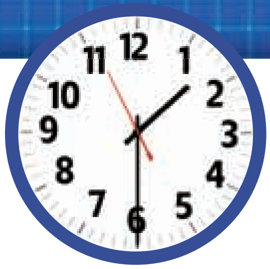
Dr. Sol Vent did an experiment to find the solubility of a compound. The data below were collected using 100 mL of water. Use the table below to answer the questions that follow.

Temperature (°C)	10	25	40	60	95
Dissolved solute (g)	150	70	34	25	15

24. Use a computer or graph paper to construct a graph of Dr. Vent's results. Examine the graph. To increase the solubility, would you increase or decrease the temperature? Explain.

25. If 200 mL of water were used instead of 100 mL, how many grams of the compound would dissolve at 40°C?

26. Based on the solubility of this compound, is this compound a solid, liquid, or gas? Explain your answer.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 In 1912, the *Titanic* was the largest ship ever to set sail. This majestic ship was considered to be unsinkable. Yet, on April 15, 1912, the *Titanic* hit a large iceberg. The resulting damage caused the *Titanic* to sink, killing 1,500 of its passengers and crew.

How could an iceberg destroy the 2.5 cm thick steel plates that made up the *Titanic*'s hull? Analysis of a recovered piece of steel showed that the steel contained large amounts of sulfur. Sulfur is a normal component of steel. However, the recovered piece has much more sulfur than today's steel does. The excess sulfur may have made the steel <u>brittle</u>, much like glass. Scientists suspect that this brittle steel may have cracked on impact with the iceberg, allowing water to enter the hull.

1. In this passage, what does the word *brittle* mean?

A likely to break or crack
B very strong
C clear and easily seen through
D lightweight

2. What is the main idea of the second paragraph of this passage?

F The *Titanic*'s hull was 2.5 cm thick.
G The steel in the *Titanic*'s hull may have been brittle.
H The large amount of sulfur in the *Titanic*'s hull may be responsible for the hull's cracking.
I Scientists were able to recover a piece of steel from the *Titanic*'s hull.

3. What was the *Titanic* thought to be in 1912?

A the fastest ship afloat
B the smallest ship to set sail
C a ship not capable of being sunk
D the most luxurious ship to set sail

Passage 2 Perfume making is an ancient art. It was practiced by the ancient Egyptians, who rubbed their bodies with a substance made by soaking fragrant woods and resins in water and oil. Ancient Israelites also practiced the art of perfume making. This art was also known to the early Chinese, Arabs, Greeks, and Romans.

Over time, perfume making has developed into a fine art. A good perfume may contain more than 100 ingredients. The most familiar ingredients come from fragrant plants, such as sandalwood or roses. These plants get their pleasant odor from essential oils, which are stored in tiny, baglike parts called *sacs*. The parts of plants that are used for perfumes include the flowers, roots, and leaves. Other perfume ingredients come from animals and from human-made chemicals.

1. How did ancient Egyptians make perfume?

A by using 100 different ingredients
B by soaking woods and resins in water and oil
C by using plants or flowers
D by making tiny, baglike parts called sacs

2. What is the main idea of the second paragraph?

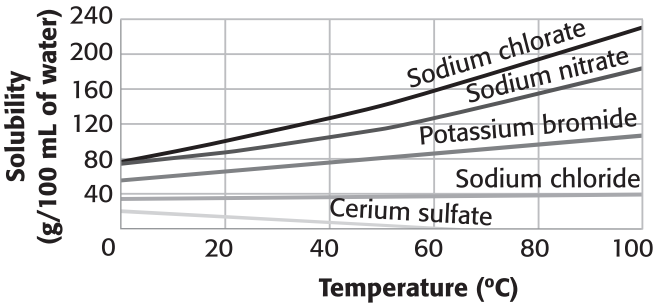
F Perfume making hasn't changed since ancient Egypt.
G The ancient art of perfume making has been replaced by simple science.
H Perfume making is a complex procedure involving many ingredients.
I Natural ingredients are no longer used in perfume.

3. How are good perfumes made?

A from plant oils only
B by combining one or two ingredients
C according to early Chinese formulas
D by blending as many as 100 ingredients

INTERPRETING GRAPHICS

The graph below was constructed from data collected during a laboratory investigation. Use the graph below to answer the questions that follow.



1. Which of the following values is the amount of sodium nitrate that can dissolve in 100 mL of water at 40°C?

A 0 g
B 40 g
C 80 g
D 100 g

2. How many grams of sodium chloride can dissolve in 100 mL of water at 60°C?

F 40 g
G 80 g
H 125 g
I 160 g

3. At what temperature will 80 g of potassium bromide completely dissolve in 100 mL of water?

A approximately 20°C
B approximately 42°C
C approximately 88°C
D approximately 100°C

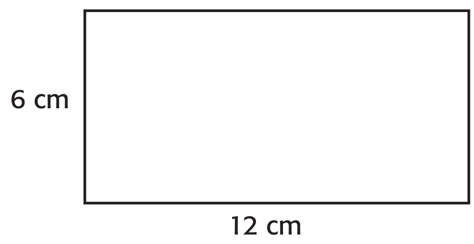
4. At 20°C, which solid is the most soluble?

F sodium chloride
G sodium chlorate
H potassium bromide
I sodium nitrate

MATH

Read each question below, and choose the best answer.

Use the rectangle below to answer questions 1 and 2.



1. What is the perimeter of the rectangle shown above?

A 12 cm
B 18 cm
C 36 cm
D 72 cm

2. If the length of all the sides of the rectangle shown above were doubled, what would be the area of the larger rectangle?

F 36 cm^2
G 72 cm^2
H 144 cm^2
I 288 cm^2

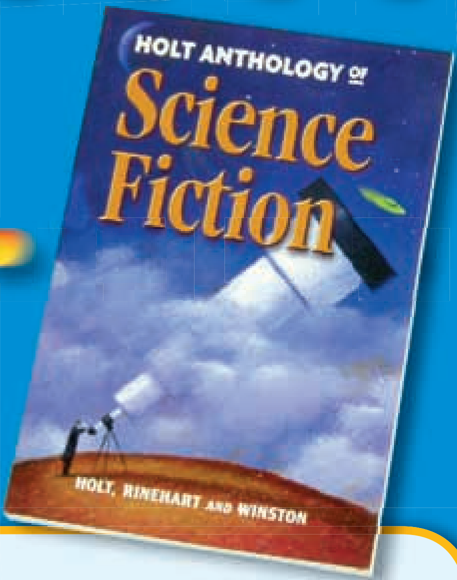
3. One way to calculate the concentration of a solution is to divide the grams of solute by the milliliters of solvent. What is the concentration of a solution that is made by dissolving 65 g of sugar (the solute) in 500 mL of water (the solvent)?

A 0.13 g·mL
B 0.13 g/mL
C 7.7 g·mL
D 7.7 g/mL

4. If 16/n = 1/2, what is the value of *n*?

F 2
G 8
H 16
I 32

Science in Action



Science, Technology, and Society

Dry Cleaning: How Stains Are Dissolved

Sometimes, just water and detergent won't remove stains. For example, have you gotten ink on your favorite sweater? Or have you spilled something greasy on your shirt? In that case, your clothes will probably have to be dry-cleaned. In spite of its name, dry cleaning does involve liquids. First, the kind of stain on your clothing must be determined. If the stain will dissolve in water, a stain remover for that particular stain is applied. Then, the stain is removed with a steam gun. But some stains, such as grease or oil, won't dissolve in water. This kind of stain is treated with a liquid solvent. The clothing is then cleaned in a dry-cleaning machine.

Language Arts ACTIVITY

WRITING SKILL Imagine that you are a stained article of clothing. Write a five-paragraph short story describing how you became stained and how the stain was removed by the dry-cleaning process. You may have to research the dry-cleaning process before writing your story.

Science Fiction

"The Strange Case of Dr. Jekyll and Mr. Hyde" by Robert Louis Stevenson

Although Dr. Henry Jekyll was wild as a young man, he has become a respected doctor and scientist. Dr. Jekyll wants to understand the nature of human identity. His theory is that if he can separate his personality into "good" and "evil" parts, he can get rid of his evil side. Then, he can lead a happy, useful life.

Into Dr. Jekyll's life comes the mysterious Mr. Hyde, a man of action and anger. He sparks fear in the hearts of people he meets. Who is he? And what does he have to do with the deaths of two people? To find out more, read Stevenson's "The Strange Case of Dr. Jekyll and Mr. Hyde" in the *Holt Anthology of Science Fiction*.

Social Studies ACTIVITY

"The Strange Case of Dr. Jekyll and Mr. Hyde" was published in 1886. The story takes place in London, England. What was London like in the 1870s and 1880s? Use the library or the Internet to find information about London and its people at that time. Make a chart that compares London in the 1870s with your hometown today.

Careers

Aundra Nix

Metallurgist Aundra Nix is a chief metallurgist for a copper mine in Sahuarita, Arizona, where she supervises laboratories and other engineers. "To be able to look at rock in the ground and follow it through a process of drilling, blasting, hauling, crushing, grinding, and finally mineral separation—where you can hold a mineral that is one-third copper in your hand—is exciting."

Although she is a supervisor, Nix enjoys the flexible nature of her job. "My work environment includes office and computer work, plant work, and outdoor work. In this field you can 'get your hands into it,' which I always prefer," says Nix. "I did not want a career where it may be years before you see the results of your work." Aundra Nix enjoyed math and science, "so engineering seemed to be a natural area to study," she says. Nix's advice to students planning their own career is to learn all they can in science and technology, because that is the future.

Math ACTIVITY

A large copper-mining company employed about 2,300 people at three locations in New Mexico. Because of an increase in demand for copper, 570 of these workers were hired over a period of a year. Of the 570 new workers, 115 were hired within a three-week period. What percentage of the total work force do the newly hired employees represent? Of the new workers who were hired, what percentage was hired during the three-week hiring period?

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HP5MIXF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS04.

8

The Periodic Table

About the PHOTO

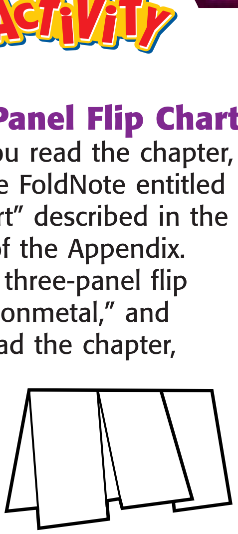
You already know or have heard about elements on the periodic table, such as oxygen, carbon, and neon. Neon gas was discovered in 1898. In 1902, a French engineer, chemist, and inventor named Georges Claude made the first neon lamp. In 1910, Claude made the first neon sign, and in 1923, he introduced neon signs to the United States. Now, artists such as Eric Ehlenberger use glass and neon to create interesting works of art, such as these neon jellyfish.

PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "Metal," "Nonmetal," and "Metalloid." As you read the chapter, write information you learn about each category under the appropriate flap.



START-UP ACTIVITY

Placement Pattern

In this activity, you will identify the pattern your teacher used to create a new classroom seating arrangement.

Procedure

1. Draw a seating chart for the new classroom arrangement that your teacher gave to you. Write the name of each of your classmates in the place on the chart that corresponds to his or her seat.
2. Write information about yourself, such as your name, date of birth, hair color, and height, in the space that represents you on the chart.
3. Gather the same information about the people near you, and write it in the spaces on the chart.

Analysis

1. From the information you gathered, identify a pattern that might explain the order of people in the chart. Collect more information if needed.
2. Test your pattern by gathering information from a person you did not talk to before.
3. If the new information does not support your pattern, reanalyze your data and collect more information to determine another pattern.

SECTION 1

Arranging the Elements

Suppose you went to the video store and all the videos were mixed together. How could you tell the comedies from the action movies? If the videos were not arranged in a pattern, you wouldn't know what kind of movie you had chosen!

Scientists in the early 1860s had a similar problem. At that time, scientists knew some of the properties of more than 60 elements. However, no one had organized the elements according to these properties. Organizing the elements according to their properties would help scientists understand how elements interact with each other.

READING WARM-UP

Objectives

- Describe how Mendeleev arranged elements in the first periodic table.
- Explain how elements are arranged in the modern periodic table.
- Compare metals, nonmetals, and metalloids based on their properties and on their location in the periodic table.
- Describe the difference between a period and a group.

Terms to Learn

periodic
periodic law
period
group

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the difference between periods and groups.

Discovering a Pattern

Dmitri Mendeleev (duh MEE tree MEN duh LAY uhf), a Russian chemist, discovered a pattern to the elements in 1869. First, he wrote the names and properties of the elements on cards. Then, he arranged his cards, as shown in **Figure 1,** by different properties, such as density, appearance, and melting point. After much thought, he arranged the elements in order of increasing atomic mass. When he did so, a pattern appeared.

Reading Check **How had Mendeleev arranged elements when he noticed a pattern?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *By playing "chemical solitaire" on long train rides, Mendeleev organized the elements according to their properties.*

Table 1 Properties of Germanium		
	Mendeleev's predictions (1869)	**Actual properties**
Atomic mass	70	72.6
Density*	5.5 g/cm^3	5.3 g/cm^3
Appearance	dark gray metal	gray metal
Melting point*	high melting point	937°C

* at room temperature and pressure

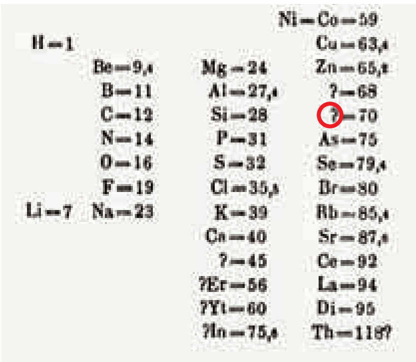


Figure 2 *Mendeleev used question marks to mark some elements that he thought would be found later.*

Periodic Properties of the Elements

Mendeleev saw that when the elements were arranged in order of increasing atomic mass, those that had similar properties occurred in a repeating pattern. That is, the pattern was periodic. **Periodic** means "happening at regular intervals." The days of the week are periodic. They repeat in the same order every 7 days. Similarly, Mendeleev found that the elements' properties followed a pattern that repeated every seven elements. His table became known as the *periodic table of the elements.*

periodic describes something that occurs or repeats at regular intervals

Predicting Properties of Missing Elements

Figure 2 shows part of Mendeleev's first try at arranging the elements. The question marks show gaps in the pattern. Mendeleev predicted that elements yet to be found would fill these gaps. He used the pattern he found to predict their properties. **Table 1** compares his predictions for one missing element—germanium—with its actual properties. By 1886, all of the gaps had been filled. His predictions were right.

periodic law the law that states that the repeating chemical and physical properties of elements change periodically with the atomic numbers of the elements

Changing the Arrangement

A few elements' properties did not fit the pattern in Mendeleev's table. Mendeleev thought that more-accurate atomic masses would fix these flaws in his table. But new atomic mass measurements showed that the masses he had used were correct. In 1914, Henry Moseley (MOHZ lee), a British scientist, determined the number of protons—the atomic number—in an atom. All elements fit the pattern in Mendeleev's periodic table when they were arranged by atomic number.

Look at the periodic table on the next two pages. All of the more than 30 elements discovered since 1914 follow the periodic law. The **periodic law** states that the repeating chemical and physical properties of elements change periodically with the elements' atomic numbers.

Reading Check What property is used to arrange elements in the periodic table?

CONNECTION TO Language Arts

WRITING SKILL **Hidden Help** You may be asked to memorize some of the chemical symbols. A story or poem that uses the symbols might be helpful. In your **science journal,** write a short story, poem, or just a few sentences in which the words correspond to and bring to mind the chemical symbols of the first 20 elements.

Periodic Table of the Elements

Each square on the table includes an element's name, chemical symbol, atomic number, and atomic mass.

The color of the chemical symbol indicates the physical state at room temperature. Carbon is a solid.

6	**Atomic number**
C	**Chemical symbol**
Carbon	**Element name**
12.0	**Atomic mass**

The background color indicates the type of element. Carbon is a nonmetal.

Background	
Metals	light blue
Metalloids	light green
Nonmetals	yellow

Chemical symbol	
Solid	magenta
Liquid	blue
Gas	green

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	1 **H** Hydrogen 1.0								
Period 2	3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0							
Period 3	11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3							
Period 4	19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9
Period 5	37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9
Period 6	55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2
Period 7	87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (265)†	109 **Mt** Meitnerium (268)†

A row of elements is called a *period*.

A column of elements is called a *group* or *family*.

Values in parentheses are of the most stable isotope of the element.

† Estimated from currently available IUPAC data.

Lanthanides	58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4
Actinides	90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)

These elements are placed below the table to allow the table to be narrower.

Topic: Periodic Table
Go To: go.hrw.com
Keyword: HN0 PERIODIC
Visit the HRW Web site for updates on the periodic table.

This zigzag line reminds you where the metals, nonmetals, and metalloids are.

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 **He** Helium 4.0
			5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
			13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulfur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
110 **Ds** Darmstadtium (269)†	111 **Uuu** Unununium (272)†	112 **Uub** Ununbium (277)†		114 **Uuq** Ununquadium (285)†				

The names and three-letter symbols of elements are temporary. They are based on the atomic numbers of the elements. Official names and symbols will be approved by an international committee of scientists.

63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.2	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Quick Lab

Conduction Connection

1. Fill a **plastic-foam cup** with **hot water.**
2. Stand a **piece of copper wire** and a **graphite lead** from a mechanical pencil in the water.
3. After 1 min, touch the top of each object. Record your observations.
4. Which material conducted thermal energy the best? Why?

The Periodic Table and Classes of Elements

At first glance, you might think studying the periodic table is like trying to explore a thick jungle without a guide—you can easily get lost! However, the table itself contains a lot of information that will help you along the way.

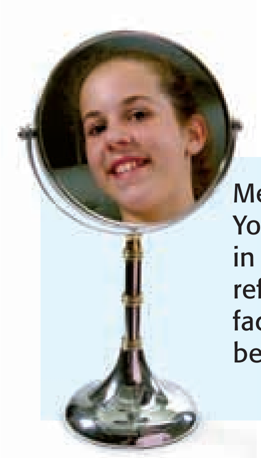
Elements are classified as metals, nonmetals, and metalloids, according to their properties. The number of electrons in the outer energy level of an atom is one characteristic that helps determine which category an element belongs in. The zigzag line on the periodic table can help you recognize which elements are metals, which are nonmetals, and which are metalloids.

Metals

Most elements are metals. Metals are found to the left of the zigzag line on the periodic table. Atoms of most metals have few electrons in their outer energy level. Most metals are solid at room temperature. Mercury, however, is a liquid at room temperature. Some additional information on properties shared by most metals is shown in **Figure 3.**

Reading Check **What are four properties shared by most metals?**

Figure 3 Properties of Metals



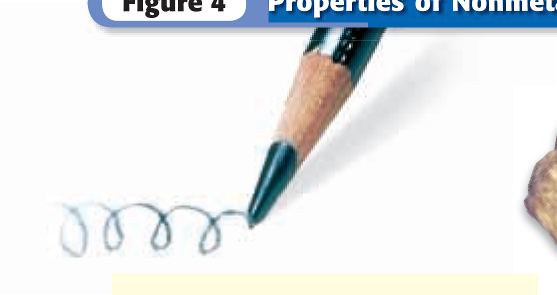
Metals tend to be **shiny.** You can see a reflection in a mirror because light reflects off the shiny surface of a thin layer of silver behind the glass.

Most metals are **ductile,** which means that they can be drawn into thin wires. All metals are **good conductors of electric current.** The wires in the electrical devices in your home are made of copper.

Most metals are **malleable,** which means that they can be flattened with a hammer and will not shatter. Aluminum is flattened into sheets to make cans and foil.

Most metals are **good conductors of thermal energy.** This iron griddle conducts thermal energy from a stove top to cook your favorite foods.

Figure 4 Properties of Nonmetals



Nonmetals are **not malleable or ductile.** In fact, solid nonmetals, such as carbon in the graphite of the pencil lead, are brittle and will break or shatter when hit with a hammer.

Sulfur, like most nonmetals, is **not shiny.**

Nonmetals are **poor conductors of thermal energy and electric current.** If the gap in a spark plug is too wide, the nonmetals nitrogen and oxygen in the air will stop the spark and a car's engine will not run.

Nonmetals

Nonmetals are found to the right of the zigzag line on the periodic table. Atoms of most nonmetals have an almost complete set of electrons in their outer level. Atoms of the elements in Group 18, the noble gases, have a complete set of electrons. More than half of the nonmetals are gases at room temperature. Many properties of nonmetals are the opposite of the properties of metals, as shown in **Figure 4.**

Metalloids

Metalloids, also called *semiconductors,* are the elements that border the zigzag line on the periodic table. Atoms of metalloids have about half of a complete set of electrons in their outer energy level. Metalloids have some properties of metals and some properties of nonmetals, as shown in **Figure 5.**

MATH PRACTICE

Percentages

Elements are classified as metals, nonmetals, and metalloids. Use the periodic table to determine the percentage of elements in each of the three categories.

Figure 5 Properties of Metalloids

Tellurium is **shiny,** but it is **brittle** and can easily be smashed into a powder.

Boron is almost as **hard** as diamond, but it is also **very brittle.** At high temperatures, it is a **good conductor of electric current.**

SCHOOL to HOME

Patterns of Symbols

Divide a sheet of paper into four columns. Look at the elements whose atomic numbers are 1 to 20 on the periodic table. With a parent, find patterns that describe the relationship between the chemical symbols and names of elements. In each column, write all of the chemical symbols and names that follow a single pattern. At the top of each column, write a sentence describing the pattern.

ACTIVITY

period in chemistry, a horizontal row of elements in the periodic table

group a vertical column of elements in the periodic table; elements in a group share chemical properties

Decoding the Periodic Table

The periodic table may seem to be in code. In a way, it is. But the colors and symbols will help you decode the table.

Each Element Is Identified by a Chemical Symbol

Each square on the periodic table includes an element's name, chemical symbol, atomic number, and atomic mass. The names of the elements come from many sources. Some elements, such as mendelevium, are named after scientists. Others, such as californium, are named after places. Some element names vary by country. But the chemical symbols are the same worldwide. For most elements, the chemical symbol has one or two letters. The first letter is always capitalized. Any other letter is always lowercase. The newest elements have temporary three-letter symbols.

Rows Are Called *Periods*

Each horizontal row of elements (from left to right) on the periodic table is called a **period.** Look at Period 4 in **Figure 6.** The physical and chemical properties of elements in a row follow a repeating, or periodic, pattern as you move across the period. Properties such as conductivity and reactivity change gradually from left to right in each period.

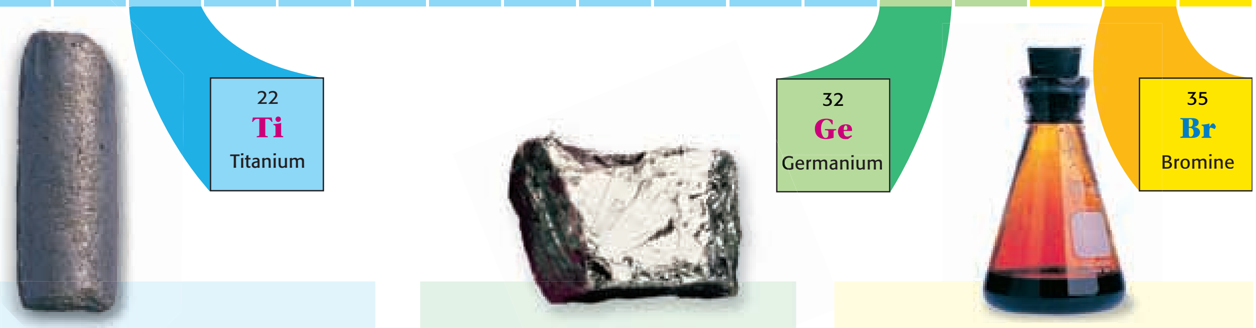
Columns Are Called *Groups*

Each vertical column of elements (from top to bottom) on the periodic table is called a **group.** Elements in the same group often have similar chemical and physical properties. For this reason, a group is also called a *family*.

Reading Check **Why is a group sometimes called a family?**

Figure 6 *As you move from left to right across a row, the elements become less metallic.*

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr



Elements at the left end of a period, such as **titanium,** are very metallic.

Elements farther to the right, such as **germanium,** are less metallic.

Elements at the far-right end of a period, such as **bromine,** are nonmetallic.

SECTION Review

Summary

- Mendeleev developed the first periodic table by listing the elements in order of increasing atomic mass. He used his table to predict that elements with certain properties would be discovered later.
- Properties of elements repeat in a regular, or periodic, pattern.
- Moseley rearranged the elements in order of increasing atomic number.
- The periodic law states that the repeating chemical and physical properties of elements relate to and depend on elements' atomic numbers.
- Elements in the periodic table are classified as metals, nonmetals, and metalloids.
- Each element has a chemical symbol.
- A horizontal row of elements is called a *period*.
- Physical and chemical properties of elements change across each period.
- A vertical column of elements is called a *group* or *family*.
- Elements in a group usually have similar properties.

Using Key Terms

1. In your own words, write a definition for the term *periodic*.

Understanding Key Ideas

2. Which of the following elements should be the best conductor of electric current?

a. germanium
b. sulfur
c. aluminum
d. helium

3. Compare a period and a group on the periodic table.

4. What property did Mendeleev use to position the elements on the periodic table?

5. State the periodic law.

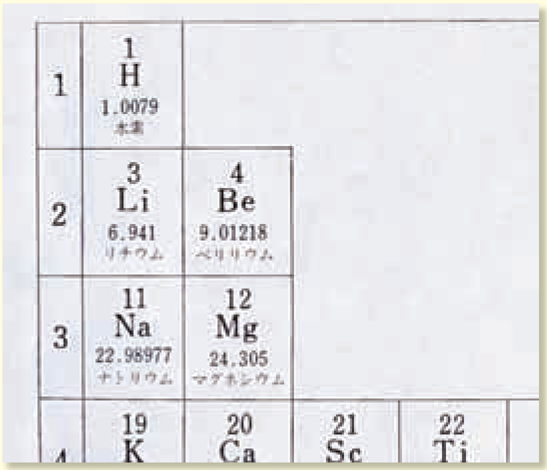
Critical Thinking

6. Identifying Relationships An atom that has 117 protons in its nucleus has not yet been made. Once this atom is made, to which group will element 117 belong? Explain your answer.

7. Applying Concepts Are the properties of sodium, Na, more like the properties of lithium, Li, or magnesium, Mg? Explain your answer.

Interpreting Graphics

8. The image below shows part of a periodic table. Compare the image below with the similar part of the periodic table in your book.



SECTION 2

Grouping the Elements

You probably know a family with several members who look a lot alike. The elements in a family or group in the periodic table often—but not always—have similar properties.

READING WARM-UP

Objectives

- Explain why elements in a group often have similar properties.
- Describe the properties of the elements in the groups of the periodic table.

Terms to Learn

alkali metal
alkaline-earth metal
halogen
noble gas

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

The properties of the elements in a group are similar because the atoms of the elements have the same number of electrons in their outer energy level. Atoms will often take, give, or share electrons with other atoms in order to have a complete set of electrons in their outer energy level. Elements whose atoms undergo such processes are called *reactive* and can combine to form compounds.

Group 1: Alkali Metals

3 Li Lithium
11 Na Sodium
19 K Potassium
37 Rb Rubidium
55 Cs Cesium
87 Fr Francium

Group contains: metals
Electrons in the outer level: 1
Reactivity: very reactive
Other shared properties: softness; color of silver; shininess; low density

Alkali metals (AL kuh LIE MET uhlz) are elements in Group 1 of the periodic table. They share physical and chemical properties, as shown in **Figure 1.** Alkali metals are the most reactive metals because their atoms can easily give away the one outer-level electron. Pure alkali metals are often stored in oil. The oil keeps them from reacting with water and oxygen in the air. Alkali metals are so reactive that in nature they are found only combined with other elements. Compounds formed from alkali metals have many uses. For example, sodium chloride (table salt) is used to flavor your food. Potassium bromide is used in photography.

Hydrogen

Although the element hydrogen appears above the alkali metals on the periodic table, it is not considered a member of Group 1. It will be described separately at the end of this section.

Figure 1 **Properties of Alkali Metals**

Alkali metals are soft enough to be cut with a knife.

Alkali metals react with water to form hydrogen gas.

Group 2: Alkaline-Earth Metals

4	Be Beryllium
12	Mg Magnesium
20	Ca Calcium
38	Sr Strontium
56	Ba Barium
88	Ra Radium

Group contains: metals
Electrons in the outer level: 2
Reactivity: very reactive but less reactive than alkali metals
Other shared properties: color of silver; higher densities than alkali metals

Alkaline-earth metals (AL kuh LIEN UHRTH MET uhlz) are less reactive than alkali metals are. Atoms of alkaline-earth metals have two outer-level electrons. It is more difficult for atoms to give two electrons than to give one when joining with other atoms. Group 2 elements and their compounds have many uses. For example, magnesium can be mixed with other metals to make low-density materials used in airplanes. And compounds of calcium are found in cement, chalk, and even you, as shown in **Figure 2.**

Figure 2 *Calcium, an alkaline-earth metal, is an important part of a compound that keeps your bones and teeth healthy.*

Groups 3–12: Transition Metals

21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn
39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd
57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg
89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Uuu	112 Uub

Group contains: metals
Electrons in the outer level: 1 or 2
Reactivity: less reactive than alkaline-earth metals
Other shared properties: shininess; good conductors of thermal energy and electric current; higher densities and melting points than elements in Groups 1 and 2 (except for mercury)

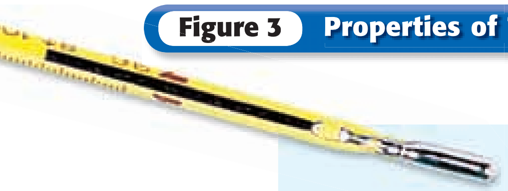
Groups 3–12 do not have individual names. Instead, all of these groups are called *transition metals*. The atoms of transition metals do not give away their electrons as easily as atoms of the Group 1 and Group 2 metals do. So, transition metals are less reactive than alkali metals and alkaline-earth metals are.

Reading Check **Why are alkali metals more reactive than transition metals are?** (*See the Appendix for answers to Reading Checks.*)

alkali metal one of the elements of Group 1 of the periodic table (lithium, sodium, potassium, rubidium, cesium, and francium)

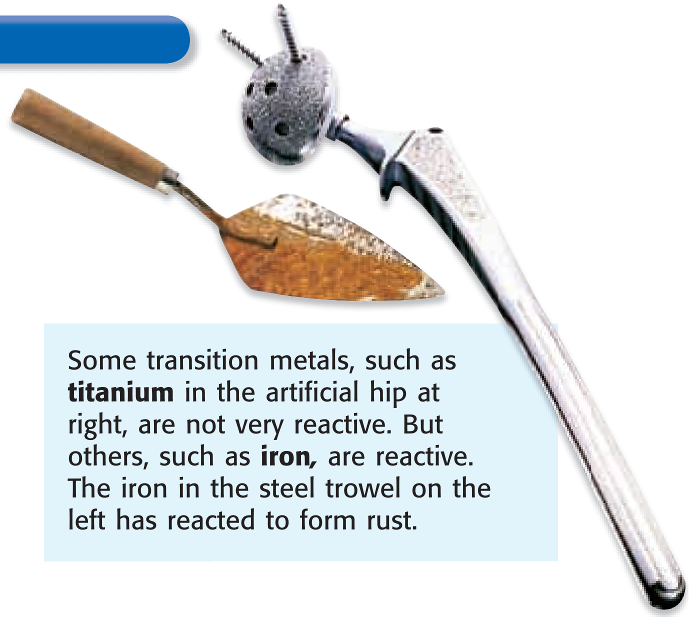
alkaline-earth metal one of the elements of Group 2 of the periodic table (beryllium, magnesium, calcium, strontium, barium, and radium)

Figure 3 Properties of Transition Metals



Mercury is used in thermometers. Unlike the other transition metals, mercury is liquid at room temperature.

Many transition metals—but not all—are silver colored! This **gold** ring proves it!



Some transition metals, such as **titanium** in the artificial hip at right, are not very reactive. But others, such as **iron**, are reactive. The iron in the steel trowel on the left has reacted to form rust.

Properties of Transition Metals

The properties of the transition metals vary widely, as shown in **Figure 3.** But, because these elements are metals, they share the properties of metals. Transition metals tend to be shiny and to conduct thermal energy and electric current well.

Figure 4 *Do you see red? The color red appears on a computer monitor because of a compound formed from europium that coats the back of the screen.*

Lanthanides and Actinides

Some transition metals from Periods 6 and 7 appear in two rows at the bottom of the periodic table to keep the table from being too wide. The elements in each row tend to have similar properties. Elements in the first row follow lanthanum and are called *lanthanides*. The lanthanides are shiny, reactive metals. Some of these elements are used to make steel. An important use of a compound of one lanthanide element is shown in **Figure 4.**

Elements in the second row follow actinium and are called *actinides*. All atoms of actinides are radioactive, or unstable. The atoms of a radioactive element can change into atoms of another element. Elements listed after plutonium, element 94, do not occur in nature. They are made in laboratories. Very small amounts of americium (AM uhr ISH ee uhm), element 95, are used in some smoke detectors.

Reading Check **Are lanthanides and actinides transition metals?**

57 La Lanthanum														
89 Ac Actinium														
Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Group 13: Boron Group

5	B	Boron
13	Al	Aluminum
31	Ga	Gallium
49	In	Indium
81	Tl	Thallium

Group contains: one metalloid and four metals
Electrons in the outer level: 3
Reactivity: reactive
Other shared properties: solids at room temperature

The most common element from Group 13 is aluminum. In fact, aluminum is the most abundant metal in Earth's crust. Until the 1880s, however, aluminum was considered a precious metal because the process used to make pure aluminum was very expensive. During the 1850s and 1860s, Emperor Napoleon III of France used aluminum dinnerware because aluminum was more valuable than gold.

Today, the process of making pure aluminum is easier and less expensive than it was in the 1800s. Aluminum is now an important metal used in making aircraft parts. Aluminum is also used to make lightweight automobile parts, foil, cans, and siding.

Like the other elements in the boron group, aluminum is reactive. Why can it be used in so many things? A thin layer of aluminum oxide quickly forms on aluminum's surface when aluminum reacts with oxygen in the air. This layer prevents further reaction of the aluminum.

CONNECTION TO Environmental Science

WRITING SKILL **Recycling Aluminum**

Aluminum recycling is a very successful program. In your **science journal,** write a one-page report that describes how aluminum is processed from its ore. In your report, identify the ore and compare the energy needed to extract aluminum from the ore with the energy needed to process recycled aluminum.

Group 14: Carbon Group

6	C	Carbon
14	Si	Silicon
32	Ge	Germanium
50	Sn	Tin
82	Pb	Lead
114	Uuq	Ununquadium

Group contains: one nonmetal, two metalloids, and two metals
Electrons in the outer level: 4
Reactivity: varies among the elements
Other shared properties: solids at room temperature

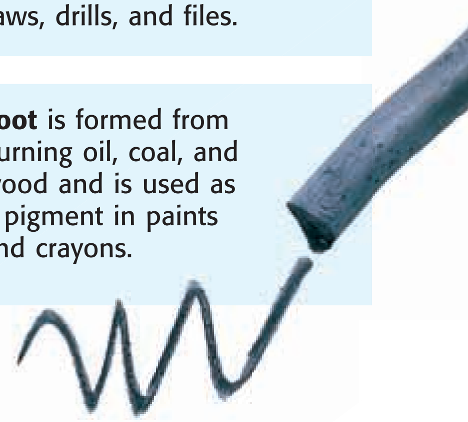
The nonmetal carbon can be found uncombined in nature, as shown in **Figure 5.** Carbon also forms a wide variety of compounds. Some of these compounds, such as proteins, fats, and carbohydrates, are necessary for living things on Earth.

The metalloids silicon and germanium, also in Group 14, are used to make computer chips. The metal tin is useful because it is not very reactive. For example, a tin can is really made of steel coated with tin. Because the tin is less reactive than the steel is, the tin keeps the iron in the steel from rusting.

Reading Check **What metalloids from Group 14 are used to make computer chips?**

Figure 5 *Diamond and soot have very different properties, yet both are natural forms of carbon.*

Diamond is the hardest material known. It is used as a jewel and on cutting tools, such as saws, drills, and files.



Soot is formed from burning oil, coal, and wood and is used as a pigment in paints and crayons.

Group 15: Nitrogen Group

7	**N** Nitrogen
15	**P** Phosphorus
33	**As** Arsenic
51	**Sb** Antimony
83	**Bi** Bismuth

Group contains: two nonmetals, two metalloids, and one metal
Electrons in the outer level: 5
Reactivity: varies among the elements
Other shared properties: solids at room temperature (except for nitrogen)

Nitrogen, which is a gas at room temperature, makes up about 80% of the air you breathe. Nitrogen removed from air can be reacted with hydrogen to make ammonia for fertilizers.

Although nitrogen is not very reactive, phosphorus is extremely reactive, as shown in **Figure 6.** In fact, in nature phosphorus is only found combined with other elements.

Figure 6 *Simply striking a match on the side of this box causes chemicals on the match to react with phosphorus on the box and begin to burn.*

Group 16: Oxygen Group

8	**O** Oxygen
16	**S** Sulfur
34	**Se** Selenium
52	**Te** Tellurium
84	**Po** Polonium

Group contains: three nonmetals, one metalloid, and one metal
Electrons in the outer level: 6
Reactivity: Reactive
Other shared properties: All but oxygen are solid at room temperature.

Oxygen makes up about 20% of air. Oxygen is necessary for substances to burn. Oxygen is also important to most living things, such as the diver in **Figure 7.** Sulfur is another commonly found member of Group 16. Sulfur can be found as a yellow solid in nature. It is used to make sulfuric acid, the most widely used compound in the chemical industry.

Reading Check **Which gases from Groups 15 and 16 make up most of the air you breathe?**

Figure 7 *This diver is breathing a mixture that contains oxygen gas.*

Figure 8 Physical Properties of Some Halogens

Group 17: Halogens

9	**F** Fluorine
17	**Cl** Chlorine
35	**Br** Bromine
53	**I** Iodine
85	**At** Astatine

Group contains: nonmetals
Electrons in the outer level: 7
Reactivity: very reactive
Other shared properties: poor conductors of electric current; violent reactions with alkali metals to form salts; never in uncombined form in nature

Halogens (HAL oh juhnz) are very reactive nonmetals because their atoms need to gain only one electron to have a complete outer level. The atoms of halogens combine readily with other atoms, especially metals, to gain that missing electron. The reaction of a halogen with a metal makes a salt, such as sodium chloride. Both chlorine and iodine are used as disinfectants. Chlorine is used to treat water. Iodine mixed with alcohol is used in hospitals.

Although the chemical properties of the halogens are similar, the physical properties are quite different, as shown in **Figure 8.**

halogen one of the elements of Group 17 of the periodic table (fluorine, chlorine, bromine, iodine, and astatine); halogens combine with most metals to form salts

CONNECTION TO Biology

Water Treatment Chlorine has been used to treat drinking water since the early 20th century. Chlorinating water helps protect people from many diseases by killing the organisms in water that cause the diseases. But there is much more to water treatment than just adding chlorine. Research how a water treatment plant purifies water for your use. Construct a model of a treatment plant. Use labels to describe the role of each part of the plant in treating the water you use each day.

ACTIVITY

Group 18: Noble Gases

Figure 9 *In addition to neon, other noble gases can be used to make "neon" lights.*

2	**He** Helium
10	**Ne** Neon
18	**Ar** Argon
36	**Kr** Krypton
54	**Xe** Xenon
86	**Rn** Radon

Group contains: nonmetals
Electrons in the outer level: 8 (except helium, which has 2)
Reactivity: unreactive
Other shared properties: colorless, odorless gases at room temperature

Noble gases are unreactive nonmetals and are in Group 18 of the periodic table. The atoms of these elements have a full set of electrons in their outer level. So, they do not need to lose or gain any electrons. Under normal conditions, they do not react with other elements. Earth's atmosphere is almost 1% argon. But all the noble gases are found in small amounts.

The unreactivity of the noble gases makes them useful. For example, ordinary light bulbs last longer when they are filled with argon. Because argon is unreactive, it does not react with the metal filament in the light bulb even when the filament gets hot. A more reactive gas might react with the filament, causing the light to burn out. The low density of helium makes blimps and weather balloons float. Another popular use of noble gases is shown in **Figure 9.**

Reading Check **Why are noble gases unreactive?**

noble gas one of the elements of Group 18 of the periodic table (helium, neon, argon, krypton, xenon, and radon); noble gases are unreactive

Hydrogen

1	**H** Hydrogen

Electrons in the outer level: 1
Reactivity: reactive
Other properties: colorless, odorless gas at room temperature; low density; explosive reactions with oxygen

The properties of hydrogen do not match the properties of any single group, so hydrogen is set apart from the other elements in the table. Hydrogen is above Group 1 because atoms of the alkali metals also have only one electron in their outer level. Atoms of hydrogen can give away one electron when they join with other atoms. However, the physical properties of hydrogen are more like those of nonmetals than those of metals. So, hydrogen really is in a group of its own. Hydrogen is found in stars. In fact, it is the most abundant element in the universe. Its reactive nature makes it useful as a fuel in rockets, as shown in **Figure 10.**

Figure 10 *Hydrogen reacts violently with oxygen. The hot water vapor that forms as a result of this reaction helps guide the space shuttle into orbit.*

SECTION Review

Summary

- Alkali metals (Group 1) are the most reactive metals. Atoms of the alkali metals have one electron in their outer level.
- Alkaline-earth metals (Group 2) are less reactive than the alkali metals are. Atoms of the alkaline-earth metals have two electrons in their outer level.
- Transition metals (Groups 3–12) include most of the well-known metals and the lanthanides and actinides.
- Groups 13–16 contain the metalloids and some metals and nonmetals.
- Halogens (Group 17) are very reactive non-metals. Atoms of the halogens have seven electrons in their outer level.
- Noble gases (Group 18) are unreactive nonmetals. Atoms of the noble gases have a full set of electrons in their outer level.
- Hydrogen is set off by itself in the periodic table. Its properties do not match the properties of any one group.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

noble gas	alkaline-earth metal
halogen	alkali metal

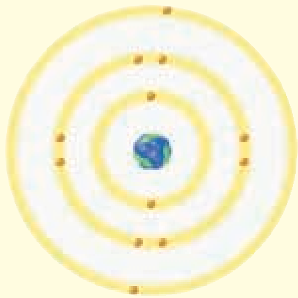
1. An atom of a(n) ___ has a full set of electrons in its outermost energy level.
2. An atom of a(n) ___ has one electron in its outermost energy level.
3. An atom of a(n) ___ tends to gain one electron when it combines with another atom.
4. An atom of a(n) ___ tends to lose two electrons when it combines with another atom.

Understanding Key Ideas

5. Which group contains elements whose atoms have six electrons in their outer level?
   - a. Group 2
   - b. Group 6
   - c. Group 16
   - d. Group 18
6. What are two properties of the alkali metals?
7. What causes the properties of elements in a group to be similar?
8. What are two properties of the halogens?
9. Why is hydrogen set apart from the other elements in the periodic table?
10. Which group contains elements whose atoms have three electrons in their outer level?

Interpreting Graphics

11. Look at the model of an atom below. Does the model represent a metal atom or a nonmetal atom? Explain your answer.



Critical Thinking

12. **Making Inferences** Why are neither the alkali metals nor the alkaline-earth metals found uncombined in nature?
13. **Making Comparisons** Compare the element hydrogen with the alkali metal sodium.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Alkali Metals; Halogens and Noble Gases

SciLinks code: HSM0043; HSM0711

Model-Making Lab

Create a Period Table

OBJECTIVES

Classify objects based on their properties.

Identify patterns and trends in data.

MATERIALS

- bag of objects
- balance, metric
- meterstick
- paper, graphing (2 sheets)
- paper, 3 × 3 cm squares (20)

You probably have classification systems for many things in your life, such as your clothes, your books, and your CDs. One of the most important classification systems in science is the periodic table of the elements. In this lab, you will develop your own classification system for a collection of ordinary objects. You will analyze trends in your system and compare your system with the periodic table of the elements.

Procedure

1. Your teacher will give you a bag of objects. Your bag is missing one item. Examine the items carefully. Describe the missing object in as many ways as you can. Be sure to include the reasons why you think the missing object has the characteristics you describe.
2. Lay the paper squares out on your desk or table so that you have a grid of five rows of four squares each.
3. Arrange your objects on the grid in a logical order. (You must decide what order is logical!) You should end up with one blank square for the missing object.
4. Record a description of the basis for your arrangement.

5. Measure the mass (g) and diameter (mm) of each object, and record your results in the appropriate square. Each square (except the empty one) should have one object and two written measurements on it.
6. Examine your pattern again. Does the order in which your objects are arranged still make sense? Explain.
7. Rearrange the squares and their objects if necessary to improve your arrangement. Record a description of the basis for the new arrangement.
8. Working across the rows, number the squares 1 to 20. When you get to the end of a row, continue numbering in the first square of the next row.
9. Copy your grid. In each square, be sure to list the type of object and label all measurements with appropriate units.

Analyze the Results

1. **Constructing Graphs** Make a graph of mass (y-axis) versus object number (x-axis). Label each axis, and title the graph.
2. **Constructing Graphs** Now make a graph of diameter (y-axis) versus object number (x-axis).

Draw Conclusions

3. **Analyzing Graphs** Discuss each graph with your classmates. Try to identify any important features of the graph. For example, does the graph form a line or a curve? Is there anything unusual about the graph? What do these features tell you? Record your answers.
4. **Evaluating Models** How is your arrangement of objects similar to the periodic table of the elements found in this textbook? How is your arrangement different from that periodic table?
5. **Making Predictions** Look again at your prediction about the missing object. Do you think your prediction is still accurate? Try to improve your description by estimating the mass and diameter of the missing object. Record your estimates.
6. **Evaluating Methods** Mendeleev created a periodic table of elements and predicted characteristics of missing elements. How is your experiment similar to Mendeleev's work?

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

group	period
alkali metals	halogens
alkaline-earth metals	noble gases

1. Elements in the same vertical column on the periodic table belong to the same ___.

2. Elements in the same horizontal row on the periodic table belong to the same ___.

3. The most reactive metals are ___.

4. Elements that are unreactive are called ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

5. Mendeleev's periodic table was useful because it
   - **a.** showed the elements arranged by atomic number.
   - **b.** had no empty spaces.
   - **c.** showed the atomic number of the elements.
   - **d.** allowed for the prediction of the properties of missing elements.

6. Most nonmetals are
   - **a.** shiny.
   - **b.** poor conductors of electric current.
   - **c.** flattened when hit with a hammer.
   - **d.** solids at room temperature.

7. Which of the following items is NOT found on the periodic table?
   - **a.** the atomic number of each element
   - **b.** the name of each element
   - **c.** the date that each element was discovered
   - **d.** the atomic mass of each element

8. Which of the following statements about the periodic table is false?
   - **a.** There are more metals than nonmetals on the periodic table.
   - **b.** Atoms of elements in the same group have the same number of electrons in their outer level.
   - **c.** The elements at the far left of the periodic table are nonmetals.
   - **d.** Elements are arranged by increasing atomic number.

9. Which of the following statements about alkali metals is true?
   - **a.** Alkali metals are generally found in their uncombined form.
   - **b.** Alkali metals are Group 1 elements.
   - **c.** Alkali metals should be stored underwater.
   - **d.** Alkali metals are unreactive.

10. Which of the following statements about elements is true?
    - **a.** Every element occurs naturally.
    - **b.** All elements are found in their uncombined form in nature.
    - **c.** Each element has a unique atomic number.
    - **d.** All of the elements exist in approximately equal quantities.

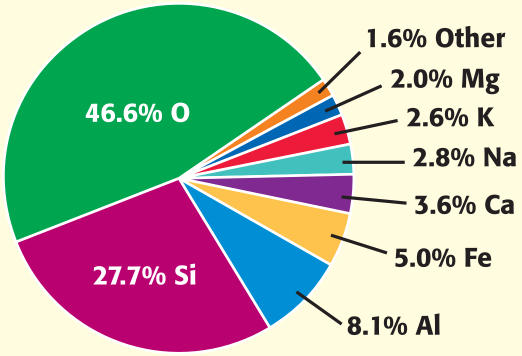
Short Answer

11 How is Moseley's basis for arranging the elements different from Mendeleev's?

12 How is the periodic table like a calendar?

Math Skills

Examine the chart of the percentages of elements in the Earth's crust below. Then, answer the questions that follow.



13 Excluding the "Other" category, what percentage of the Earth's crust are alkali metals?

14 Excluding the "Other" category, what percentage of the Earth's crust are alkaline-earth metals?

CRITICAL THINKING

15 **Concept Mapping** Use the following terms to create a concept map: *periodic table, elements, groups, periods, metals, nonmetals,* and *metalloids*.

16 **Forming Hypotheses** Why was Mendeleev unable to make any predictions about the noble gas elements?

17 **Identifying Relationships** When an element that has 115 protons in its nucleus is synthesized, will it be a metal, a nonmetal, or a metalloid? Explain your answer.

18 **Applying Concepts** Your classmate offers to give you a piece of sodium that he found on a hiking trip. What is your response? Explain.

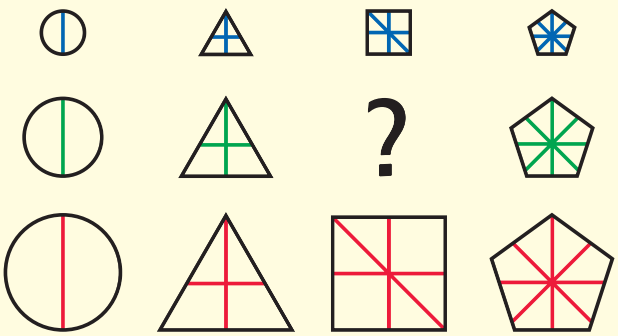
19 **Applying Concepts** Identify each element described below.

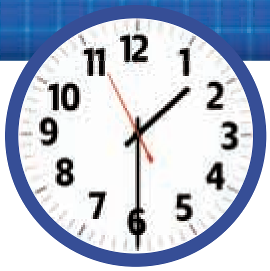
a. This metal is very reactive, has properties similar to those of magnesium, and is in the same period as bromine.

b. This nonmetal is in the same group as lead.

INTERPRETING GRAPHICS

20 Study the diagram below to determine the pattern of the images. Predict the missing image, and draw it. Identify which properties are periodic and which properties are shared within a group.





Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Napoleon III (1808–1873) ruled as emperor of France from 1852 to 1870. Napoleon III was the nephew of the famous French military leader and emperor Napoleon I. Early in his reign, Napoleon III was an authoritarian ruler. France's economy did well under his dictatorial rule, so the French rebuilt cities and built railways. During the 1850s and 1860s, Napoleon III used aluminum dinnerware because aluminum was more valuable than gold. Despite his wealth and French economic prosperity, Napoleon III lost public support and popularity. So, in 1860, he began a series of reforms that allowed more individual freedoms in France.

1. What is the meaning of the word *authoritarian* in the passage?

- **A** controlling people's thoughts and actions
- **B** writing books and stories
- **C** being an expert on a subject
- **D** being very wealthy

2. Which of the following statements best describes why Napoleon III probably changed the way he ruled France?

- **F** He was getting old.
- **G** He was unpopular and had lost public support.
- **H** He had built as many railroads as he could.
- **I** He used aluminum dinnerware.

3. According to the passage, in what year did Napoleon III die?

- **A** 1808
- **B** 1873
- **C** 1860
- **D** 1852

Passage 2 Named after architect Buckminster Fuller, buckyballs resemble the geodesic domes that are characteristic of the architect's work. Excitement over buckyballs began in 1985, when scientists projected light from a laser onto a piece of graphite. In the soot that remained, researchers found a completely new kind of molecule! Buckyballs are also found in the soot from a candle flame. Some scientists claim to have detected buckyballs in space. In fact, one suggestion is that buckyballs are at the center of the condensing clouds of gas, dust, and debris that form galaxies.

1. Which of the following statements correctly describes buckyballs?

- **A** They are a kind of dome-shaped building.
- **B** They are shot from lasers.
- **C** They were unknown before 1985.
- **D** They are named for the scientist who discovered them.

2. Based on the passage, which of the following statements is an opinion?

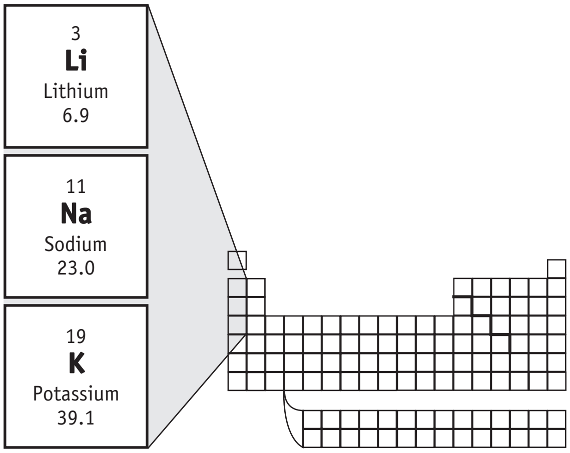
- **F** Buckyballs might be in the clouds that form galaxies.
- **G** Buckyballs are named after an architect.
- **H** Scientists found buckyballs in soot.
- **I** Buckyballs are a kind of molecule.

3. According to the passage, why were scientists excited?

- **A** Buckyballs were found in space.
- **B** An architect created a building that resembled a molecule.
- **C** Buckyballs were found to be in condensing clouds of gas that form galaxies.
- **D** A new kind of molecule was found.

INTERPRETING GRAPHICS

Use the image of the periodic table below to answer the questions that follow.



1. Which of the following statements is correct for the elements shown?

A Lithium has the greatest atomic number.
B Sodium has the least atomic mass.
C Atomic number decreases as you move down the column.
D Atomic mass increases as you move down the column.

2. Which of the following statements best describes the outer electrons in atoms of the elements shown?

F The atoms of each element have 1 outer-level electron.
G Lithium atoms have 3 outer-level electrons, sodium atoms have 11, and potassium atoms have 19.
H Lithium atoms have 7 outer-level electrons, sodium atoms have 23, and potassium atoms have 39.
I The atoms of each element have 11 outer-level electrons.

3. The elements featured in the image belong to which of the following groups?

A noble gases
B alkaline-earth metals
C halogens
D alkali metals

MATH

Read each question below, and choose the best answer.

1. Elvira's house is 7.3 km from her school. What is this distance expressed in meters?

A 0.73 m
B 73 m
C 730 m
D 7,300 m

2. A chemical company is preparing a shipment of 10 g each of four elements. Each element must be shipped in its own container that is completely filled with the element. Which container will be the largest?

Element	Density (g/cm^3)	Mass (g)
Aluminum	2.702	10
Arsenic	5.727	10
Germanium	5.350	10
Silicon	2.420	10

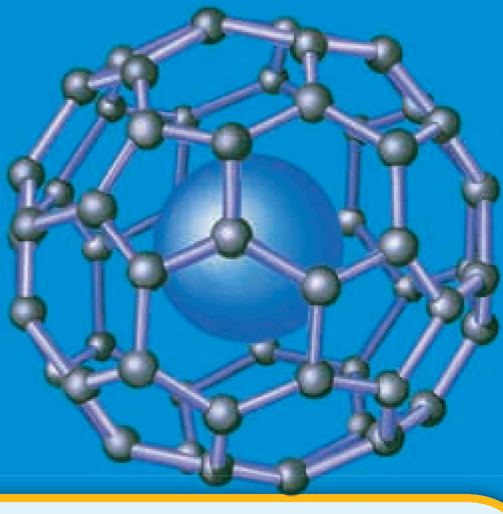
F the container of aluminum
G the container of arsenic
H the container of germanium
I the container of silicon

3. Arjay has samples of several common elements. Each element has a unique atomic mass (expressed in amu). Which of the following lists shows the atomic masses in order from least to greatest?

A 63.55, 58.69, 55.85, 58.93
B 63.55, 58.93, 58.69, 55.85
C 55.85, 58.69, 58.93, 63.55
D 55.85, 63.55, 58.69, 58.93

Standardized Test Preparation

Science in Action



Weird Science

Buckyballs

In 1985, scientists found a completely new kind of molecule! This carbon molecule has 60 carbon atoms linked together in a shape similar to that of a soccer ball. This molecule is called a buckyball. Buckyballs have also been found in the soot from candle flames. And some scientists claim to have detected buckyballs in space. Chemists have been trying to identify the molecules' properties. One property is that a buckyball can act like a cage and hold smaller substances, such as individual atoms. Buckyballs are both slippery and strong. Scientists are exploring their use in tough plastics and cutting tools.

Language Arts ACTIVITY

WRITING SKILL Imagine that you are trapped within a buckyball. Write a one-page short story describing your experience. Describe the windows in your molecular prison.

Science, Technology, and Society

The Science of Fireworks

Explosive and dazzling, a fireworks display is both a science and an art. More than 1,000 years ago, the Chinese made black powder, or gunpowder. The powder was used to set off firecrackers and primitive missiles. The shells of fireworks contain several different chemicals. Black powder at the bottom of the shell launches the shell into the sky. A second layer of black powder ignites the rest of the chemicals and causes an explosion that lights up the sky! Colors can be created by mixing chemicals such as strontium (for red), magnesium (for white), or copper (for blue) with the gunpowder.

Math ACTIVITY

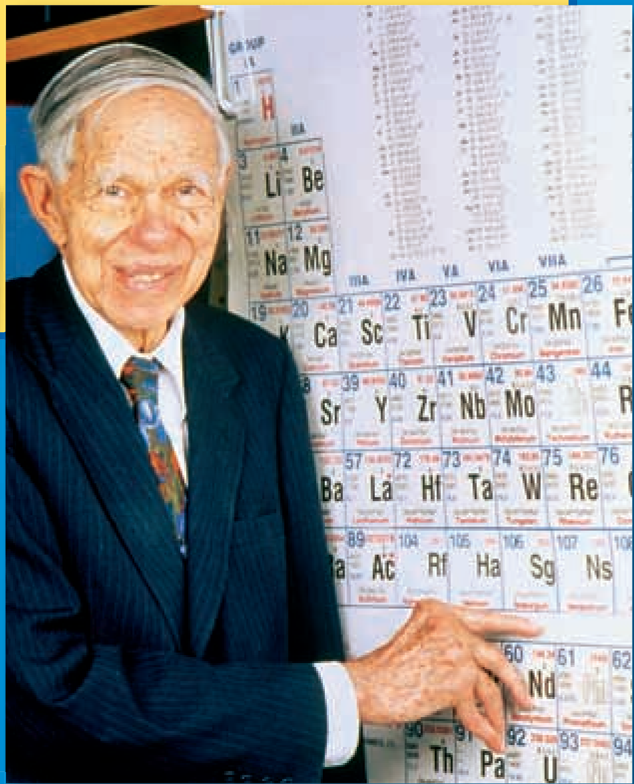
Fireworks can cost between \$200 and \$2,000 each. If a show uses 20 fireworks that cost \$200 each, 12 fireworks that cost \$500 each, and 10 fireworks that cost \$1,200 each, what is the total cost for the fireworks?

People in Science

Glenn T. Seaborg

Making Elements When you look at the periodic table, you can thank Dr. Glenn Theodore Seaborg and his colleagues for many of the actinide elements. While working at the University of California at Berkeley, Seaborg and his team added a number of elements to the periodic table. His work in identifying properties of plutonium led to his working on the top-secret Manhattan Project at the University of Chicago. He was outspoken about the beneficial uses of atomic energy and, at the same time, opposed the production and use of nuclear weapons.

Seaborg's revision of the layout of the periodic table—the actinide concept—is the most significant since Mendeleev's original design. For his scientific achievements, Dr. Seaborg was awarded the 1951 Nobel Prize in Chemistry jointly with his colleague, Dr. Edwin M. McMillan. Element 106, which Seaborg neither discovered nor created, was named seaborgium in his honor. This was the first time an element had been named after a living person.



Social Studies ACTIVITY

WRITING SKILL Write a newspaper editorial to express an opinion for or against the Manhattan Project. Be sure to include information to support your view.

go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HP5PRTF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS12.

UNIT 3

TIMELINE

Interactions of Matter

In this unit you will study the interactions through which matter can change its identity. You will learn how atoms bond with one another to form compounds and how atoms join in different combinations to form new substances through chemical reactions. You will also learn about the benefits and risks of using chemicals. This timeline includes some of the events leading to the current understanding of these interactions of matter.

1828

Urea, a compound found in urine, is produced in a laboratory. Until this time, chemists had believed that compounds created by living organisms could not be produced in the laboratory.

1858

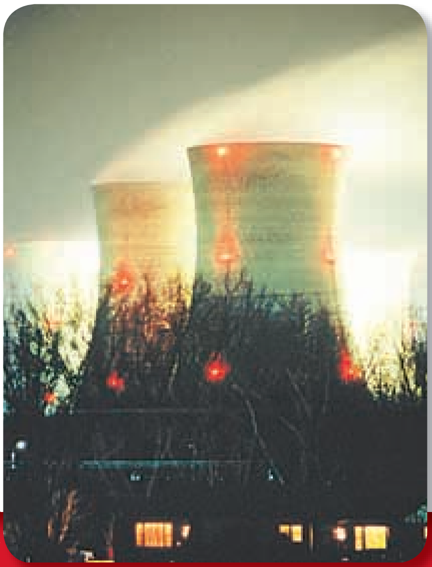
German chemist Friedrich August Kekulé suggests that carbon forms four chemical bonds and can form long chains.

1942

The first nuclear chain reaction is carried out in a squash court under the football stadium at the University of Chicago.

1979

Public fear about nuclear power grows after an accident occurs at the Three Mile Island nuclear power station located in Pennsylvania.



1867
Swedish chemist Alfred Nobel develops dynamite. Dynamite's explosive power is a result of the decomposition reaction of nitroglycerin.

1898
The United States defeats Spain in the Spanish-American War.

1903
Marie Curie, Pierre Curie, and Henri Becquerel are awarded the Nobel Prize in physics for the discovery of radioactivity.

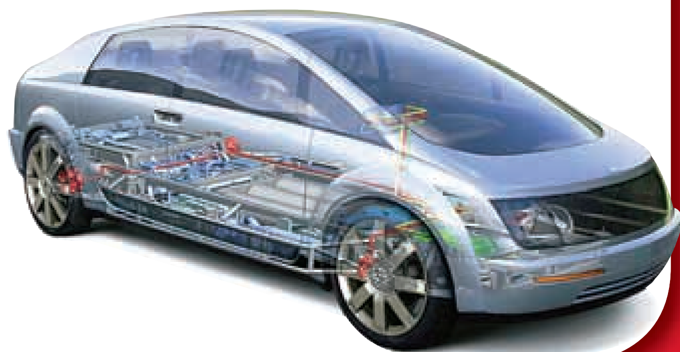
1964
Dr. Martin Luther King, Jr., American civil rights leader, is awarded the Nobel Peace Prize.

1969
The *Nimbus III* weather satellite is launched by the United States, representing the first civilian use of nuclear batteries.

1996
Evidence of organic compounds in a meteorite leads scientists to speculate that life may have existed on Mars more than 3.6 billion years ago.

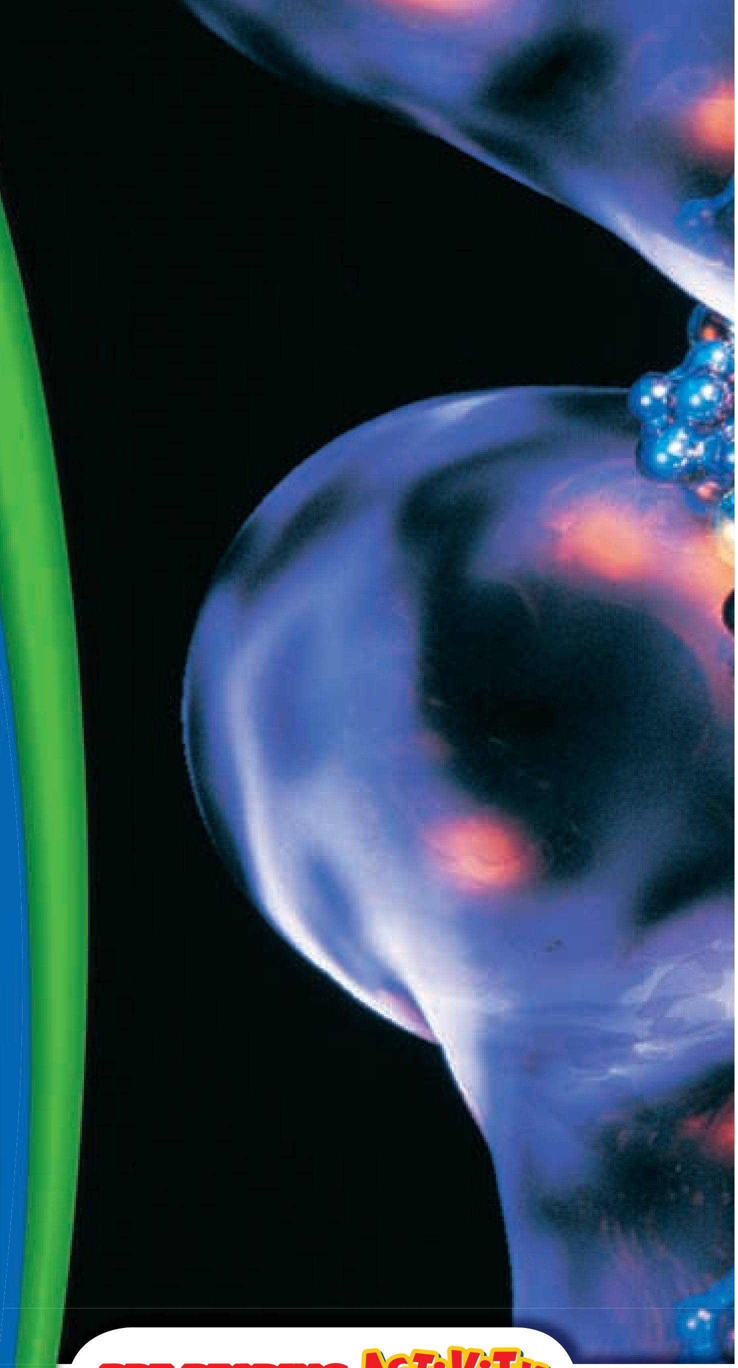
2001
The first total solar eclipse of the millenium occurs on June 21.

2002
Hy-wire, the world's first drivable vehicle to combine a hydrogen fuel cell with by-wire technology, is introduced.



9

Chemical Bonding



About the PHOTO

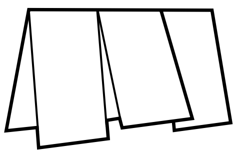
What looks like a fantastic "sculpture" is really a model of deoxyribonucleic acid (DNA). DNA is one of the most complex molecules in living things. In DNA, atoms are bonded together in two very long spiral strands. These strands join to form a double spiral. The DNA in living cells has all the coding for passing on the traits of that cell and that organism.

PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "Ionic bond," "Covalent bond," and "Metallic bond." As you read the chapter, write information you learn about each category under the appropriate flap.



START-UP ACTIVITY

From Glue to Goop

Particles of glue can bond to other particles and hold objects together. Different types of bonds create differences in the properties of substances. In this activity, you will see how the formation of bonds causes a change in the properties of white glue.

Procedure

1. Fill a **small paper cup** 1/4 full of **white glue.** Record the properties of the glue.
2. Fill a **second small paper cup** 1/4 full of **borax solution.**
3. Pour the borax solution into the cup of white glue, and stir well using a **plastic spoon** or a **wooden craft stick.**
4. When the material becomes too thick to stir, remove it from the cup and knead it with your fingers. Record the properties of the material.

Analysis

1. Compare the properties of the glue with those of the new material.
2. The properties of the material resulted from bonds between the borax and the glue. Predict the properties of the material if less borax is used.

SECTION 1

Electrons and Chemical Bonding

READING WARM-UP

Objectives

- Describe chemical bonding.
- Identify the number of valence electrons in an atom.
- Predict whether an atom is likely to form bonds.

Terms to Learn

chemical bonding
chemical bond
valence electron

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Have you ever stopped to consider that by using only the 26 letters of the alphabet, you make all of the words you use every day?

Although the number of letters is limited, combining the letters in different ways allows you to make a huge number of words. In the same way that words can be formed by combining letters, substances can be formed by combining atoms.

Combining Atoms Through Chemical Bonding

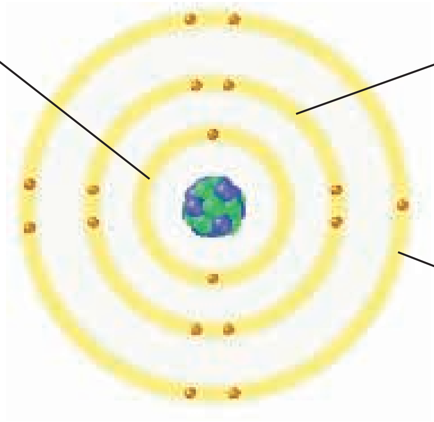
Look at **Figure 1.** Now, look around the room. Everything you see—desks, pencils, paper, and even your friends—is made of atoms of elements. All substances are made of atoms of one or more of the approximately 100 elements. For example, the atoms of carbon, hydrogen, and oxygen combine in different patterns to form sugar, alcohol, and citric acid. **Chemical bonding** is the joining of atoms to form new substances. The properties of these new substances are different from the properties of the original elements. An interaction that holds two atoms together is called a **chemical bond.** When chemical bonds form, electrons are shared, gained, or lost.

Discussing Bonding Using Theories and Models

We cannot see atoms and chemical bonds with the unaided eye. For more than 150 years, scientists have done many experiments that have led to a theory of chemical bonding. Remember that a theory is an explanation for some phenomenon that is based on observation, experimentation, and reasoning. The use of models helps people discuss the theory of how and why atoms form bonds.

Figure 1 *Everything you see in this photo is formed by combining atoms.*

Figure 2 **Electron Arrangement in an Atom**



a The **first energy level** is closest to the nucleus and can hold up to 2 electrons.

b Electrons will begin filling the **second energy level** only after the first level is full. The second energy level can hold up to 8 electrons.

c The **third energy level** in this model of a chlorine atom has only 7 electrons, so the atom has a total of 17 electrons. This outer level of the atom is not full.

Electron Number and Organization

To understand how atoms form chemical bonds, you need to know about the electrons in an atom. The number of electrons in an atom can be determined from the atomic number of the element. The *atomic number* is the number of protons in an atom. But atoms have no charge. So, the atomic number also represents the number of electrons in the atom.

Electrons in an atom are organized in energy levels. **Figure 2** shows a model of the arrangement of electrons in a chlorine atom. This model and models like it are useful for counting electrons in energy levels of atoms. But, these models do not show the true structure of atoms.

chemical bonding the combining of atoms to form molecules or ionic compounds

chemical bond an interaction that holds atoms or ions together

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

Outer-Level Electrons and Bonding

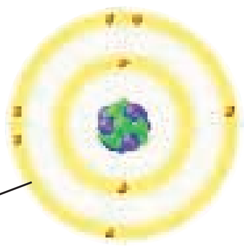
Not all of the electrons in an atom make chemical bonds. Most atoms form bonds using only the electrons in the outermost energy level. An electron in the outermost energy level of an atom is a **valence electron** (VAY luhns ee LEK TRAHN). The models in **Figure 3** show the valence electrons for two atoms.

Reading Check **Which electrons are used to form bonds?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 **Counting Valence Electrons**

Oxygen
Electron total: 8
First level: 2 electrons
Second level: 6 electrons

An oxygen atom has 6 valence electrons.



Sodium
Electron total: 11
First level: 2 electrons
Second level: 8 electrons
Third level: 1 electron

A sodium atom has 1 valence electron.

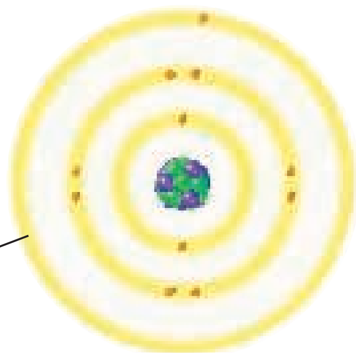


Figure 4 **Determining the Number of Valence Electrons**

Atoms of elements in **Groups 1 and 2** have the same number of valence electrons as their group number.

Atoms of elements in **Groups 3–12** do not have a rule relating their valence electrons to their group number.

Atoms of elements in **Groups 13–18** have 10 fewer valence electrons than their group number. However, helium atoms have only 2 valence electrons.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Uuu	Uub		Uuq				

Valence Electrons and the Periodic Table

You can use a model to determine the number of valence electrons of an atom. But what would you do if you didn't have a model? You can use the periodic table to determine the number of valence electrons for atoms of some elements.

Elements are grouped based on similar properties. Within a group, or family, the atoms of each element have the same number of valence electrons. So, the group numbers can help you determine the number of valence electrons for some atoms, as shown in **Figure 4.**

CONNECTION TO Social Studies

WRITING SKILL **History of a Noble Gas** When Dmitri Mendeleev organized the first periodic table, he did not include the noble gases. The noble gases had not been discovered at that time. Research the history of the discovery of one of the noble gases. Write a paragraph in your **science journal** to summarize what you learned.

To Bond or Not to Bond

Not all atoms bond in the same manner. In fact, some atoms rarely bond at all! The number of electrons in the outermost energy level of an atom determines whether an atom will form bonds.

Atoms of the noble gases (Group 18) do not usually form chemical bonds. Atoms of Group 18 elements (except helium) have 8 valence electrons. Having 8 valence electrons is a special condition. In fact, atoms that have 8 electrons in their outermost energy level do not usually form bonds. The outermost energy level of an atom is considered to be full if the energy level contains 8 electrons.

Reading Check **The atoms of which group in the periodic table rarely form chemical bonds?**

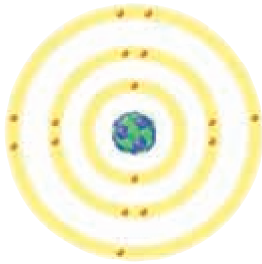
Filling The Outermost Level

An atom that has fewer than 8 valence electrons is much more likely to form bonds than an atom that has 8 valence electrons is. Atoms bond by gaining, losing, or sharing electrons to have a filled outermost energy level. A filled outermost level contains 8 valence electrons. **Figure 5** describes how atoms can achieve a filled outermost energy level.

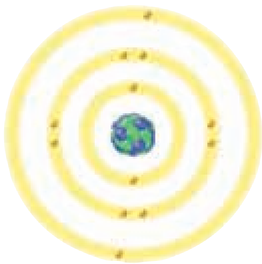
Is Two Electrons a Full Set?

Not all atoms need 8 valence electrons to have a filled outermost energy level. Helium atoms need only 2 valence electrons. The outermost energy level in a helium atom is the first energy level. The first energy level of any atom can hold only 2 electrons. So, the outermost energy level of a helium atom is full if the energy level has only 2 electrons. Atoms of hydrogen and lithium also form bonds by gaining, losing, or sharing electrons to achieve 2 electrons in the first energy level.

Figure 5 **Filling Outermost Energy Levels**



Sulfur
An atom of sulfur has 6 valence electrons. It can have 8 valence electrons by sharing 2 electrons with or gaining 2 electrons from other atoms.



Magnesium
An atom of magnesium has 2 valence electrons. It can have a full outer level by losing 2 electrons. The second energy level becomes the outermost energy level and contains 8 electrons.

SECTION Review

Summary

- Chemical bonding is the joining of atoms to form new substances. A chemical bond is an interaction that holds two atoms together.
- A valence electron is an electron in the outermost energy level of an atom.
- Most atoms form bonds by gaining, losing, or sharing electrons until they have 8 valence electrons. Atoms of some elements need only 2 electrons to fill their outermost level.

Using Key Terms

1. Use the following terms in the same sentence: *chemical bond* and *valence electron*.

Understanding Key Ideas

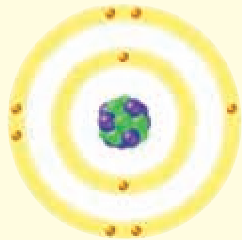
2. Which of the following atoms do not usually form bonds?
   a. calcium
   b. neon
   c. hydrogen
   d. oxygen
3. Describe chemical bonding.
4. Explain how to use the valence electrons in an atom to predict if the atom will form bonds.

Critical Thinking

5. **Making Inferences** How can an atom that has 5 valence electrons achieve a full set of valence electrons?
6. **Applying Concepts** Identify the number of valence electrons in a barium atom.

Interpreting Graphics

7. Look at the model below. How many valence electrons are in a fluorine atom? Will fluorine atoms form bonds? Explain.



Fluorine

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Electron; Periodic Table
SciLinks code: HSM0489; HSM1125

SECTION 2

Ionic Bonds

Have you ever accidentally tasted sea water? If so, you probably didn't enjoy it. What makes sea water taste different from the water in your home?

Sea water tastes different because salt is dissolved in it. One of the salts in sea water is the same as the salt that you eat. The chemical bonds in salt are ionic (ie AHN ik) bonds.

READING WARM-UP

Objectives

- Explain how ionic bonds form.
- Describe how positive ions form.
- Describe how negative ions form.
- Explain why ionic compounds are neutral.

Terms to Learn

ionic bond
ion
crystal lattice

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Forming Ionic Bonds

An **ionic bond** is a bond that forms when electrons are transferred from one atom to another atom. During ionic bonding, one or more valence electrons are transferred from one atom to another. Like all chemical bonds, ionic bonds form so that the outermost energy levels of the atoms in the bonds are filled. **Figure 1** shows another substance that contains ionic bonds.

Charged Particles

An atom is neutral because the number of electrons in an atom equals the number of protons. So, the charges of the electrons and protons cancel each other. A transfer of electrons between atoms changes the number of electrons in each atom. But the number of protons stays the same in each atom. The negative charges and positive charges no longer cancel out, and the atoms become ions. **Ions** are charged particles that form when atoms gain or lose electrons. An atom normally cannot gain electrons without another atom nearby to lose electrons (or cannot lose electrons without a nearby atom to gain them). But it is easier to study the formation of ions one at a time.

ionic bond a bond that forms when electrons are transferred from one atom to another, which results in a positive ion and a negative ion

ion a charged particle that forms when an atom or group of atoms gains or loses one or more electrons

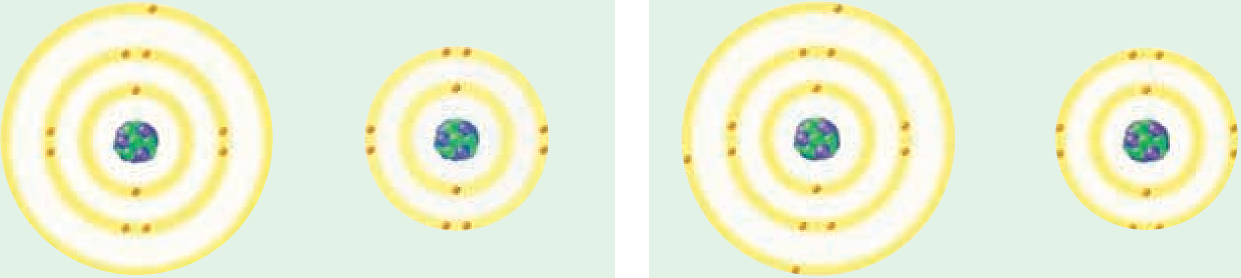
Reading Check **Why are atoms neutral?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *Calcium carbonate in this snail's shell contains ionic bonds.*

Figure 2 **Forming Positive Ions**

Here's How It Works: During chemical changes, a sodium atom can lose its 1 electron in the third energy level to another atom. The filled second level becomes the outermost level, so the resulting sodium ion has 8 valence electrons.

Here's How It Works: During chemical changes, an aluminum atom can lose its 3 electrons in the third energy level to another atom. The filled second level becomes the outermost level, so the resulting aluminum ion has 8 valence electrons.



Sodium atom (Na)

11+	protons
11−	electrons
0	charge

Sodium ion (Na^+)

11+	protons
10−	electrons
1+	charge

Aluminum atom (Al)

13+	protons
13−	electrons
0	charge

Aluminum ion (Al^{3+})

13+	protons
10−	electrons
3+	charge

Forming Positive Ions

Ionic bonds form during chemical changes when atoms pull electrons away from other atoms. The atoms that lose electrons form ions that have fewer electrons than protons. Because the positive charges outnumber the negative charges, these ions have a positive charge.

Metal Atoms and the Loss of Electrons

Atoms of most metals have few valence electrons. Metal atoms tend to lose these valence electrons and form positive ions. Look at the models in **Figure 2.** When a sodium atom loses its only valence electron to another atom, the sodium atom becomes a sodium ion. A sodium ion has 1 more proton than it has electrons. So, the sodium ion has a 1+ charge. The chemical symbol for this ion is written as Na^+. Notice that the charge is written to the upper right of the chemical symbol. **Figure 2** also shows a model for the formation of an aluminum ion.

The Energy Needed to Lose Electrons

Energy is needed to pull electrons away from atoms. Only a small amount of energy is needed to take electrons from metal atoms. In fact, the energy needed to remove electrons from atoms of elements in Groups 1 and 2 is so small that these elements react very easily. The energy needed to take electrons from metals comes from the formation of negative ions.

SCHOOL to HOME

Studying Salt

Spread several grains of salt on a dark sheet of construction paper. Use a magnifying lens to examine the salt. Ask an adult at home to examine the salt. Discuss what you saw. Then, gently tap the salt with a small hammer. Examine the salt again. Describe your observations in your **science journal.**

ACTIVITY

MATH PRACTICE

Calculating Charge

Calculating the charge of an ion is the same as adding integers (positive or negative whole numbers and 0) that have opposite signs. You write the number of protons as a positive integer and the number of electrons as a negative integer. Then, you add the integers. Calculate the charge of an ion that contains 16 protons and 18 electrons. Write the ion's symbol and name.

Forming Negative Ions

Some atoms gain electrons from other atoms during chemical changes. The ions that form have more electrons than protons. So, these ions have a negative charge.

Nonmetal Atoms Gain Electrons

The outermost energy level of nonmetal atoms is almost full. Only a few electrons are needed to fill the outer level of a nonmetal atom. So, atoms of nonmetals tend to gain electrons from other atoms. Look at the models in **Figure 3.** When an oxygen atom gains 2 electrons, it becomes an oxide ion that has a 2− charge. The symbol for the oxide ion is O^{2-}. Notice that the name of the negative ion formed from oxygen ends with *-ide*. This ending is used for the names of the negative ions formed when atoms gain electrons. **Figure 3** also shows a model of how a chloride ion is formed.

The Energy of Gaining Electrons

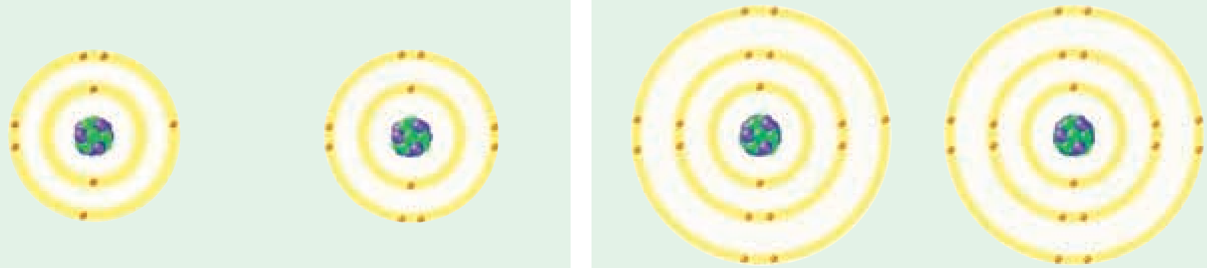
Energy is given off by most nonmetal atoms when they gain electrons. The more easily an atom gains an electron, the more energy the atom releases. Atoms of Group 17 elements give off the most energy when they gain an electron. These elements are very reactive. An ionic bond will form between a metal and a nonmetal if the nonmetal releases more energy than is needed to take electrons from the metal.

✓ *Reading Check* **Atoms of which group on the periodic table give off the most energy when forming negative ions?**

Figure 3 **Forming Negative Ions**

Here's How It Works: During chemical changes, an oxygen atom gains 2 electrons in the second energy level from another atom. An oxide ion that has 8 valence electrons is formed. Thus, its outermost energy level is filled.

Here's How It Works: During chemical changes, a chlorine atom gains 1 electron in the third energy level from another atom. A chloride ion that has 8 valence electrons is formed. Thus, its outermost energy level is filled.



Oxygen atom (O)

8+	protons
8−	electrons
0	charge

Oxide ion (O^{2-})

8+	protons
10−	electrons
2−	charge

Chlorine atom (Cl)

17+	protons
17−	electrons
0	charge

Chloride ion (Cl^{-})

17+	protons
18−	electrons
1−	charge

Ionic Compounds

When ionic bonds form, the number of electrons lost by the metal atoms equals the number gained by the nonmetal atoms. The ions that bond are charged, but the compound formed is neutral because the charges of the ions cancel each other. When ions bond, they form a repeating three-dimensional pattern called a **crystal lattice** (KRIS tuhl LAT is), like the one shown in **Figure 4.** The strong attraction between ions in a crystal lattice gives ionic compounds certain properties, which include brittleness, high melting points, and high boiling points.

crystal lattice the regular pattern in which a crystal is arranged

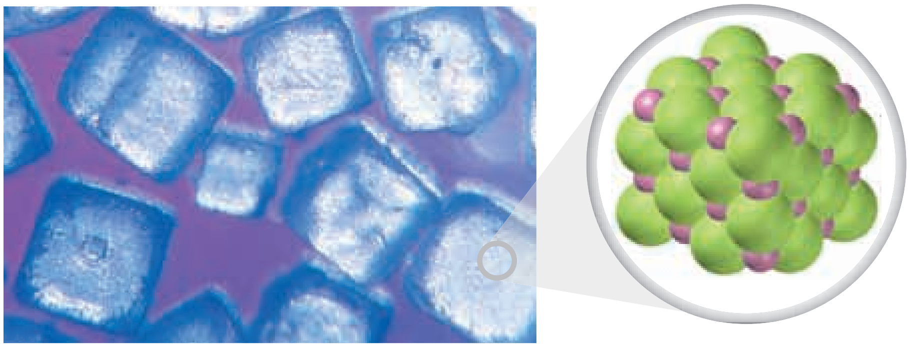


Figure 4 *This model of the crystal lattice of sodium chloride, or table salt, shows a three-dimensional view of the bonded ions. In the model, the sodium ions are pink and the chloride ions are green.*

SECTION Review

Summary

- An ionic bond is a bond that forms when electrons are transferred from one atom to another. During ionic bonding, the atoms become oppositely charged ions.
- Ionic bonding usually occurs between atoms of metals and atoms of nonmetals.
- Energy is needed to remove electrons from metal atoms. Energy is released when most nonmetal atoms gain electrons.

Using Key Terms

1. Use the following terms in the same sentence: *ion* and *ionic bond*.
2. In your own words, write a definition for the term *crystal lattice*.

Understanding Key Ideas

3. Which types of atoms usually become negative ions?
   - **a.** metals
   - **b.** nonmetals
   - **c.** noble gases
   - **d.** All of the above
4. How does an atom become a positive ion? a negative ion?
5. What are two properties of ionic compounds?

Math Skills

6. What is the charge of an ion that has 12 protons and 10 electrons? Write the ion's symbol.

Critical Thinking

7. **Applying Concepts** Which group of elements gains two valence electrons when the atoms form ionic bonds?
8. **Identifying Relationships** Explain why ionic compounds are neutral even though they are made up of charged particles.
9. **Making Comparisons** Compare the formation of positive ions with the formation of negative ions in terms of energy changes.

SECTION 3

Covalent and Metallic Bonds

Imagine bending a wooden coat hanger and a wire coat hanger. The wire one would bend easily, but the wooden one would break. Why do these things behave differently?

One reason is that the bonds between the atoms of each object are different. The atoms of the wooden hanger are held together by covalent bonds (KOH VAY luhnt BAHNDZ). But the atoms of the wire hanger are held together by metallic bonds. Read on to learn about the difference between these kinds of chemical bonds.

READING WARM-UP

Objectives

- Explain how covalent bonds form.
- Describe molecules.
- Explain how metallic bonds form.
- Describe the properties of metals.

Terms to Learn

covalent bond
molecule
metallic bond

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Covalent Bonds

Most things around you, such as water, sugar, oxygen, and wood, are held together by covalent bonds. Substances that have covalent bonds tend to have low melting and boiling points and are brittle in the solid state. For example, oxygen has a low boiling point, which is why it is a gas at room temperature. And wood is brittle, so it breaks when bent.

A **covalent bond** forms when atoms share one or more pairs of electrons. When two atoms of nonmetals bond, a large amount of energy is needed for either atom to lose an electron. So, two nonmetals don't transfer electrons to fill the outermost energy levels of their atoms. Instead, two nonmetal atoms bond by sharing electrons with each another, as shown in the model in **Figure 1.**

covalent bond a bond formed when atoms share one or more pairs of electrons

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

Figure 1 *By sharing electrons in a covalent bond, each hydrogen atom (the smallest atom) has a full outermost energy level containing two electrons.*

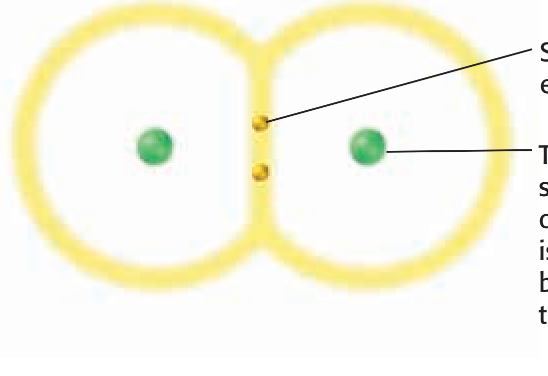
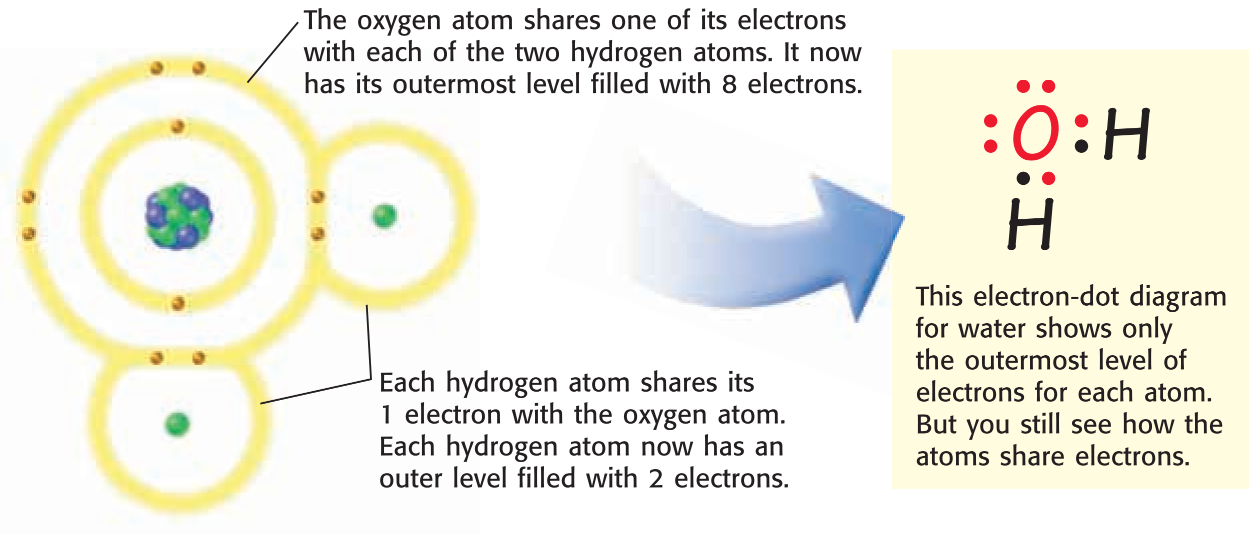


Figure 2 Covalent Bonds in a Water Molecule



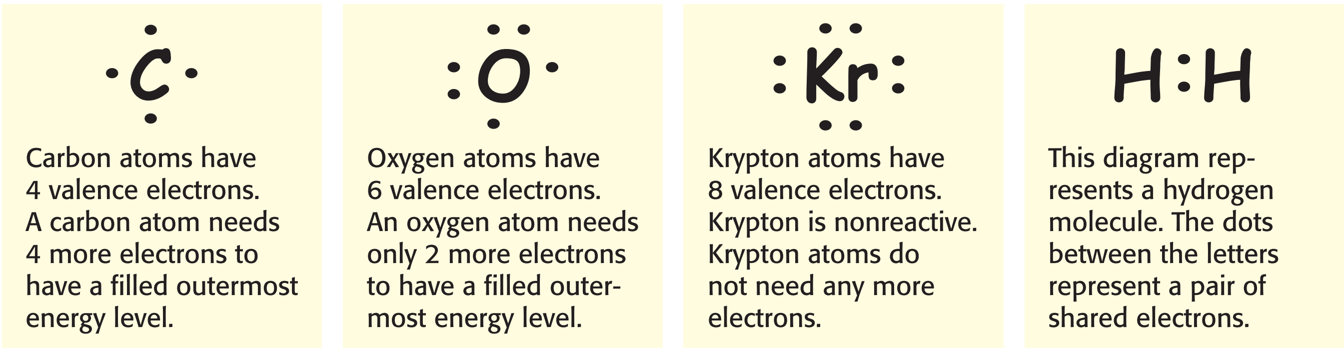
Covalent Bonds and Molecules

Substances containing covalent bonds consist of individual particles called molecules (MAHL i KYOOLZ). A **molecule** usually consists of two or more atoms joined in a definite ratio. A hydrogen molecule is composed of two covalently bonded hydrogen atoms. However, most molecules are composed of atoms of two or more elements. The models in **Figure 2** show two ways to represent the covalent bonds in a water molecule.

molecule the smallest unit of a substance that keeps all of the physical and chemical properties of that substance

One way to represent atoms and molecules is to use electron-dot diagrams. An electron-dot diagram is a model that shows only the valence electrons in an atom. Electron-dot diagrams can help you predict how atoms might bond. To draw an electron-dot diagram, write the symbol of the element and place one dot around the symbol for every valence electron in the atom, as shown in **Figure 3.** Place the first 4 dots alone on each side, and then pair up any remaining dots.

Figure 3 Using Electron-Dot Diagrams



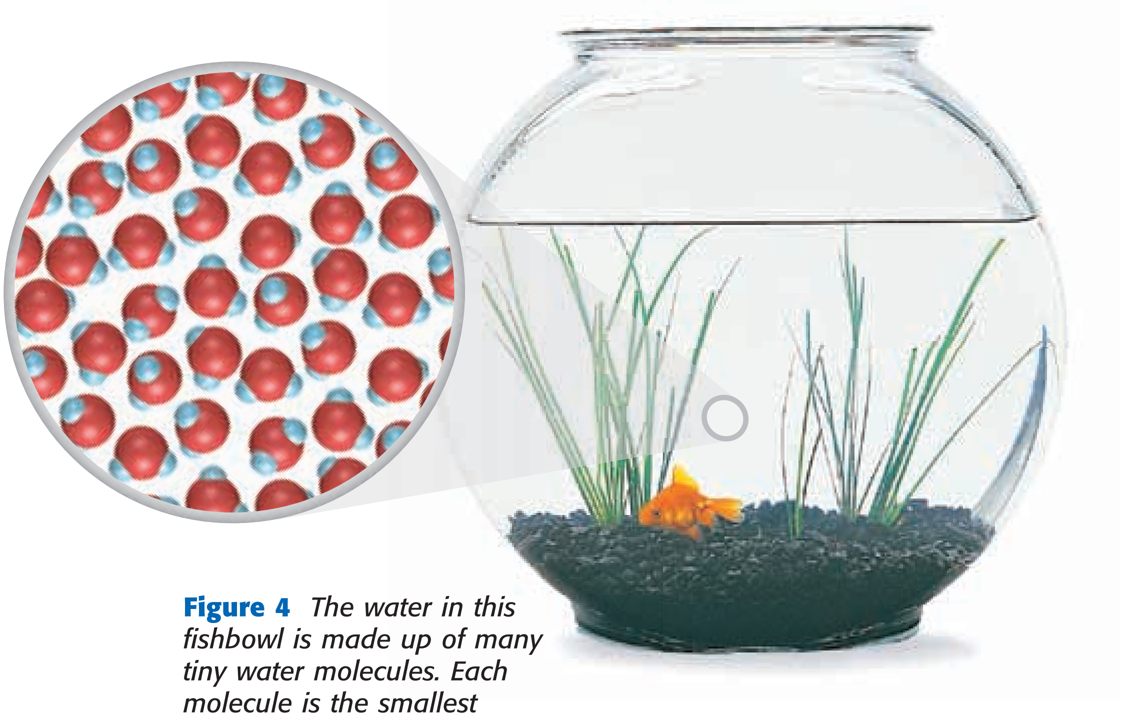


Figure 4 *The water in this fishbowl is made up of many tiny water molecules. Each molecule is the smallest particle that has the chemical properties of water.*

Covalent Compounds and Molecules

An atom is the smallest particle into which an element can be divided and still be the same element. Likewise, a molecule is the smallest particle into which a covalently bonded compound can be divided and still be the same compound. Look at the three-dimensional models in **Figure 4.** They show how a sample of water is made up of many individual molecules of water. Imagine dividing water over and over. You would eventually end up with a single molecule of water. What would happen if you separated the hydrogen and oxygen atoms that make up a water molecule? Then, you would no longer have water.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5BNDW.**

The Simplest Molecules

Molecules are composed of at least two covalently bonded atoms. The simplest molecules are made up of two bonded atoms. Molecules made up of two atoms of the same element are called *diatomic molecules*. Elements that are found in nature as diatomic molecules are called *diatomic elements*. Hydrogen is a diatomic element. Oxygen, nitrogen, and the halogens fluorine, chlorine, bromine, and iodine are also diatomic elements. Look at **Figure 5.** The shared electrons are counted as valence electrons for each atom. So, both atoms of the molecule have filled outermost energy levels.

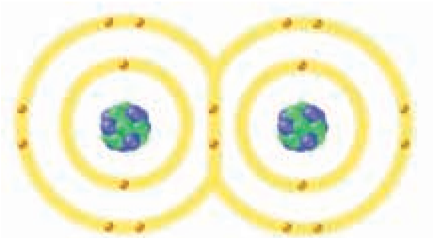


Figure 5 *Two covalently bonded fluorine atoms have filled outermost energy levels. The two electrons shared by the atoms are counted as valence electrons for each atom.*

Reading Check **How many atoms are in a diatomic molecule?**

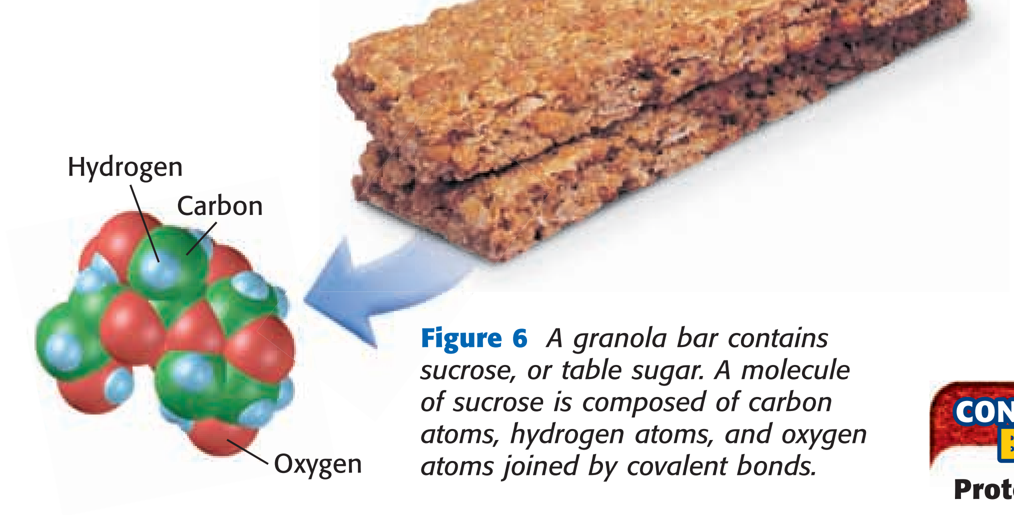


Figure 6 *A granola bar contains sucrose, or table sugar. A molecule of sucrose is composed of carbon atoms, hydrogen atoms, and oxygen atoms joined by covalent bonds.*

More-Complex Molecules

Diatomic molecules are the simplest molecules. They are also some of the most important molecules. You could not live without diatomic oxygen molecules. But other important molecules are much more complex. Soap, plastic bottles, and even proteins in your body are examples of complex molecules. Carbon atoms are the basis of many of these complex molecules. Each carbon atom needs to make four covalent bonds to have 8 valence electrons. These bonds can be with atoms of other elements or with other carbon atoms, as shown in the model in **Figure 6.**

CONNECTION TO Biology

Proteins Proteins perform many functions throughout your body. A single protein can have thousands of covalently bonded atoms. Proteins are built from smaller molecules called *amino acids*. Make a poster showing how amino acids are joined to make proteins.

ACTIVITY

Metallic Bonds

Look at the unusual metal sculptures shown in **Figure 7.** Some metal pieces have been flattened, while other metal pieces have been shaped into wires. How could the artist change the shape of the metal into all of these different forms without breaking the metal into pieces? Metal can be shaped because of the presence of a metallic bond, a special kind of chemical bond. A **metallic bond** is a bond formed by the attraction between positively charged metal ions and the electrons in the metal. Positively charged metal ions form when metal atoms lose electrons.

metallic bond a bond formed by the attraction between positively charged metal ions and the electrons around them

Figure 7 *The different shapes of metal in these sculptures are possible because of the bonds that hold the metal together.*

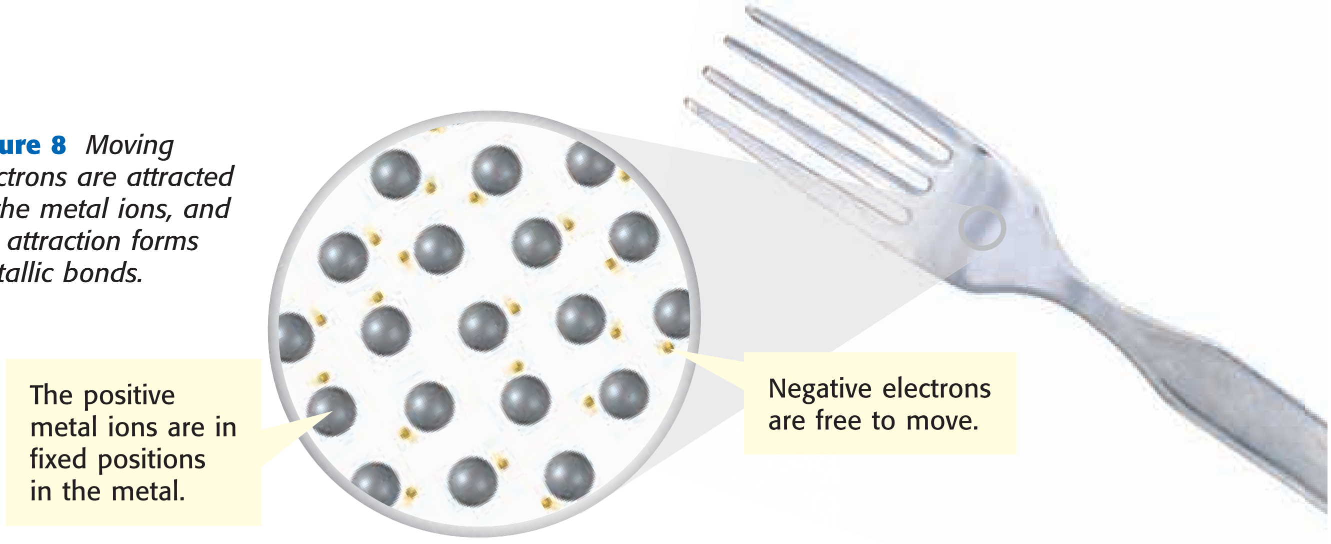


Figure 8 *Moving electrons are attracted to the metal ions, and the attraction forms metallic bonds.*

Movement of Electrons Throughout a Metal

Bonding in metals is a result of the metal atoms being so close to one another that their outermost energy levels overlap. This overlapping allows valence electrons to move throughout the metal, as shown in **Figure 8.** You can think of a metal as being made up of positive metal ions that have enough valence electrons "swimming" around to keep the ions together. The electrons also cancel the positive charge of the ions. Metallic bonds extend throughout the metal in all directions.

Quick Lab

Bending with Bonds

1. Straighten out a **wire paper clip.** Record your observations.
2. Bend a **piece of chalk.** Record your observations.
3. Chalk is composed of calcium carbonate, a compound containing ionic bonds. What kind of bond is present in the paper clip?
4. Explain why you could change the shape of the paper clip but could not bend the chalk without breaking it.

Properties of Metals

Metallic bonding is what gives metals their particular properties. These properties include electrical conductivity, malleability, and ductility.

Conducting Electric Current

Metallic bonding allows metals to conduct electric current. For example, when you turn on a lamp, electrons move within the copper wire that connects the lamp to the outlet. The electrons that move are the valence electrons in the copper atoms. These electrons are free to move because the electrons are not connected to any one atom.

Reshaping Metals

Because the electrons swim freely around the metal ions, the atoms in metals can be rearranged. As a result, metals can be reshaped. The properties of *ductility* (the ability to be drawn into wires) and *malleability* (the ability to be hammered into sheets) describe a metal's ability to be reshaped. For example, copper is made into wires for use in electrical cords. Aluminum can be pounded into thin sheets and made into aluminum foil.

Reading Check **What is ductility?**

Bending Without Breaking

When a piece of metal is bent, some of the metal ions are forced closer together. You might expect the metal to break because all of the metal ions are positively charged. Positively charged ions repel one another. However, positive ions in a metal are always surrounded by and attracted to the electrons in the metal—even if the metal ions move. The electrons constantly move around and between the metal ions. The moving electrons maintain the metallic bonds no matter how the shape of the metal changes. So, metal objects can be bent without being broken, as shown in **Figure 9.**

Figure 9 *Metal can be reshaped without breaking because metallic bonds occur in many directions.*

SECTION Review

Summary

- In covalent bonding, two atoms share electrons. A covalent bond forms when atoms share one or more pairs of electrons.
- Covalently bonded atoms form a particle called a *molecule*. A molecule is the smallest particle of a compound that has the chemical properties of the compound.
- In metallic bonding, the valence electrons move throughout the metal. A bond formed by the attraction between positive metal ions and the electrons in the metal is a metallic bond.
- Properties of metals include conductivity, ductility, and malleability.

Using Key Terms

1. Use each of the following terms in a separate sentence: *covalent bond* and *metallic bond*.
2. In your own words, write a definition for the term *molecule*.

Understanding Key Ideas

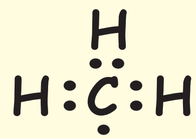
3. Between which of the following atoms is a covalent bond most likely to occur?
   a. calcium and lithium
   b. sodium and fluorine
   c. nitrogen and oxygen
   d. helium and argon
4. What happens to the electrons in covalent bonding?
5. How many dots does an electron-dot diagram of a sulfur atom have?
6. List three properties of metals that are a result of metallic bonds.
7. Describe how the valence electrons in a metal move.
8. Explain the difference between ductility and malleability. Give an example of when each property is useful.

Critical Thinking

9. **Identifying Relationships** How do the metallic bonds in a staple allow it to function properly?
10. **Applying Concepts** Draw an electron-dot diagram for ammonia (a nitrogen atom covalently bonded to three hydrogen atoms).

Interpreting Graphics

11. This electron-dot diagram is not complete. Which atom needs to form another bond? Explain.



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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Types of Chemical Bonds; Properties of Metals

SciLinks code: HSM1565; HSM1231

Model-Making Lab

Covalent Marshmallows

OBJECTIVES

Build a three-dimensional model of a water molecule.

Draw an electron-dot diagram of a water molecule.

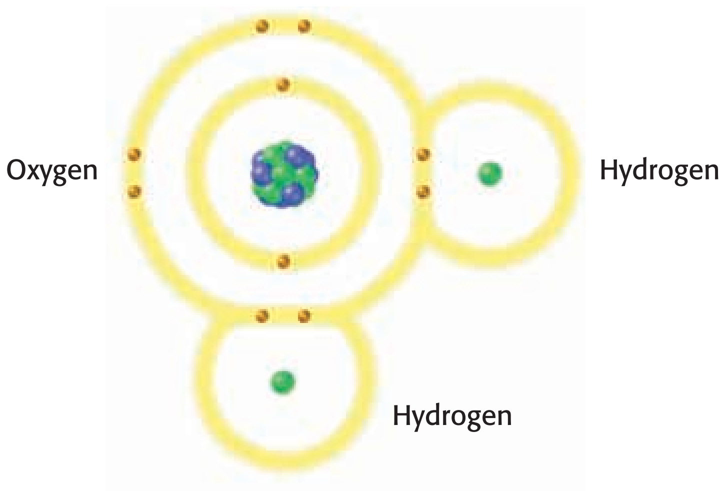
MATERIALS

- marshmallows (two of one color, one of another color)
- toothpicks

SAFETY

A hydrogen atom has 1 electron in its outermost energy level, but 2 electrons are required to fill its outermost level. An oxygen atom has 6 electrons in its outermost level, but 8 electrons are required to fill its outermost level. To fill their outermost energy levels, two atoms of hydrogen and one atom of oxygen can share electrons, as shown below. Such a sharing of electrons to fill the outermost level of atoms is called *covalent bonding*. When hydrogen and oxygen bond in this manner, a molecule of water is formed. In this lab, you will build a three-dimensional model of water to better understand the covalent bonds formed in a water molecule.

A Model of a Water Molecule



Procedure

1. Using the marshmallows and toothpicks, create a model of a water molecule. Use the diagram above for guidance in building your model.
2. Draw a sketch of your model. Be sure to label the hydrogen and oxygen atoms on your sketch.
3. Draw an electron-dot diagram of the water molecule.

Analyze the Results

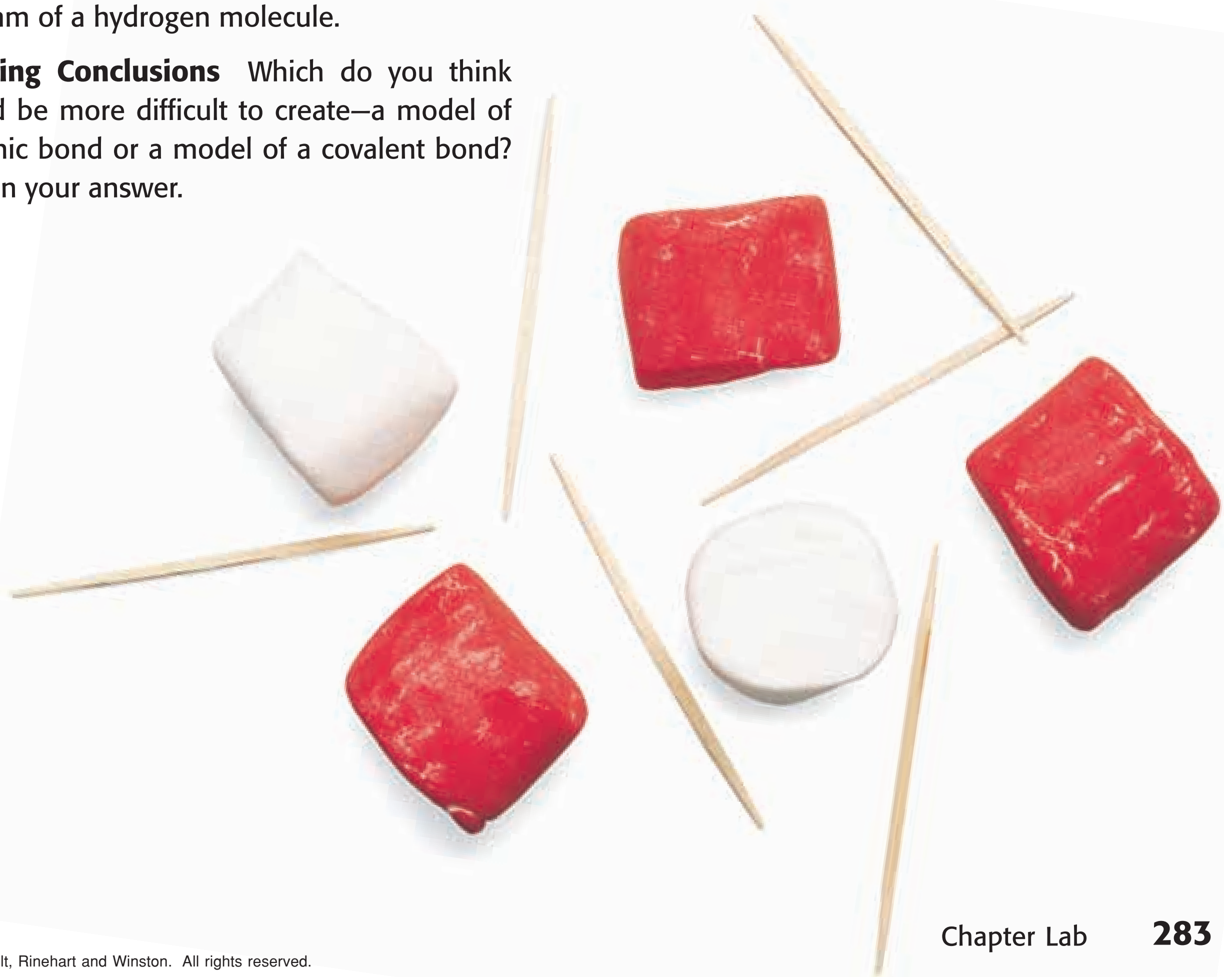
1. **Classifying** What do the marshmallows represent? What do the toothpicks represent?
2. **Evaluating Models** Why are the marshmallows different colors?
3. **Analyzing Results** Compare your model with the diagram on the previous page. How might your model be improved to more accurately represent a water molecule?

Draw Conclusions

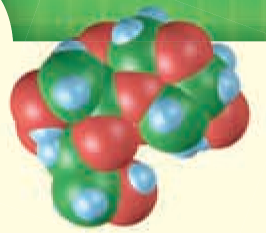
4. **Making Predictions** Hydrogen in nature can covalently bond to form hydrogen molecules, H_2. How could you use the marshmallows and toothpicks to model this bond?
5. **Applying Conclusions** Draw an electron-dot diagram of a hydrogen molecule.
6. **Drawing Conclusions** Which do you think would be more difficult to create—a model of an ionic bond or a model of a covalent bond? Explain your answer.

Applying Your Data

Create a model of a carbon dioxide molecule, which consists of two oxygen atoms and one carbon atom. The structure is similar to the structure of water, although the three atoms bond in a straight line instead of at angles. The bond between each oxygen atom and the carbon atom in a carbon dioxide molecule is a *double bond,* so use two connections. Do the double bonds in carbon dioxide appear stronger or weaker than the single bonds in water? Explain your answer.



Chapter Review



USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

crystal lattice	ionic bond
molecule	chemical bond
chemical bonding	metallic bond
valence electron	ion
covalent bond	

1. An interaction that holds two atoms together is a(n) ___.

2. A charged particle that forms when an atom transfers electrons is a(n) ___.

3. A bond formed when atoms share electrons is a(n) ___.

4. Electrons free to move throughout a material are associated with a(n) ___.

5. An electron in the outermost energy level of an atom is a(n) ___.

6. Ionic compounds are bonded in a three-dimensional pattern called a(n) ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Which element has a full outermost energy level containing only two electrons?
   - **a.** fluorine, F
   - **b.** helium, He
   - **c.** hydrogen, H
   - **d.** oxygen, O

8. Which of the following describes what happens when an atom becomes an ion with a 2– charge?
   - **a.** The atom gains 2 protons.
   - **b.** The atom loses 2 protons.
   - **c.** The atom gains 2 electrons.
   - **d.** The atom loses 2 electrons.

9. The properties of ductility and malleability are associated with which type of bonds?
   - **a.** ionic
   - **b.** covalent
   - **c.** metallic
   - **d.** All of the above

10. What type of element tends to lose electrons when it forms bonds?
    - **a.** metal
    - **b.** metalloid
    - **c.** nonmetal
    - **d.** noble gas

11. Which pair of atoms can form an ionic bond?
    - **a.** sodium, Na, and potassium, K
    - **b.** potassium, K, and fluorine, F
    - **c.** fluorine, F, and chlorine, Cl
    - **d.** sodium, Na, and neon, Ne

Short Answer

12. List two properties of covalent compounds.

13. Explain why an iron ion is attracted to a sulfide ion but not to a zinc ion.

14. Compare the three types of bonds based on what happens to the valence electrons of the atoms.

Math Skills

15 For each atom below, write the number of electrons it must gain or lose to have 8 valence electrons. Then, calculate the charge of the ion that would form.

a. calcium, Ca

b. phosphorus, P

c. bromine, Br

d. sulfur, S

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *chemical bonds, ionic bonds, covalent bonds, metallic bonds, molecule,* and *ions*.

17 **Identifying Relationships** Predict the type of bond each of the following pairs of atoms would form:

a. zinc, Zn, and zinc, Zn

b. oxygen, O, and nitrogen, N

c. phosphorus, P, and oxygen, O

d. magnesium, Mg, and chlorine, Cl

18 **Applying Concepts** Draw electron-dot diagrams for each of the following atoms, and state how many bonds it will have to make to fill its outer energy level.

a. sulfur, S

b. nitrogen, N

c. neon, Ne

d. iodine, I

e. silicon, Si

19 **Predicting Consequences** Using your knowledge of valence electrons, explain the main reason so many different molecules are made from carbon atoms.

20 **Making Inferences** Does the substance being hit in the photo below contain ionic or metallic bonds? Explain your answer.

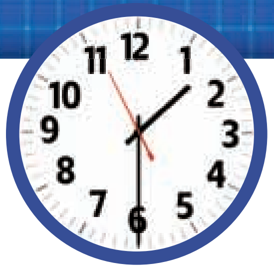
INTERPRETING GRAPHICS

Use the picture of a wooden pencil below to answer the questions that follow.

21 In which part of the pencil are metallic bonds found?

22 List three materials in the pencil that are composed of molecules that have covalent bonds.

23 Identify two differences between the properties of the material that has metallic bonds and the materials that have covalent bonds.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 In 1987, pilots Richard Rutan and Jeana Yeager flew the *Voyager* aircraft around the world without refueling. The record-breaking trip lasted a little more than nine days. To carry enough fuel for the trip, the plane had to be as lightweight as possible. Using fewer bolts than the number of bolts usually used to attach parts would make the airplane lighter. But without bolts, what would hold the parts together? The designers decided to use glue!

They could not use regular glue. They used superglue. When superglue is applied, it combines with water from the air to form chemical bonds. So, the materials stick together as if they were one material. Superglue is so strong that the weight of a two-ton elephant cannot separate two metal plates glued together with just a few drops!

1. Who are Richard Rutan and Jeana Yeager?

A the designers of the *Voyager* aircraft
B the pilots of the *Voyager* aircraft
C the inventors of superglue
D chemists that study superglue

2. In the passage, what does *aircraft* mean?

F an airplane
G a helicopter
H a hot-air balloon
I an airplane that doesn't need fuel

3. The author probably wrote this passage to

A encourage people to fly airplanes.
B tell airplane designers how to make airplanes that need less fuel.
C explain why superglue was a good substitute for bolts in the *Voyager* aircraft.
D explain why people should buy superglue instead of regular glue.

Passage 2 One of the first contact lenses was developed by a Hungarian physician named Joseph Dallos in 1929. He came up with a way to make a mold of the human eye. He used these molds to make a glass lens that followed the shape of the eye. Unfortunately, the glass lenses he made were not very comfortable.

Many years later, in an effort to solve the comfort problem of contact lenses, Czechoslovakian chemists Otto Wichterle and Drahoslav Lim invented a water-absorbing plastic gel. The lenses made from this gel were soft and pliable, and they allowed air to pass through the lens to the eye. These characteristics made the lenses more comfortable to wear than glass lenses.

1. In the passage, what does *pliable* mean?

A able to be bent
B very stiff
C spongelike
D similar to glass

2. Which of the following statements is a fact from the passage?

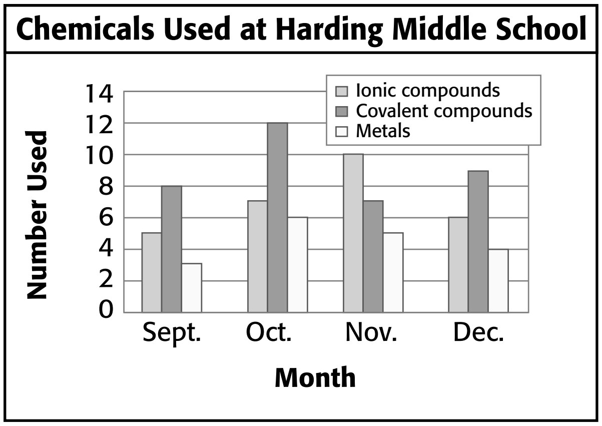
F The first contact lenses were plastic.
G Two Hungarian physicians developed a way of making molds of human eyes.
H Glass contact lenses were not comfortable.
I Joseph Dallos was a chemist.

3. What is a possible reason that glass contact lenses were not comfortable?

A Glass contact lenses allow air to pass through the lens to the eye.
B Glass contact lenses did not follow the shape of the human eye.
C Glass contact lenses absorb water.
D Glass contact lenses are very hard.

INTERPRETING GRAPHICS

The graph below shows chemicals used by the science department at Harding Middle School. Use the graph below to answer the questions that follow.



1. In which month were the most ionic compounds used?
- **A** September
- **B** October
- **C** November
- **D** December

2. Which type of chemical was used the least number of times?
- **F** ionic compounds
- **G** covalent compounds
- **H** metals
- **I** both ionic compounds and metals

3. How many covalent compounds were used during all four months?
- **A** 16
- **B** 25
- **C** 28
- **D** 36

4. In which month were the most compounds used?
- **F** September
- **G** October
- **H** November
- **I** December

MATH

Read each question below, and choose the best answer.

1. Protons have a charge of 1+ and electrons have a charge of 1−. A magnesium ion has 12 protons and 10 electrons. What is the charge of the ion?
- **A** 2+
- **B** 2−
- **C** 10−
- **D** 12+

2. Fructose is the chemical name for a sugar found in some fruits. The chemical formula for fructose is $C_6H_{12}O_6$. The *C* is the symbol for carbon, the *O* is the symbol for oxygen, and the *H* is the symbol for hydrogen. The numbers after each letter tell you how many atoms of each element are in one molecule of fructose. What percentage of the atoms in fructose are carbon atoms?
- **F** 0.25%
- **G** 6%
- **H** 25%
- **I** 33%

3. The density of an object is found by dividing its mass by its volume. Katie has a piece of silver metal that has a mass of 5.4 g and a volume of 2.0 cm^3. What is the density of Katie's metal?
- **A** 0.37 cm^3/g
- **B** 2.7 g/cm^3
- **C** 7.4 g/cm^3
- **D** 10.8 $g \bullet cm^3$

4. Ms. Mazza is a chemistry teacher. During class, her students ask her four to six questions every 10 min. What is a reasonable estimate of the number of questions asked during a 45 min class period?
- **F** 12 questions
- **G** 15 questions
- **H** 23 questions
- **I** 40 questions

Science in Action

Science, Technology, and Society

Superglue Bandages and Stitches

If you aren't careful when using superglue, you may accidentally learn that superglue quickly bonds skin together! This property of superglue led to the development of new kinds of superglue that can be used as alternatives for bandages and stitches. Using superglue to close wounds has several advantages over using bandages and stitches. For example, superglue bandages can cover cuts on parts of the body that are difficult to cover with regular bandages. And superglue stitches are less painful than regular stitches. Finally, wounds closed with superglue are easier to care for than wounds covered by bandages or closed with stitches.

Math ACTIVITY

A wound can be closed 3 times faster with glue than it can be with stitches. If it takes a doctor 27 min to close a wound by using stitches, how long would it take to close the same wound by using glue?

Weird Science

How Geckos Stick to Walls

Geckos are known for their ability to climb up smooth surfaces. Recently, scientists found the secret to the gecko's sticky talent. Geckos have millions of microscopic hairs on the bottom of their feet. Each hair splits into as many as 1,000 tinier hairs called *hairlets*. At the end of each hairlet is a small pad. As the gecko walks, each pad forms a van der Waals force with the surface on which the gecko is walking. A van der Waals force is an attraction similar to an ionic bond, but the van der Waals force is much weaker than an ionic bond and lasts for only an instant. But because there are so many pads on a gecko's foot, the van der Waals forces are strong enough to keep the gecko from falling.

Language Arts ACTIVITY

WRITING SKILL Imagine that you could stick to walls as well as a gecko can. Write a five-paragraph short story describing what you would do with your wall-climbing ability.

Careers

Roberta Jordan

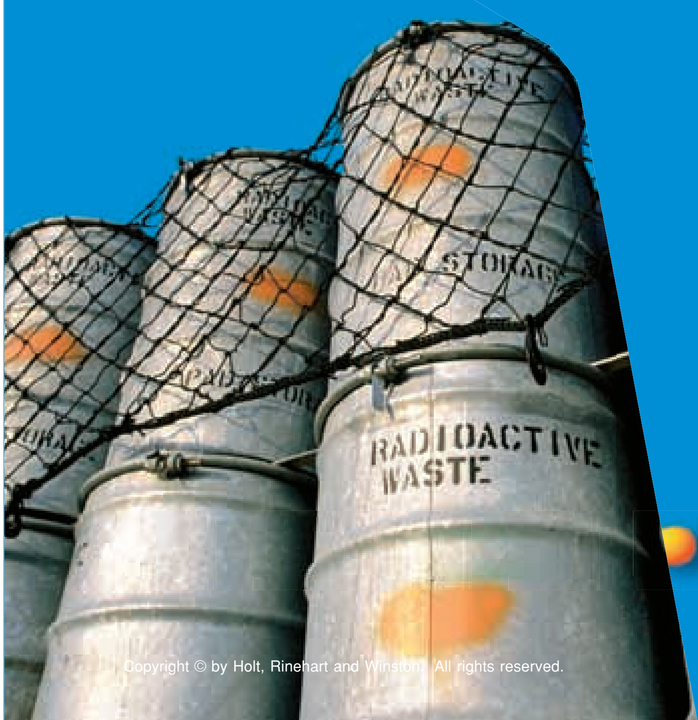
Analytical Chemist Have you ever looked at something and wondered what chemicals it contained? That's what analytical chemists do for a living. They use tests to find the chemical makeup of a sample. Roberta Jordan is an analytical chemist at the Idaho National Engineering and Environmental Laboratory in Idaho Falls, Idaho.

Jordan's work focuses on the study of radioactive waste generated by nuclear power plants and nuclear-powered submarines. Jordan works with engineers to develop safe ways to store the radioactive waste. She tells the engineers which chemicals need to be studied and which techniques to use to study those chemicals.

Jordan enjoys her job because she is always learning new techniques. "One of the things necessary to be a good chemist is you have to be creative. You have to be able to think above and beyond the normal ways of doing things to come up with new ideas, new experiments," she explains. Jordan believes that a person interested in a career in chemistry has many opportunities. "There are a lot of things out there that need to be discovered," says Jordan.

Social Studies ACTIVITY

Many elements in the periodic table were discovered by analytical chemists. Pick an element from the periodic table, and research its history. Make a poster about the discovery of that element.



To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HP5BNDF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS13.

10

Chemical Reactions

About the PHOTO

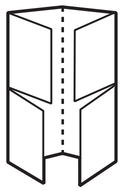
Dazzling fireworks and the Statue of Liberty are great examples of chemical reactions. Chemical reactions cause fireworks to soar, explode, and light up the sky. And the Statue of Liberty has its distinctive green color because of the reaction between the statue's copper and chemicals in the air.

PRE-READING ACTIVITY

FOLDNOTES

Four-Corner Fold

Before you read the chapter, create the FoldNote entitled "Four-Corner Fold" described in the **Study Skills** section of the Appendix. Label the flaps of the four-corner fold with "Chemical formulas," "Chemical equations," "Types of chemical reactions," and "Rates of chemical reactions." Write what you know about each topic under the appropriate flap. As you read the chapter, add other information that you learn.



START-UP ACTIVITY

A Model Formula

Chemicals react in very precise ways. In this activity, you will model a chemical reaction and will predict how chemicals react.

Procedure

1. You will receive **several marshmallow models.** The models are marshmallows attached by **toothpicks.** Each of these models is a Model A.
2. Your teacher will show you an example of Model B and Model C. Take apart one or more Model As to make copies of Model B and Model C.
3. If you have marshmallows left over, use them to make more Model Bs and Model Cs. If you need more parts to complete a Model B or Model C, take apart another Model A.
4. Repeat step 3 until you have no parts left over.

Analysis

1. How many Model As did you use to make copies of Model B and Model C?
2. How many Model Bs did you make? How many Model Cs did you make?
3. Suppose you needed to make six Model Bs. How many Model As would you need? How many Model Cs could you make with the leftover marshmallows?

SECTION 1

Forming New Substances

Each fall, a beautiful change takes place when leaves turn colors. You see bright oranges and yellows that had been hidden by green all summer. What causes this change?

To answer this question, you need to know what causes leaves to be green. Leaves are green because they contain a green substance, or *pigment*. This pigment is called *chlorophyll* (KLAWR uh FIL). During the spring and summer, the leaves have a large amount of chlorophyll in them. But in the fall, when temperatures drop and there are fewer hours of sunlight, chlorophyll breaks down to form new substances that have no color. The green chlorophyll is no longer present to hide the other pigments. You can now see the orange and yellow colors that were present all along.

Chemical Reactions

A chemical change takes place when chlorophyll breaks down into new substances. This change is an example of a chemical reaction. A **chemical reaction** is a process in which one or more substances change to make one or more new substances. The chemical and physical properties of the new substances differ from those of the original substances. Some results of chemical reactions are shown in **Figure 1.**

READING WARM-UP

Objectives

- Describe how chemical reactions produce new substances that have different chemical and physical properties.
- Identify four signs that indicate that a chemical reaction might be taking place.
- Explain what happens to chemical bonds during a chemical reaction.

Terms to Learn

chemical reaction
precipitate

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

chemical reaction the process by which one or more substances change to produce one or more different substances

Figure 1 **Results of Chemical Reactions**

The change of color in the fall is a result of chemical changes in the leaves.

When you mix water with baking powder, substances in the baking powder react to form bubbles of carbon dioxide gas. These bubbles give the muffin its sponge-like texture.

Signs of Chemical Reactions

How can you tell when a chemical reaction is taking place? **Figure 2** shows some signs that tell you that a reaction may be taking place. In some chemical reactions, gas bubbles form. Other reactions form solid precipitates (pree SIP uh TAYTS). A **precipitate** is a solid substance that is formed in a solution. During other chemical reactions, energy is given off. This energy may be in the form of light, thermal energy, or electricity. Reactions often have more than one of these signs. And the more of these signs that you see, the more likely that a chemical reaction is taking place.

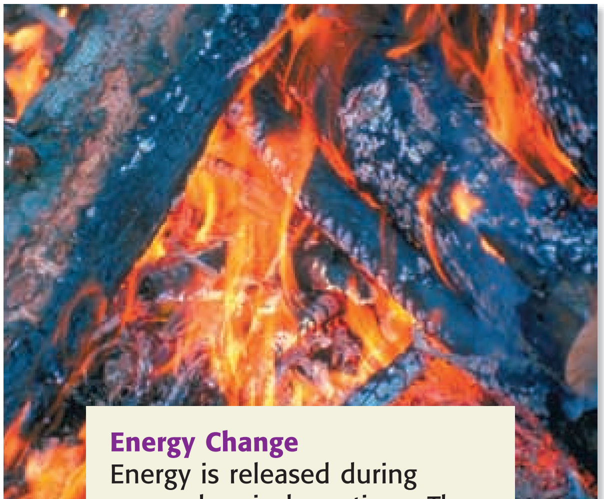
precipitate a solid that is produced as a result of a chemical reaction in solution

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

Figure 2 **Some Signs of Chemical Reactions**

Gas Formation
The chemical reaction in the beaker has formed a brown gas, nitrogen dioxide. This gas is formed when a strip of copper is placed into nitric acid.

Solid Formation
Here you see potassium chromate solution being added to a silver nitrate solution. The dark red solid is a precipitate of silver chromate.



Energy Change
Energy is released during some chemical reactions. The fire in this photo gives off light energy and thermal energy. During some other chemical reactions, energy is taken in.

Color Change
Don't spill chlorine bleach on your jeans! The bleach reacts with the blue dye on the fabric and causes the color of the material to change.

A Change of Properties

Even though the signs we look for to see if a reaction is taking place are good signals of chemical reactions, they do not guarantee that a reaction is happening. For example, gas can be given off when a liquid boils. But this example is a physical change, not a chemical reaction.

So, how can you be sure that a chemical reaction is occurring? The most important sign is the formation of new substances that have different properties. Look at **Figure 3.** The starting materials in this reaction are sugar and sulfuric acid. Several things tell you that a chemical reaction is taking place. Bubbles form, a gas is given off, and the beaker becomes very hot. But most important, new substances form. And the properties of these substances are very different from those of the starting substances.

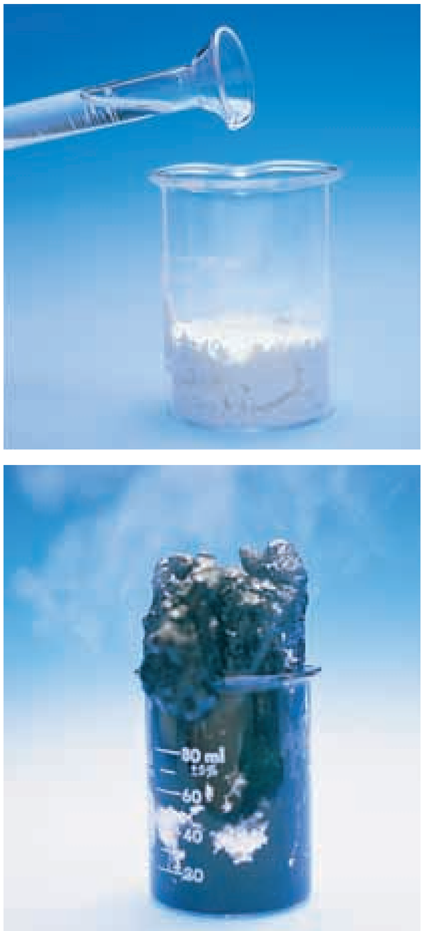


Figure 3 *The top photo shows the starting substances: table sugar and sulfuric acid, a clear liquid. The substances formed in this chemical reaction are very different from the starting substances.*

Bonds: Holding Molecules Together

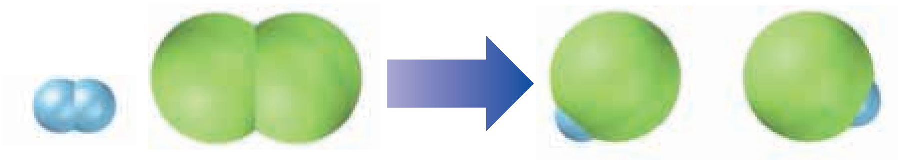
A *chemical bond* is a force that holds two atoms together in a molecule. For a chemical reaction to take place, the original bonds must break and new bonds must form.

Breaking and Making Bonds

How do new substances form in a chemical reaction? First, chemical bonds in the starting substances must break. Molecules are always moving. If the molecules bump into each other with enough energy, the chemical bonds in the molecules break. The atoms then rearrange, and new bonds form to make the new substances. **Figure 4** shows how bonds break and form in the reaction between hydrogen and chlorine.

✓ *Reading Check* **What happens to the bonds of substances during a chemical reaction?**

Figure 4 **Reaction of Hydrogen and Chlorine**



hydrogen + **chlorine** **hydrogen chloride**

Breaking Bonds Hydrogen and chlorine are diatomic. Diatomic molecules are two atoms bonded together. The bonds joining these atoms must first break before the atoms can react with each other.

Making Bonds A new substance, hydrogen chloride, forms as new bonds are made between hydrogen atoms and chlorine atoms.

New Bonds, New Substances

What happens when hydrogen and chlorine are combined? A chlorine gas molecule is a diatomic (DIE uh TAHM ik) molecule. That is, a chlorine molecule is made of two atoms of chlorine. Chlorine gas has a greenish yellow color. Hydrogen gas is also a diatomic molecule. Hydrogen gas is a flammable, colorless gas. When chlorine gas and hydrogen gas react, the bond between the hydrogen atoms breaks. And the bond between the chlorine atoms also breaks. A new bond forms between each hydrogen and chlorine atom. A new substance, hydrogen chloride, is formed. Hydrogen chloride is a nonflammable, colorless gas. Its properties differ from the properties of both of the starting substances.

Let's look at another example. Sodium is a metal that reacts violently in water. Chlorine gas is poisonous. When chlorine gas and sodium react, the result is a familiar compound—table salt. Sodium chloride, or table salt, is a harmless substance that almost everyone uses. The salt's properties are very different from sodium's or chlorine's. Salt is a new substance.

Quick Lab

Reaction Ready

1. Place a **piece of chalk** in a **plastic cup.**
2. Add **5 mL of vinegar** to the cup. Record your observations.
3. What evidence of a chemical reaction do you see?
4. What type of new substance was formed?

SECTION Review

Summary

- A chemical reaction is a process by which substances change to produce new substances with new chemical and physical properties.
- Signs that indicate a chemical reaction has taken place are a color change, formation of a gas or a solid, and release of energy.
- During a reaction, bonds are broken, atoms are rearranged, and new bonds are formed.

Using Key Terms

1. Use the following terms in the same sentence: *chemical reaction* and *precipitate*.

Understanding Key Ideas

2. Most chemical reactions
   a. have starting substances that collide with each other.
   b. do not break bonds.
   c. do not rearrange atoms.
   d. cannot be seen.
3. If the chemical properties of a substance have not changed, has a chemical reaction occurred?

Critical Thinking

4. **Analyzing Processes** Steam is escaping from a teapot. Is this a chemical reaction? Explain.
5. **Applying Concepts** Explain why charcoal burning in the grill is a chemical change.

Interpreting Graphics

Use the photo below to answer the questions that follow.

6. What evidence of a chemical reaction is shown in the photo?
7. What is happening to the bonds of the starting substances?

SciLinks

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Chemical Reactions
SciLinks code: HSM0274

SECTION 2

Chemical Formulas and Equations

READING WARM-UP

Objectives

- Interpret and write simple chemical formulas.
- Write and balance simple chemical equations.
- Describe the basis for and the results of Lavoisier's work with reactions.
- Explain how a balanced equation shows the law of conservation of mass.

Terms to Learn

chemical formula
chemical equation
reactant
product
law of conservation of mass

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

How many words can you make using the 26 letters of the alphabet? Many thousands? Now, think of how many sentences you can make with all of those words.

Letters are used to form words. In the same way, chemical symbols are put together to make chemical formulas that describe substances. Chemical formulas can be placed together to describe a chemical reaction, just like words can be put together to make a sentence.

Chemical Formulas

All substances are formed from about 100 elements. Each element has its own chemical symbol. A **chemical formula** is a shorthand way to use chemical symbols and numbers to represent a substance. A chemical formula shows how many atoms of each kind are present in a molecule.

As shown in **Figure 1,** the chemical formula for water is H_2O. This formula tells you that one water molecule is made of two atoms of hydrogen and one atom of oxygen. The small 2 in the formula is a subscript. A *subscript* is a number written below and to the right of a chemical symbol in a formula. Sometimes, a symbol, such as O for oxygen in water's formula, has no subscript. If there is no subscript, only one atom of that element is present. Look at **Figure 1** for more examples of chemical formulas.

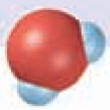
chemical formula a combination of chemical symbols and numbers to represent a substance

Figure 1 **Chemical Formulas of Different Substances**

Water

H_2O

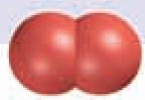
Water molecules are made up of 3 atoms—2 atoms of hydrogen bonded to 1 atom of oxygen.



Oxygen

O_2

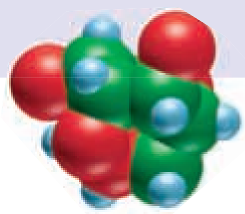
Oxygen is a diatomic molecule. Each molecule has 2 atoms of oxygen bonded together.



Glucose

$C_6H_{12}O_6$

Glucose molecules have 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen.



Carbon dioxide

CO_2

The ***absence of a prefix*** indicates one carbon atom.

The prefix ***di-*** indicates two oxygen atoms.

Dinitrogen monoxide

N_2O

The prefix ***di-*** indicates two nitrogen atoms.

The prefix ***mono-*** indicates one oxygen atom.

Figure 2 *The formulas of these covalent compounds can be written by using the prefixes in the names of the compounds.*

Writing Formulas for Covalent Compounds

If you know the name of the covalent compound, you can often write the chemical formula for that compound. Covalent compounds are usually composed of two nonmetals. The names of many covalent compounds use prefixes. Each prefix represents a number, as shown in **Table 1.** The prefixes tell you how many atoms of each element are in a formula. **Figure 2** shows you how to write a chemical formula from the name of a covalent compound.

Table 1 **Prefixes Used in Chemical Names**

mono-	1	*hexa-*	6
di-	2	*hepta-*	7
tri-	3	*octa-*	8
tetra-	4	*nona-*	9
penta-	5	*deca-*	10

Writing Formulas for Ionic Compounds

If the name of a compound contains the name of a metal and the name of a nonmetal, the compound is ionic. To write the formula for an ionic compound, make sure the compound's charge is 0. In other words, the formula must have subscripts that cause the charges of the ions to cancel out. **Figure 3** shows you how to write a chemical formula from the name of an ionic compound.

Reading Check **What kinds of elements make up an ionic compound?** (*See the Appendix for answers to Reading Checks.*)

Sodium chloride

$NaCl$

A sodium ion has a **1+ charge.**

A chloride ion has a **1− charge.**

One sodium ion and one chloride ion have an overall **charge of (1+) + (1−) = 0.**

Magnesium chloride

$MgCl_2$

A magnesium ion has a **2+ charge.**

A chloride ion has a **1− charge.**

One magnesium ion and two chloride ions have an overall **charge of (2+) + 2(1−) = 0.**

Figure 3 *The formula of an ionic compound is written by using enough of each ion so that the overall charge is 0.*

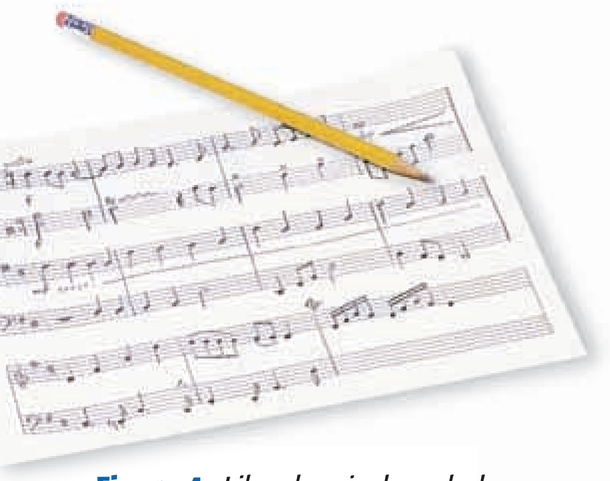


Figure 4 *Like chemical symbols, the symbols on this musical score are understood around the world!*

Chemical Equations

Think about a piece of music, such as the one in **Figure 4.** Someone writing music must tell the musician what notes to play, how long to play each note, and how each note should be played. Words aren't used to describe the musical piece. Instead, musical symbols are used. The symbols can be understood by anyone who can read music.

Describing Reactions by Using Equations

In the same way that composers use musical symbols, chemists around the world use chemical symbols and chemical formulas. Instead of changing words and sentences into other languages to describe reactions, chemists use chemical equations. A **chemical equation** uses chemical symbols and formulas as a shortcut to describe a chemical reaction. A chemical equation is short and is understood by anyone who understands chemical formulas.

chemical equation a representation of a chemical reaction that uses symbols to show the relationship between the reactants and the products

reactant a substance or molecule that participates in a chemical reaction

product the substance that forms in a chemical reaction

From Reactants to Products

When carbon burns, it reacts with oxygen to form carbon dioxide. **Figure 5** shows how a chemist would use an equation to describe this reaction. The starting materials in a chemical reaction are **reactants** (ree AK tuhnts). The substances formed from a reaction are **products.** In this example, carbon and oxygen are reactants. Carbon dioxide is the product.

Reading Check **What is the difference between reactants and products in a chemical reaction?**

Figure 5 **The Parts of a Chemical Equation**

Charcoal is used to cook food on a barbecue grill. When carbon in charcoal reacts with oxygen in the air, the primary product is carbon dioxide, as shown by the chemical equation.

The formulas of the **reactants** are written before the arrow.

The formulas of the **products** are written after the arrow.

$$C + O_2 \longrightarrow CO_2$$

A **plus sign** separates the formulas of two or more reactants or products from one another.

The **arrow,** also called the *yields sign,* separates the formulas of the reactants from the formulas of the products.

Figure 6 **Examples of Similar Symbols and Formulas**

CO_2

The chemical formula for the compound **carbon dioxide** is CO_2. Carbon dioxide is a colorless, odorless gas that you exhale.

CO

The chemical formula for the compound **carbon monoxide** is CO. Carbon monoxide is a colorless, odorless, and poisonous gas.

Co

The chemical symbol for the element **cobalt** is Co. Cobalt is a hard, bluish gray metal.

The Importance of Accuracy

The symbol or formula for each substance in a chemical equation must be written correctly. For a compound, use the correct chemical formula. For an element, use the proper chemical symbol. But watch out! For a diatomic element you must use its chemical formula. An equation that has the wrong chemical symbol or formula will not correctly describe the reaction. In fact, even a simple mistake can make a huge difference. **Figure 6** shows how formulas and symbols can be confused.

Quick Lab

Mass Before and After

1. Place **5 g of baking soda** into a **sealable plastic bag.**
2. Place **5 mL of vinegar** into a **plastic film canister.** Put the lid on the canister. Place the canister into the bag. Squeeze the air out of the bag. Seal the bag tightly.
3. Use a **balance** to measure the mass of the bag and its contents. Record the mass.
4. Keeping the bag closed, open the canister in the bag. Mix the vinegar with the baking soda. Record your observations.
5. When the reaction has stopped, measure the mass of the bag and its contents. Record the mass.
6. Compare the mass of the materials before the reaction and the mass of the materials after the reaction. Explain.

Balancing Chemical Equations

Even if all of the chemical symbols and formulas for a reaction are written correctly, the chemical equation must be balanced. To understand why chemical equations are balanced, you need to understand something about closed systems.

Nothing Goes In or Out

Imagine that you are doing an activity in class. You work in several teams throughout the class period. The door is closed, and no one enters or leaves the room. Even though the people you worked with changed, the people who were in the room at the beginning of class are there at the end of class. This is an example of a closed system.

Figure 7 shows a closed system that contains a certain amount of matter. The mass of the system is a measure of the system's matter. During the reaction, the gas that forms is trapped by the balloon. Notice that the mass does not change. No matter how substances in a closed system interact with each other or how they combine or break apart, the total mass of the system remains the same. When the balloon is removed and placed on the balance, the gas escapes and the mass reading on the balance decreases. Matter has not disappeared. But the gas is no longer trapped, so the balance cannot measure it.

✓ *Reading Check* **What happens to the mass of a closed system during a chemical reaction?**

MATH PRACTICE

Counting Atoms

Some chemical formulas contain parentheses. When counting atoms, multiply everything inside the parentheses by the subscript. For example, $Ca(NO_3)_2$ has one calcium atom, two (2 × 1) nitrogen atoms, and six (2 × 3) oxygen atoms. Find the number of atoms of each element in the formulas $Mg(OH)_2$ and $Al_2(SO_4)_3$.

Figure 7 **Measuring Mass During a Reaction**

The flask, balloon, water, and effervescent tablet (in the balloon) make up a closed system.

The effervescent tablet is dropped into the water and reacts. The balloon traps the carbon dioxide gas produced in the reaction. So, the system is still closed, and the mass does not change.

Removing the balloon opens the system. The gas escapes. Because the gas is matter, it has mass. The escape of the gas causes the mass reading to be less than it was before the reaction.

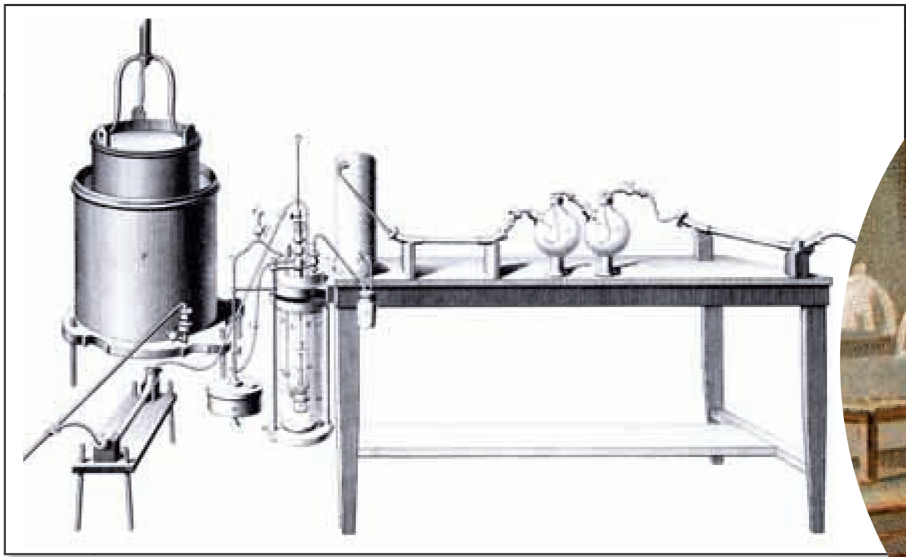


Figure 8 *Through careful experimentation and by designing his own equipment, as shown above, Antoine Lavoisier successfully tested the law of conservation of mass.*

Carefully Measuring Material

In the 1700s, the French chemist Antoine Lavoisier (lah vwah ZYAY), shown in **Figure 8,** did experiments based on the idea that many changes may take place when materials react with each other but that the total amount of matter afterward is the same as it was before. This idea is called the *conservation of matter.*

In a series of experiments, Lavoisier carefully measured the masses of all substances, including gases, in various chemical reactions. To improve the accuracy of his results, he sometimes designed his own equipment, such as that shown in **Figure 8.** He successfully tested the concept of the conservation of matter, which is described in the **law of conservation of mass.** This law states that mass is neither created nor destroyed in ordinary chemical and physical changes. In other words, the total mass of the reactants equals the total mass of the products.

law of conservation of mass the law that states that mass cannot be created or destroyed in ordinary chemical and physical changes

Reading Check **On what did Lavoisier base his work?**

The Reason Equations Must Be Balanced

Atomic theory explains the conservation of matter in this way. If the number of atoms stays the same no matter how they are arranged, then their total mass stays the same. Atoms are never lost or gained in a chemical reaction. They are just rearranged. Every atom in the reactants becomes part of the products. So, a chemical equation must show the same numbers and kinds of atoms on both sides of the arrow.

When writing a chemical equation, make sure the number of atoms of each element in the reactants equals the number of atoms of those same elements in the products. When you do so, you *balance* the equation.

How to Balance an Equation

To balance an equation, you must use coefficients (KOH uh FISH uhnts). A *coefficient* is a number that is placed in front of a chemical symbol or formula. For example, 2CO represents two carbon monoxide molecules. The number *2* is the coefficient.

For an equation to be balanced, all atoms must be counted. So, you must multiply the subscript of each element in a formula by the formula's coefficient. For example, $2H_2O$ contains a total of four hydrogen atoms and two oxygen atoms. Only coefficients—not subscripts—are changed when balancing equations. Changing the subscripts in the formula of a compound would change the compound. **Figure 9** shows you how to use coefficients to balance an equation.

Reading Check **If you see $4O_2$ in an equation, what is the coefficient?**

CONNECTION TO Language Arts

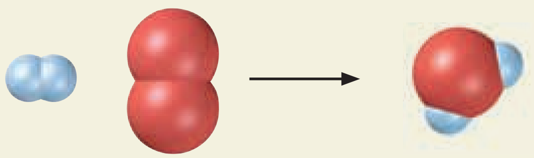
WRITING SKILL **Diatomic Molecules** Seven of the chemical elements exist as diatomic molecules. Do research to find out which seven elements are diatomic molecules. Write a short report that describes each diatomic molecule. Include the formula for each molecule.

Figure 9 **Balancing a Chemical Equation**

Follow these steps to write a balanced equation for $H_2 + O_2 \longrightarrow H_2O$.

1 **Count the atoms** of each element in the reactants and in the products. You can see that there are fewer oxygen atoms in the product than in the reactants.

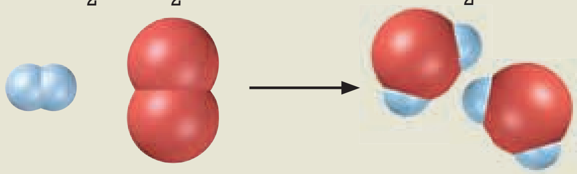
Reactants $H_2 + O_2 \longrightarrow$ **Products** H_2O



H = 2 O = 2 → H = 2 O = 1

2 **To balance the oxygen atoms,** place the coefficient 2 in front of H_2O. Doing so gives you two oxygen atoms in both the reactants and the products. But now there are too few hydrogen atoms in the reactants.

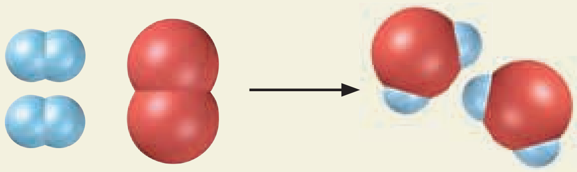
Reactants $H_2 + O_2 \longrightarrow$ **Products** $2H_2O$



H = 2 O = 2 → H = 4 O = 2

3 **To balance the hydrogen atoms,** place the coefficient 2 in front of H_2. But to be sure that your answer is correct, always double-check your work!

Reactants $2H_2 + O_2 \longrightarrow$ **Products** $2H_2O$



H = 4 O = 2 → H = 4 O = 2

SECTION Review

Summary

- A chemical formula uses symbols and subscripts to describe the makeup of a compound.
- Chemical formulas often can be written from the names of covalent and ionic compounds.
- A chemical equation uses chemical formulas, chemical symbols, and coefficients to describe a reaction.
- The total mass of a closed system remains the same during chemical reactions.
- Antoine Lavoisier measured the masses of substances in reactions. His results supported the law of conservation of mass.
- Balancing an equation requires that the same numbers and kinds of atoms be on each side of the equation.
- A balanced equation illustrates the law of conservation of mass: mass is neither created nor destroyed during ordinary physical and chemical changes.

Using Key Terms

The statements below are false. For each statement, replace the underlined word to make a true statement.

1. A chemical <u>formula</u> describes a reaction.

2. The substances formed from a chemical reaction are <u>reactants</u>.

Understanding Key Ideas

3. The correct chemical formula for carbon tetrachloride is

a. CCl_3. **c.** CCl.
b. C_3Cl. **d.** CCl_4.

4. The chemical formula for calcium oxide is

a. Ca_2O_2. **c.** CaO_2.
b. CaO. **d.** Ca_2O.

5. Balance the following equations by adding the correct coefficients.

a. $Na + Cl_2 \longrightarrow NaCl$
b. $Mg + N_2 \longrightarrow Mg_3N_2$

6. How does a balanced chemical equation illustrate that mass is never lost or gained in a chemical reaction?

Math Skills

7. Calculate the number of atoms of each element represented in each of the following: $2Na_3PO_4$, $4Al_2(SO_4)_3$, and $6PCl_5$.

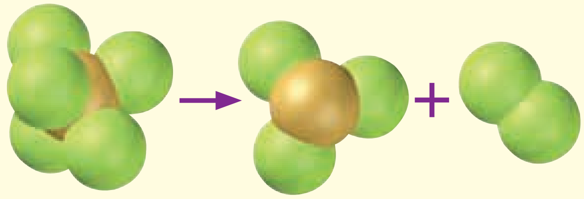
Critical Thinking

8. Analyzing Methods Describe how to write a formula for a covalent compound. Give an example of a covalent compound.

9. Applying Concepts Explain why the subscript in a formula of a chemical compound cannot be changed when balancing an equation.

Interpreting Graphics

10. In the model below, an orange ball indicates a phosphorus atom, and a green ball indicates a chlorine atom. Does the model support the law of conservation of mass? Explain.



SECTION 3

Types of Chemical Reactions

READING WARM-UP

Objectives

- Describe four types of chemical reactions.
- Classify a chemical equation as one of four types of chemical reactions.

Terms to Learn

synthesis reaction
decomposition reaction
single-displacement reaction
double-displacement reaction

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the four types of chemical reactions.

There are thousands of known chemical reactions. Can you imagine having to memorize even 50 of them?

Remembering all of them would be impossible! But fortunately, there is help. In the same way that the elements are divided into groups based on their properties, reactions can be classified based on what occurs during the reaction.

Most reactions can be placed into one of four categories: synthesis (SIN thuh sis), decomposition, single-displacement, and double-displacement. Each type of reaction has a pattern that shows how reactants become products. One way to remember what happens in each type of reaction is to imagine people at a dance. As you learn about each type of reaction, study the models of students at a dance. The models will help you recognize each type of reaction.

Synthesis Reactions

A **synthesis reaction** is a reaction in which two or more substances combine to form one new compound. For example, a synthesis reaction takes place when sodium reacts with chlorine. This synthesis reaction produces sodium chloride, which you know as table salt. A synthesis reaction would be modeled by two people pairing up to form a dancing couple, as shown in **Figure 1.**

synthesis reaction a reaction in which two or more substances combine to form a new compound

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

$$2Na + Cl_2 \longrightarrow 2NaCl$$

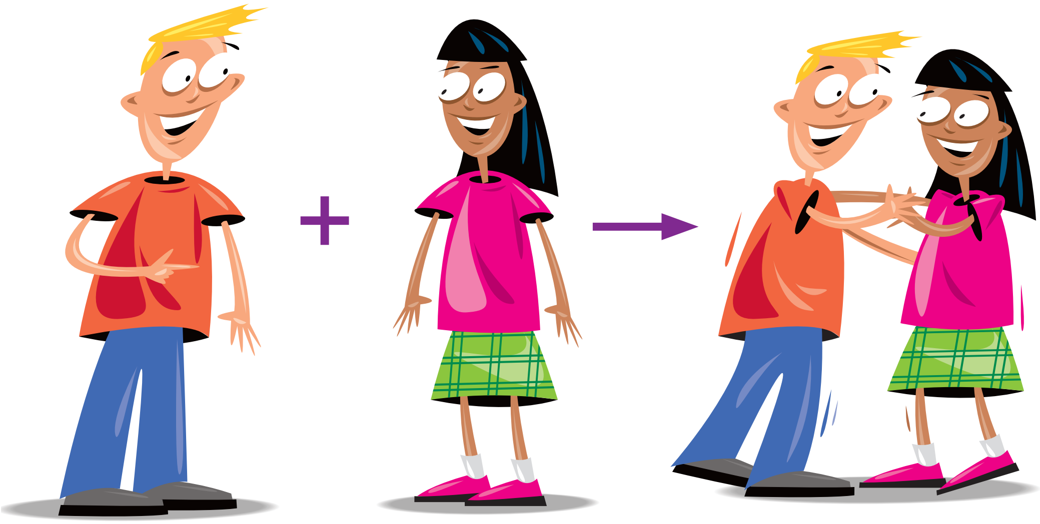


Figure 1 *Sodium reacts with chlorine to form sodium chloride in this synthesis reaction.*

$$H_2CO_3 \longrightarrow H_2O + CO_2$$

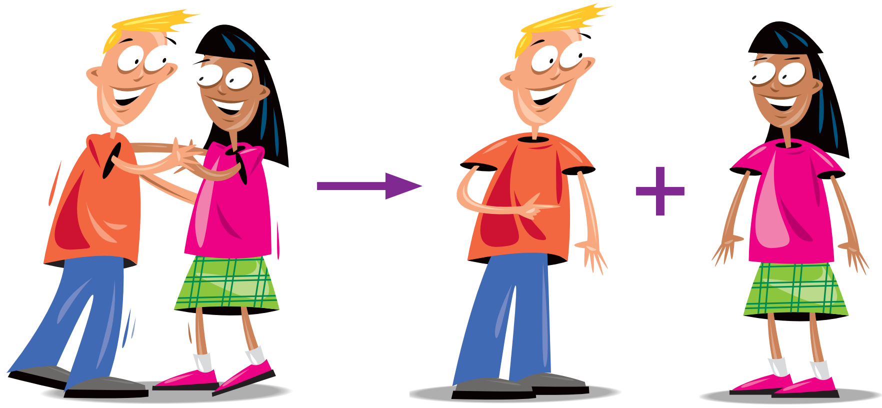


Figure 2 *In this decomposition reaction, carbonic acid, H_2CO_3, decomposes to form water and carbon dioxide.*

Decomposition Reactions

A **decomposition reaction** is a reaction in which a single compound breaks down to form two or more simpler substances. Decomposition is the reverse of synthesis. The dance model for a decomposition reaction would be a couple that finishes a dance and separates, as shown in **Figure 2.**

Reading Check **How is a decomposition reaction different from a synthesis reaction?**

decomposition reaction a reaction in which a single compound breaks down to form two or more simpler substances

single-displacement reaction a reaction in which one element takes the place of another element in a compound

Single-Displacement Reactions

Sometimes, an element replaces another element that is a part of a compound. This type of reaction is called a **single-displacement reaction.** The products of single-displacement reactions are a new compound and a different element. The dance model for a single-displacement reaction would show a person cutting in on a couple who is dancing. A new couple is formed. And a different person is left alone, as shown in **Figure 3.**

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

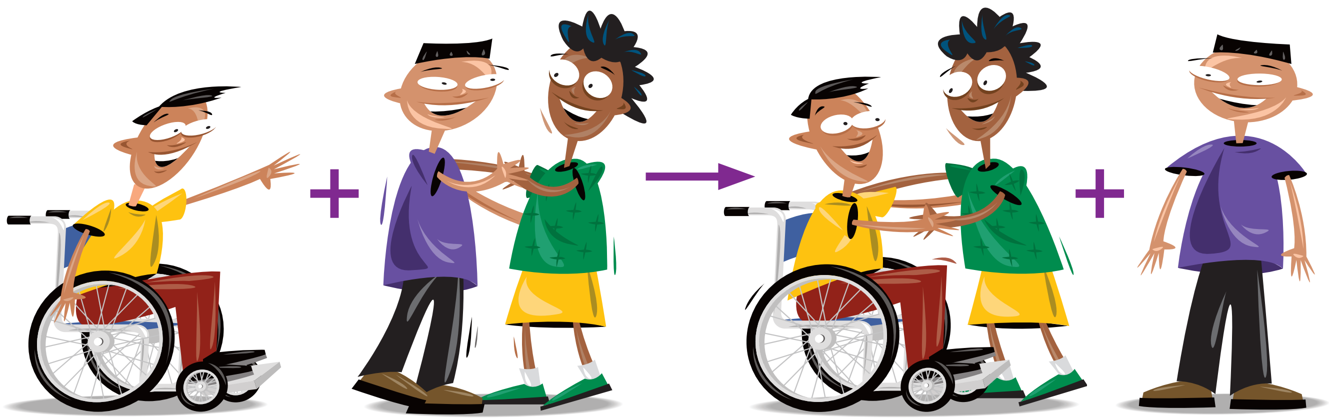


Figure 3 *Zinc replaces the hydrogen in hydrochloric acid to form zinc chloride and hydrogen gas in this single-displacement reaction.*

Figure 4 Reactivity of Elements

$Cu + 2AgNO_3 \longrightarrow 2Ag + Cu(NO_3)_2$
Copper is more reactive than silver.

$Ag + Cu(NO_3)_2 \longrightarrow$ no reaction
Silver is less reactive than copper.

Reactivity of Elements

In a single-displacement reaction, a more reactive element can displace a less reactive element in a compound. For example, **Figure 4** shows that copper is more reactive than silver. Copper (Cu) can replace the silver (Ag) ion in the compound silver nitrate. But the opposite reaction does not occur, because silver is less reactive than copper.

The elements in Group 1 of the periodic table are the most reactive metals. Very few nonmetals are involved in single-displacement reactions. In fact, only Group 17 nonmetals participate in single-displacement reactions.

Reading Check **Why can one element sometimes replace another element in a single-displacement reaction?**

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5REAW.**

QUICK LAB

Identifying Reactions

1. Study each of the following equations:

$4Na + O_2 \longrightarrow 2Na_2O$ $\quad$ $P_4 + 5O_2 \longrightarrow 2P_2O_5$

$2Ag_3N \longrightarrow 6Ag + N_2$ $\quad$ $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

2. Build models of each of these reactions using **colored clay.** Choose a different color of clay to represent each kind of atom.
3. Identify each type of reaction as a synthesis, decomposition, or single-displacement reaction.

Double-Displacement Reactions

A **double-displacement reaction** is a reaction in which ions from two compounds exchange places. One of the products of this type of reaction is often a gas or a precipitate. A dance model of a double-displacement reaction would be two couples dancing and then trading partners, as shown in **Figure 5.**

double-displacement reaction a reaction in which a gas, a solid precipitate, or a molecular compound forms from the exchange of ions between two compounds

$$NaCl + AgF \rightarrow NaF + AgCl$$

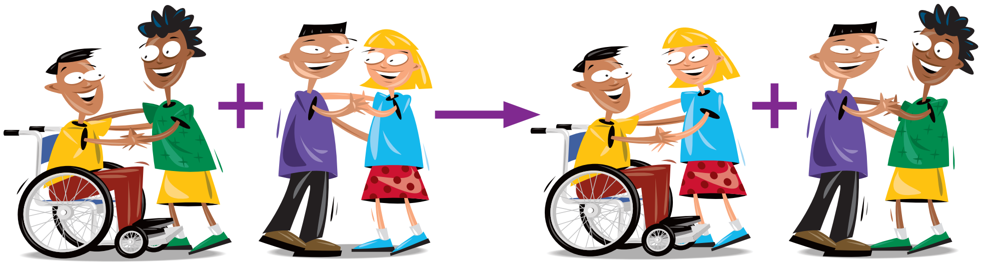


Figure 5 *A double-displacement reaction occurs when sodium chloride reacts with silver fluoride to form sodium fluoride and silver chloride (a precipitate).*

SECTION Review

Summary

- A synthesis reaction is a reaction in which two or more substances combine to form a compound.
- A decomposition reaction is a reaction in which a compound breaks down to form two or more simpler substances.
- A single-displacement reaction is a reaction in which an element takes the place of another element that is part of a compound.
- A double-displacement reaction is a reaction in which ions in two compounds exchange places.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *synthesis reaction* and *decomposition reaction.*

Understanding Key Ideas

2. What type of reaction does the following equation represent?

   $FeS + 2HCl \rightarrow FeCl_2 + H_2S$

   a. synthesis reaction
   b. double-displacement reaction
   c. single-displacement reaction
   d. decomposition reaction

3. Describe the difference between single- and double-displacement reactions.

Math Skills

4. Write the balanced equation in which potassium iodide, KI, reacts with chlorine to form potassium chloride, KCl, and iodine.

Critical Thinking

5. **Analyzing Processes** The first reaction below is a single-displacement reaction that could occur in a laboratory. Explain why the second single-displacement reaction could not occur.

   $CuCl_2 + Fe \rightarrow FeCl_2 + Cu$

   $CaS + Al \rightarrow$ no reaction

6. **Making Inferences** When two white compounds are mixed in a solution, a yellow solid forms. What kind of reaction has taken place? Explain your answer.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Reaction Types
SciLinks code: HSM1272

SECTION 4

Energy and Rates of Chemical Reactions

READING WARM-UP

Objectives

- Compare exothermic and endothermic reactions.
- Explain activation energy.
- Interpret an energy diagram.
- Describe five factors that affect the rate of a reaction.

Terms to Learn

exothermic reaction
endothermic reaction
law of conservation of energy
activation energy
inhibitor
catalyst

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

What is the difference between eating a meal and running a mile? You could say that a meal gives you energy, while running "uses up" energy.

Chemical reactions can be described in the same way. Some reactions release energy, and other reactions absorb energy.

Reactions and Energy

Chemical energy is part of all chemical reactions. Energy is needed to break chemical bonds in the reactants. As new bonds form in the products, energy is released. By comparing the chemical energy of the reactants with the chemical energy of the products, you can decide if energy is released or absorbed in the overall reaction.

Exothermic Reactions

A chemical reaction in which energy is released is called an **exothermic reaction.** *Exo* means "go out" or "exit." *Thermic* means "heat" or "energy." Exothermic reactions can give off energy in several forms, as shown in **Figure 1.** The energy released in an exothermic reaction is often written as a product in a chemical equation, as in this equation:

$$2Na + Cl_2 \rightarrow 2NaCl + \textit{energy}$$

Figure 1 **Types of Energy Released in Exothermic Reactions**

Light energy is released in the exothermic reaction that is taking place in these light sticks.

Electrical energy is released in the exothermic reaction that will take place in this battery.

Light and thermal energy are released in the exothermic reaction taking place in this campfire.

Endothermic Reactions

A chemical reaction in which energy is taken in is called an **endothermic reaction.** *Endo* means "go in." The energy that is taken in during an endothermic reaction is often written as a reactant in a chemical equation. Energy as a reactant is shown in the following equation:

$$2H_2O + \textit{energy} \rightarrow 2H_2 + O_2$$

An example of an endothermic process is photosynthesis. In photosynthesis, plants use light energy from the sun to produce glucose. Glucose is a simple sugar that is used for nutrition. The equation that describes photosynthesis is the following:

$$6CO_2 + 6H_2O + \textit{energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Reading Check **What is an endothermic reaction?** (*See the Appendix for answers to Reading Checks.*)

exothermic reaction a chemical reaction in which heat is released to the surroundings

endothermic reaction a chemical reaction that requires heat

law of conservation of energy the law that states that energy cannot be created or destroyed but can be changed from one form to another

The Law of Conservation of Energy

Neither mass nor energy can be created or destroyed in chemical reactions. The **law of conservation of energy** states that energy cannot be created or destroyed. However, energy can change forms. And energy can be transferred from one object to another in the same way that a baton is transferred from one runner to another runner, as shown in **Figure 2.**

The energy released in exothermic reactions was first stored in the chemical bonds in the reactants. And the energy taken in during endothermic reactions is stored in the products. If you could measure all the energy in a reaction, you would find that the total amount of energy (of all types) is the same before and after the reaction.

Figure 2 *Energy can be transferred from one object to another object in the same way that a baton is transferred from one runner to another runner in a relay race.*

Quick Lab

Endo Alert

1. Fill a **plastic cup** half full with **calcium chloride solution.**
2. Measure the temperature of the solution by using a **thermometer.**
3. Carefully add **1 tsp of baking soda.**
4. Record your observations.
5. When the reaction has stopped, record the temperature of the solution.
6. What evidence that an endothermic reaction took place did you observe?

Figure 3 *Chemical reactions need energy to get started in the same way that a bowling ball needs a push to get rolling.*

Rates of Reactions

A reaction takes place only if the particles of reactants collide. But there must be enough energy to break the bonds that hold particles together in a molecule. The speed at which new particles form is called the *rate of a reaction*.

Activation Energy

Before the bowling ball in **Figure 3** can roll down the alley, the bowler must first put in some energy to start the ball rolling. A chemical reaction must also get a boost of energy before the reaction can start. This boost of energy is called activation energy. **Activation energy** is the smallest amount of energy that molecules need to react.

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

Another example of activation energy is striking a match. Before a match can be used to light a campfire, the match has to be lit! A strike-anywhere match has all the reactants it needs to burn. The chemicals on a match react and burn. But, the chemicals will not light by themselves. You must strike the match against a surface. The heat produced by this friction provides the activation energy needed to start the reaction.

Reading Check **What is activation energy?**

CONNECTION TO Social Studies

WRITING SKILL **The Strike-Anywhere Match**
Research the invention of the strike-anywhere match. Find out who invented it, who patented it, and when the match was introduced to the public. In your **science journal,** write a short report about what you learn from your research.

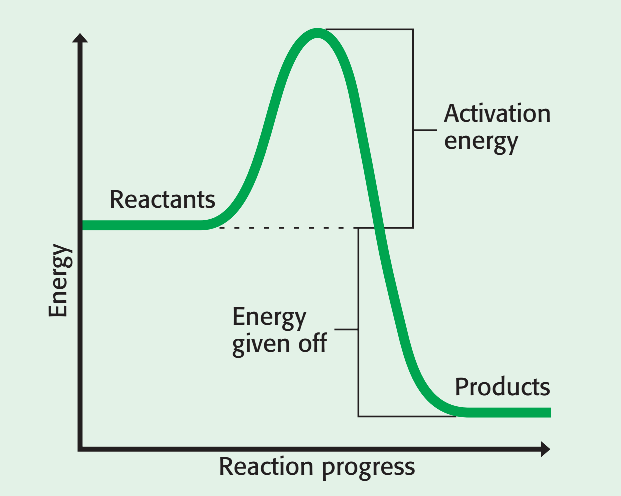
Sources of Activation Energy

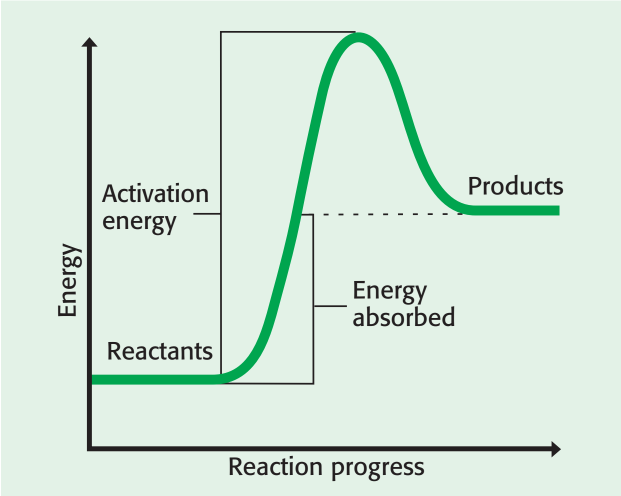
Friction is one source of activation energy. In the match example, friction provides the energy needed to break the bonds in the reactants and allow new bonds to form. An electric spark in a car's engine is another source of activation energy. This spark begins the burning of gasoline. Light can also be a source of activation energy for a reaction. **Figure 4** shows how activation energy relates to exothermic reactions and endothermic reactions.

Figure 4 **Energy Diagrams**

Exothermic Reaction Once an exothermic reaction starts, it can continue. The energy given off as the product forms continues to supply the activation energy needed for the substances to react.

Endothermic Reaction An endothermic reaction continues to absorb energy. Energy must be used to provide the activation energy needed for the substances to react.





Factors Affecting Rates of Reactions

The rate of a reaction is a measure of how fast the reaction takes place. Recall that the rate of a reaction depends on how fast new particles form. There are four factors that affect the rate of a reaction. These factors are: temperature, concentration, surface area, and the presence of an inhibitor or catalyst.

Temperature

A higher temperature causes a faster rate of reaction, as shown in **Figure 5.** At high temperatures, particles of reactants move quickly. The rapid movement causes the particles to collide often and with a lot of energy. So, many particles have the activation energy to react. And many reactants can change into products in a short time.

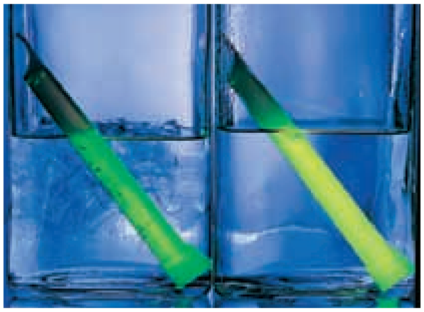


Figure 5 *The light stick on the right glows brighter than the one on the left because the one on the right is warmer. The higher temperature causes the rate of the reaction to increase.*

Quick Lab

Which Is Quicker?

1. Fill a **clear plastic cup** with **250 mL of warm water.** Fill a **second clear plastic cup** with **250 mL of cold water.**
2. Place **one-quarter of an effervescent tablet** in each of the two cups of water at the same time. Using a **stopwatch,** time each reaction.
3. Observe each reaction, and record your observations.
4. In which cup did the reaction occur at a faster rate?

Figure 6 **Concentration of Solutions**

When the amount of copper sulfate crystals dissolved in water is **small,** the concentration of the copper sulfate solution is **low.**

When the amount of copper sulfate crystals dissolved in water is **large,** the concentration of the copper sulfate solution is **high.**

Concentration

In general, a high concentration of reactants causes a fast rate of a reaction. *Concentration* is a measure of the amount of one substance dissolved in another substance, as shown in **Figure 6.** When the concentration is high, there are many reactant particles in a given volume. So, there is a small distance between particles. The particles run into each other often. Thus, the particles react faster.

Reading Check **How does a high concentration of reactants increase the rate of a reaction?**

CONNECTION TO Biology

Enzymes and Inhibitors
Enzymes are proteins that speed up reactions in your body. Sometimes, chemicals called *inhibitors* stop the action of enzymes. Research how inhibitors are beneficial in reactions in the human body. Make a poster or a model that explains what you have learned, and present it to your class.

ACTIVITY

Surface Area

Surface area is the amount of exposed surface of a substance. Increasing the surface area of solid reactants increases the rate of a reaction. Grinding a solid into a powder makes a larger surface area. Greater surface area exposes more particles of the reactant to other reactant particles. This exposure to other particles causes the particles of the reactants to collide with each other more often. So, the rate of the reaction is increased.

Inhibitors

An **inhibitor** is a substance that slows down or stops a chemical reaction. Slowing down or stopping a reaction may sometimes be useful. For example, preservatives are added to foods to slow down the growth of bacteria and fungi. The preservatives prevent bacteria and fungi from producing substances that can spoil food. Some antibiotics are examples of inhibitors. For example, penicillin prevents certain kinds of bacteria from making a cell wall. So, the bacteria die.

inhibitor a substance that slows down or stops a chemical reaction

catalyst a substance that changes the rate of a chemical reaction without being used up or changed very much

Catalysts

Some chemical reactions would be too slow to be useful without a catalyst (KAT uh LIST). A **catalyst** is a substance that speeds up a reaction without being permanently changed. Because it is not changed, a catalyst is not a reactant. A catalyst lowers the activation energy of a reaction, which allows the reaction to happen more quickly. Catalysts called *enzymes* speed up most reactions in your body. Catalysts are even found in cars, as seen in **Figure 7.** The catalytic converter decreases air pollution. It does this by increasing the rate of reactions that involve the harmful products given off by cars.

Figure 7 *This catalytic converter contains platinum and palladium. These two catalysts increase the rate of reactions that make the car's exhaust less harmful.*

SECTION Review

Summary

- Energy is given off in exothermic reactions.
- Energy is absorbed in an endothermic reaction.
- The law of conservation of energy states that energy is neither created nor destroyed.
- Activation energy is the energy needed for a reaction to occur.
- The rate of a chemical reaction is affected by temperature, concentration, surface area, and the presence of an inhibitor or catalyst.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. An <u>exothermic</u> reaction absorbs energy.
2. The rate of a reaction can be <u>increased</u> by adding an inhibitor.

Understanding Key Ideas

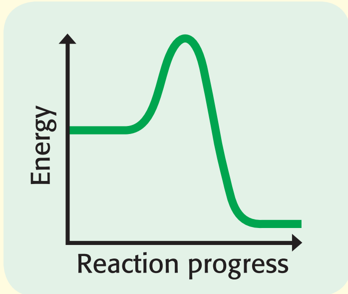
3. Which of the following will not increase the rate of a reaction?
   a. adding a catalyst
   b. increasing the temperature of the reaction
   c. decreasing the concentration of reactants
   d. grinding a solid into powder
4. How does the concentration of a solution affect the rate of reaction?

Critical Thinking

5. **Making Comparisons** Compare exothermic and endothermic reactions.
6. **Applying Concepts** Explain how chewing your food thoroughly can help your body digest food.

Interpreting Graphics

Use the diagram below to answer the questions that follow.



7. Does this energy diagram show an exothermic or an endothermic reaction? How can you tell?
8. A catalyst lowers the amount of activation energy needed to get a reaction started. What do you think the diagram would look like if a catalyst were added?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Exothermic and Endothermic Reactions

SciLinks code: HSM0555

Using Scientific Methods

Skills Practice Lab

Speed Control

The reaction rate (how fast a chemical reaction happens) is an important factor to control. Sometimes, you want a reaction to take place rapidly, such as when you are removing tarnish from a metal surface. Other times, you want a reaction to happen very slowly, such as when you are depending on a battery as a source of electrical energy.

In this lab, you will discover how changing the surface area and concentration of the reactants affects reaction rate. In this lab, you can estimate the rate of reaction by observing how fast bubbles form.

OBJECTIVES

Describe how the surface area of a solid affects the rate of a reaction.

Explain how concentration of reactants will speed up or slow down a reaction.

MATERIALS

- funnels (2)
- graduated cylinders, 10 mL (2)
- hydrochloric acid, concentrated
- hydrochloric acid, dilute
- strips of aluminum, about 5 cm x 1 cm each (6)
- scissors
- test-tube rack
- test tubes, 30 mL (6)

SAFETY

Part A: Surface Area

Ask a Question

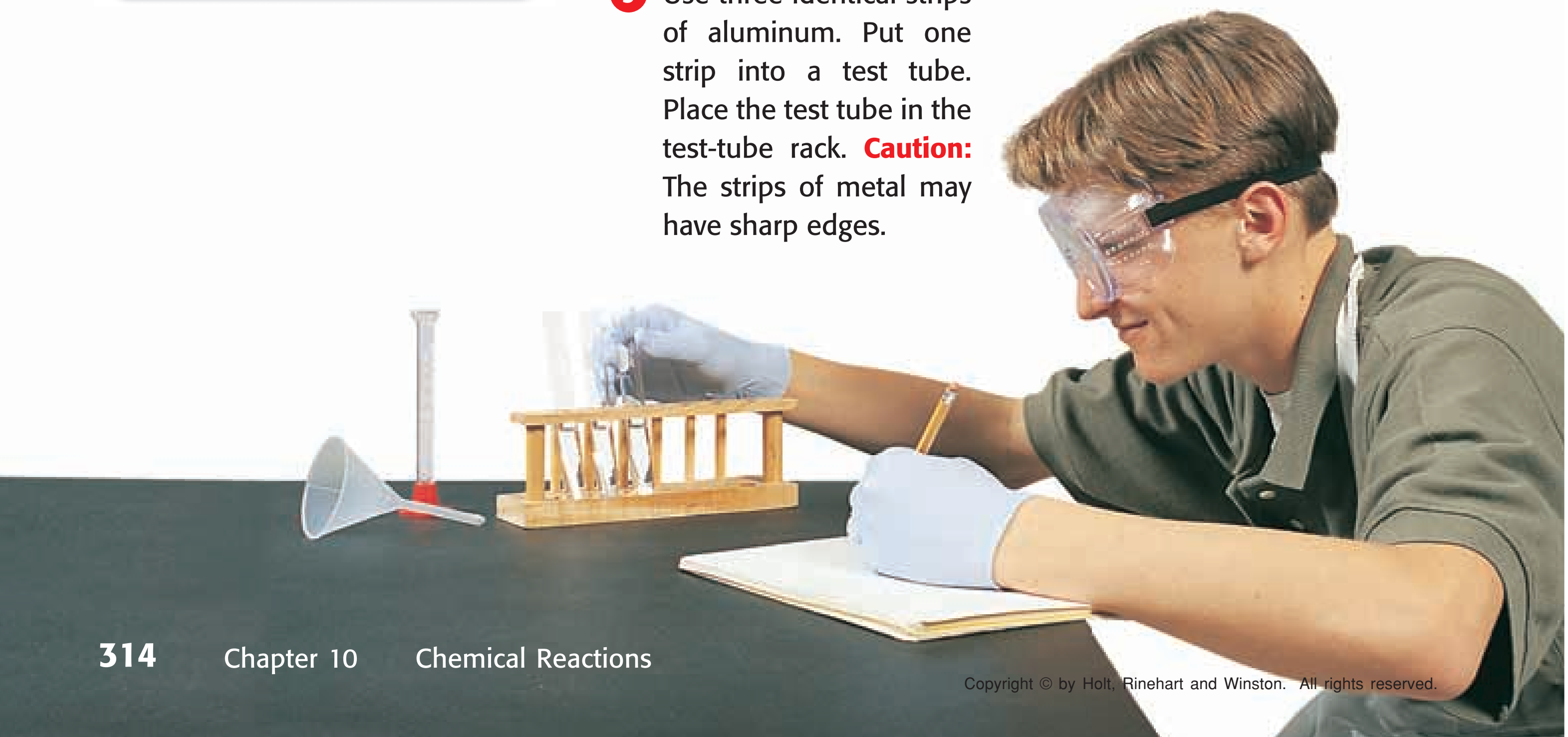
1. How does changing the surface area of a metal affect reaction rate?

Form a Hypothesis

2. Write a statement that answers the question above. Explain your reasoning.

Test the Hypothesis

3. Use three identical strips of aluminum. Put one strip into a test tube. Place the test tube in the test-tube rack. **Caution:** The strips of metal may have sharp edges.



4. Carefully fold a second strip in half and then in half again. Use a textbook or other large object to flatten the folded strip as much as possible. Place the strip in a second test tube in the test-tube rack.
5. Use scissors to cut a third strip of aluminum into the smallest possible pieces. Place all of the pieces into a third test tube, and place the test tube in the test-tube rack.
6. Use a funnel and a graduated cylinder to pour 10 mL of concentrated hydrochloric acid into each of the three test tubes. **Caution:** Hydrochloric acid is corrosive. If any acid should spill on you, immediately flush the area with water and notify your teacher.
7. Observe the rate of bubble formation in each test tube. Record your observations.

Analyze the Results

1. **Organizing Data** Which form of aluminum had the greatest surface area? the smallest surface area?
2. **Analyzing Data** The amount of aluminum and the amount of acid were the same in all three test tubes. Which form of the aluminum seemed to react the fastest? Which form reacted the slowest? Explain your answers.
3. **Analyzing Results** Do your results support the hypothesis you made? Explain.

Draw Conclusions

4. **Making Predictions** Would powdered aluminum react faster or slower than the forms of aluminum you used? Explain your answer.

Part B: Concentration

Ask a Question

1. How does changing the concentration of acid affect the reaction rate?

Form a Hypothesis

2. Write a statement that answers the question above. Explain your reasoning.

Test the Hypothesis

3. Place one of the three remaining aluminum strips in each of the three clean test tubes. (Note: Do not alter the strips.) Place the test tubes in the test-tube rack.
4. Using the second funnel and graduated cylinder, pour 10 mL of water into one of the test tubes. Pour 10 mL of dilute acid into the second test tube. Pour 10 mL of concentrated acid into the third test tube.
5. Observe the rate of bubble formation in the three test tubes. Record your observations.

Analyze the Results

1. **Explaining Events** In this set of test tubes, the strips of aluminum were the same, but the concentration of the acid was different. Was there a difference between the test tube that contained water and the test tubes that contained acid? Which test tube formed bubbles the fastest? Explain.
2. **Analyzing Results** Do your results support the hypothesis you made? Explain.

Draw Conclusions

3. **Applying Conclusions** Why should spilled hydrochloric acid be diluted with water before it is wiped up?

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

subscript	exothermic reaction
inhibitor	synthesis reaction
coefficient	reactant

1. Adding a(n) ___ will slow down a chemical reaction.

2. A chemical reaction that gives off heat is called a(n) ___.

3. A chemical reaction that forms one compound from two or more substances is called a(n) ___.

4. The 2 in the formula Ag_2S is a (an) ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

5. Balancing a chemical equation so that the same number of atoms of each element is found in both the reactants and the products is an example of
   - **a.** activation energy.
   - **b.** the law of conservation of energy.
   - **c.** the law of conservation of mass.
   - **d.** a double-displacement reaction.

6. Which of the following is the correct chemical formula for dinitrogen tetroxide?
   - **a.** N_4O_2
   - **b.** NO_2
   - **c.** N_2O_5
   - **d.** N_2O_4

7. In which type of reaction do ions in two compounds switch places?
   - **a.** a synthesis reaction
   - **b.** a decomposition reaction
   - **c.** a single-displacement reaction
   - **d.** a double-displacement reaction

8. Which of the following actions is an example of the use of activation energy?
   - **a.** plugging in an iron
   - **b.** playing basketball
   - **c.** holding a lit match to paper
   - **d.** eating

9. Enzymes in your body act as catalysts. Thus, the role of enzymes is
   - **a.** to increase the rate of chemical reactions.
   - **b.** to decrease the rate of chemical reactions.
   - **c.** to help you breathe.
   - **d.** to inhibit chemical reactions.

Short Answer

10. Name the type of reaction that each of the following equations represents.
    - **a.** $2Cu + O_2 \rightarrow 2CuO$
    - **b.** $2Na + MgSO_4 \rightarrow Na_2SO_4 + Mg$
    - **c.** $Ba(CN)_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCN$

11. Describe what happens to chemical bonds during a chemical reaction.

12. Name four ways that you can change the rate of a chemical reaction.

13. Describe four clues that signal that a chemical reaction is taking place.

Math Skills

14 Write balanced equations for the following:

a. $Fe + O_2 \rightarrow Fe_2O_3$

b. $Al + CuSO_4 \rightarrow Al_2(SO_4)_3 + Cu$

c. $Mg(OH)_2 + HCl \rightarrow MgCl_2 + H_2O$

15 Calculate the number of atoms of each element shown in the formulas below:

a. $CaSO_4$

b. $4NaOCl$

c. $Fe(NO_3)_2$

d. $2Al_2(CO_3)_3$

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *products, chemical reaction, chemical equation, chemical formulas, reactants, coefficients,* and *subscripts.*

17 **Evaluating Assumptions** Your friend is very worried by rumors that he has heard about a substance called *dihydrogen monoxide* in the city's water system. What could you say to your friend to calm his fears? (Hint: Write the formula of the substance.)

18 **Analyzing Ideas** As long as proper safety precautions have been taken, why can explosives be transported long distances without exploding?

19 **Applying Concepts** You measured the mass of a steel pipe before leaving it outdoors. One month later, the pipe had rusted, and its mass had increased. Does this change violate the law of conservation of mass? Explain your answer.

20 **Applying Concepts** Acetic acid, a compound found in vinegar, reacts with baking soda to produce carbon dioxide, water, and sodium acetate. Without writing an equation, identify the reactants and the products of this reaction.

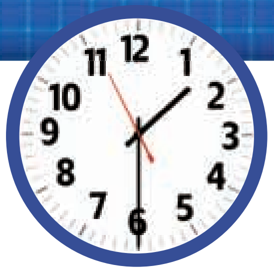
INTERPRETING GRAPHICS

Use the photo below to answer the questions that follow.

21 What evidence in the photo supports the claim that a chemical reaction is taking place?

22 Is this reaction an exothermic or endothermic reaction? Explain your answer.

23 Draw and label an energy diagram of both an exothermic and endothermic reaction. Identify the diagram that describes the reaction shown in the photo above.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The key to an air bag's success during a crash is the speed at which it inflates. Inside the bag is a gas generator that contains the compounds sodium azide, potassium nitrate, and silicon dioxide. At the moment of a crash, an electronic sensor in the car detects the sudden change in speed. The sensor sends a small electric current to the gas generator. This electric current provides the activation energy for the chemicals in the gas generator. The rate at which the reaction happens is very fast. In 1/25 of a second, the gas formed in the reaction inflates the bag. The air bag fills upward and outward. By filling the space between a person and the car's dashboard, the air bag protects him or her from getting hurt.

1. Which of the following events happens first?

- **A** The sensor sends an electric current to the gas generator.
- **B** The air bag inflates.
- **C** The air bag fills the space between the person and the dashboard.
- **D** The sensor detects a change in speed.

2. What provides the activation energy for the reaction to occur?

- **F** the speed of the car
- **G** the inflation of the air bag
- **H** the hot engine
- **I** the electric current from the sensor

3. What is the purpose of this passage?

- **A** to convince the reader to wear a seat belt
- **B** to describe the series of events that inflate an air bag
- **C** to explain why air bags are an important safety feature in cars
- **D** to show how chemical reactions protect pedestrians

Passage 2 An important tool in fighting forest fires is a slimy, red goop. This mixture of powder and water is a very powerful fire retardant. The burning of trees, grass, and brush is an exothermic reaction. The fire retardant slows or stops this self-feeding reaction by increasing the activation energy for the materials to which it sticks. A plane can carry between 4,500 and 11,000 L of the goop. The plane then drops it all in front of the raging flames of a forest fire when the pilot presses the button. Firefighters on the ground can gain valuable time when a fire is slowed with a fire retardant. This extra time allows the ground team to create a fire line that will finally stop the fire.

1. Which of the following sentences best summarizes the passage?

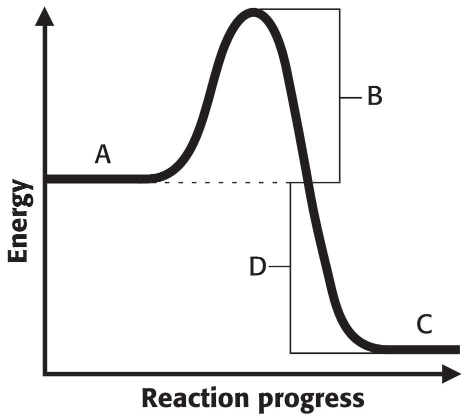
- **A** The burning of forests and other brush is an exothermic reaction.
- **B** Dropping fire retardants ahead of a flame can help firefighters on the ground stop a fire.
- **C** Firefighters on the ground create a fire line that will help stop the fire from spreading.
- **D** The slimy, red goop used as a fire retardant is made of a mixture of powder and water.

2. Based on the passage, which of the following statements is a fact?

- **F** Fire retardants are always successful in putting out fires.
- **G** No more than 4,500 L of red goop are loaded onto a plane.
- **H** A fire retardant works by increasing the activation energy for the materials that it sticks on.
- **I** The burning of trees is an endothermic reaction.

INTERPRETING GRAPHICS

Use the energy diagram below to answer the questions that follow.



1. Which letter represents the energy of the products?

A A
B B
C C
D D

2. Which letter represents the activation energy of the reaction?

F A
G B
H C
I D

3. Which of the following statements best describes the reaction represented by the graph?

A The reaction is endothermic because the energy of the products is greater than the energy of the reactants.
B The reaction is endothermic because the energy of the reactants is greater than the energy of the products.
C The reaction is exothermic because the energy of the products is greater than the energy of the reactants.
D The reaction is exothermic because the energy of the reactants is greater than the energy of the products.

MATH

Read each question below, and choose the best answer.

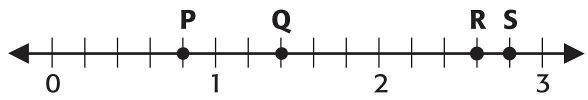
1. Nina has 15 pens in her backpack. She has 3 red pens, 10 black pens, and 2 blue pens. If Ben selects a pen to borrow at random, what is the probability that the pen selected is red?

A 2/15
B 1/5
C 1/3
D 2/3

2. How many atoms of nitrogen, N, are in the formula for calcium nitrate, $Ca(NO_3)_2$?

F 3
G 2
H 6
I 1

3. Which letter best represents the number 2 3/5 on the number line?



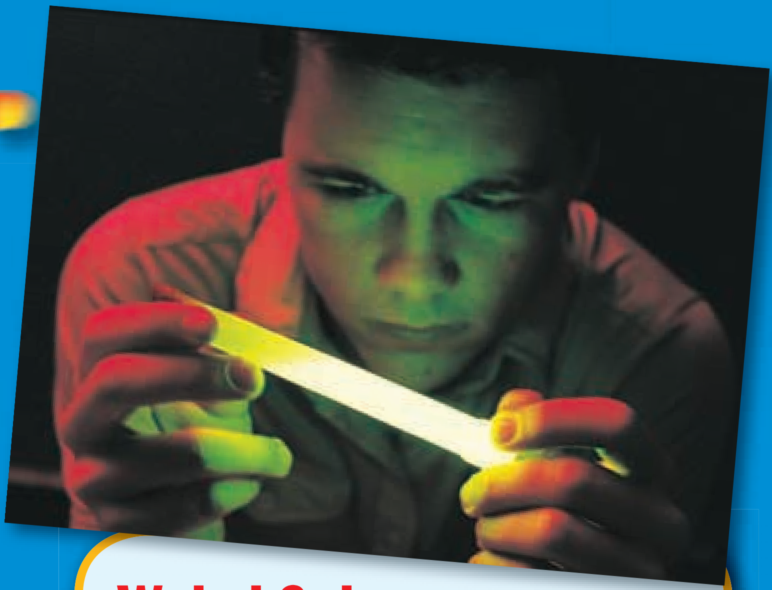
A P
B Q
C R
D S

4. According to the following chemical equation, how many reactants are needed to form water and carbon dioxide?

$$H_2CO_3 \rightarrow H_2O + CO_2$$

F one
G two
H three
I four

Science in Action



Science, Technology, and Society

Bringing Down the House!

Have you ever watched a building being demolished? It takes only minutes to demolish it, but a lot of time was spent planning the demolition. And it takes time to remove hazardous chemicals from the building. For example, asbestos, which is found in insulation, can cause lung cancer. Mercury found in thermostats can cause brain damage, birth defects, and death. It is important to remove these substances because most of the rubble is sent to a landfill. If hazardous chemicals are not removed, they could leak into the groundwater and enter the water supply.

Math ACTIVITY

A city produces 4 million tons of waste in 1 year. Of this waste, 82% is solid waste. If 38% of the solid waste comes from the construction and demolition of buildings, how many tons of waste does this represent?

Weird Science

Light Sticks

Have you ever seen light sticks at a concert? Your family may even keep them in the car for emergencies. But how do light sticks work? To activate the light stick, you have to bend it. Most light sticks are made of a plastic tube that contains a mixture of two chemicals. Also inside the tube is a thin glass vial, which contains hydrogen peroxide. As long as the glass vial is unbroken, the two chemicals are kept separate. But bending the ends of the tube breaks the glass vial. This action releases the hydrogen peroxide into the other chemicals and a chemical reaction occurs, which makes the light stick glow.

Social Studies ACTIVITY

Who invented light sticks? What was their original purpose? Research the answers to these questions. Make a poster that shows what you have learned.

Careers

Larry McKee

Arson Investigator Once a fire dies down, you might see an arson investigator like Lt. Larry McKee on the scene. "After the fire is out, I can investigate the fire scene to determine where the fire started and how it started," says McKee, who questions witnesses and firefighters about what they have seen. He knows that the color of the smoke can indicate certain chemicals. He also has help detecting chemicals from an accelerant-sniffing dog, Nikki. Nikki has been trained to detect about 11 different chemicals. If Nikki finds one of these chemicals, she begins to dig. McKee takes a sample of the suspicious material to the laboratory. He treats the sample so that any chemicals present will dissolve in a liquid. A sample of this liquid is placed into an instrument called a *gas chromatograph* and tested. The results of this test are printed out in a graph, from which the suspicious chemical is identified. Next, McKee begins to search for suspects. By combining detective work with scientific evidence, fire investigators can help find clues that can lead to the conviction of the arsonist.

Language Arts ACTIVITY

WRITING SKILL Write a one-page story about an arson investigator. Begin the story at the scene of a fire. Take the story through the different steps that you think an investigator would have to go through to solve the crime.

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword **HP5REAF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS14.

11

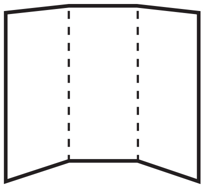
Chemicals and Our World

About the PHOTO

Have you ever used utensils made from food to eat food? You would if you used these knives, forks, and spoons! These colorful plastic utensils and the packing material held in the hands are made from chemicals found in corn. But what makes these objects so special is that the plastic is biodegradable. So, the plastic will break down easily and is better for the environment than other kinds of plastic are.

PRE-READING ACTIVITY

FOLDNOTES **Tri-Fold** Before you read the chapter, create the FoldNote entitled "Tri-Fold" described in the **Study Skills** section of the Appendix. Write what you know about chemicals in the column labeled "Know." Then, write what you want to know in the column labeled "Want." As you read the chapter, write what you learn about chemicals in the column labeled "Learn."



START-UP ACTIVITY

Playing with Plastics

The word *plastic* is a general name given to a wide range of materials. In this activity, you will test the physical properties of different kinds of plastics.

Procedure

1. Obtain **four pieces of plastic** from your teacher. Three pieces will be labeled "A," "B," or "C." The fourth piece will be labeled "Unknown."
2. Make a table that has five columns. Label the first column "Property," and label the remaining columns "A," "B," "C," and "Unknown."
3. Observe and test the physical properties of the pieces of plastic. What do the plastic pieces look like? Can you bend the plastic? Does the plastic float in water? Test as many properties as you can think of. Record the results of your property tests in your table.

Analysis

1. Did the pieces of plastic have the same properties? If not, why do you think the properties differed?
2. The unknown piece of plastic is the same kind of plastic that one of the other pieces (labeled "A," "B," or "C") is. What is the identity of the unknown piece of plastic? How do you know? How might this plastic be used?

SECTION 1

Natural and Synthetic Chemicals

READING WARM-UP

Objectives

- Explain the difference between natural and synthetic chemicals.
- Give examples of natural and synthetic chemicals.

Terms to Learn

chemical

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Imagine that you are hiking with your friend. You stop by a stream and take a sip of the water. "Water tastes so much better without any chemicals in it!" exclaims your friend.

Is the water from the stream truly free of chemicals? No! In fact, water itself is a chemical. A **chemical** is any substance that has a defined composition. The stream's water probably contains other chemicals, such as dissolved minerals and gases, too. You are surrounded by chemicals everywhere you go. Even your body is made of chemicals! All chemicals can be divided into two groups: natural chemicals and synthetic chemicals.

chemical any substance that has a defined composition

Natural Chemicals

Natural chemicals are chemicals that can be found in nature or that are made by natural processes. The water, rocks, and plants in **Figure 1** are natural chemicals or are made of natural chemicals. Other examples of natural chemicals are some metals, gases in the air, and proteins. You may think that all natural chemicals are safe. However, some natural chemicals, such as the poison in poison ivy, can be dangerous.

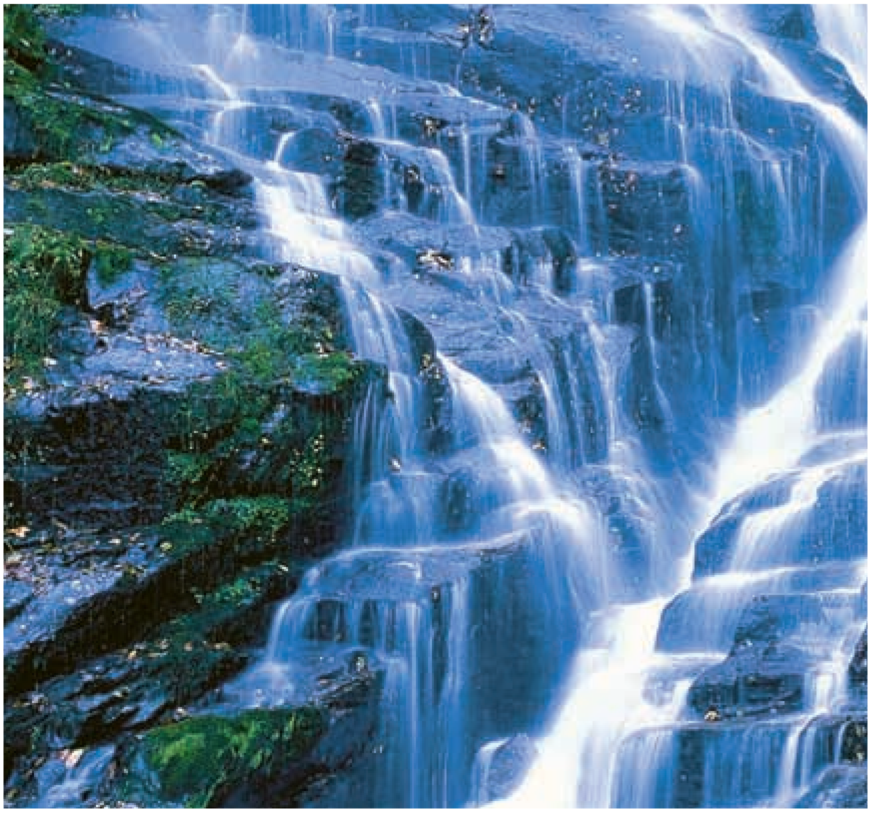
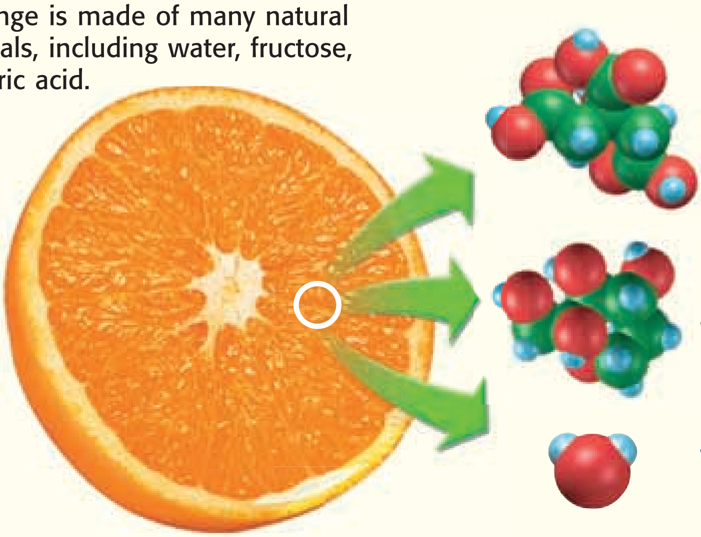


Figure 1 *Everything you see in this photo is made of natural chemicals.*

Figure 2 Natural Chemicals in an Orange

An orange is made of many natural chemicals, including water, fructose, and citric acid.



Citric acid, $C_6H_8O_7$, gives oranges their tart taste.

Fructose, $C_6H_{12}O_6$, is a sugar that is commonly found in fruits.

Water, H_2O, makes up a large part of all plants and animals.

Structure of Natural Chemicals

Particles of natural chemicals have a wide range of sizes. For example, a particle of helium gas is only one atom. But particles of proteins, such as the proteins that make up some foods, are made of hundreds or thousands of atoms joined together by chemical bonds. Some things, such as plants and animals, are made up of many kinds of natural chemicals. **Figure 2** shows three of the many natural chemicals that make up an orange. Notice that the structure of natural chemicals can be simple, like the structure of water, or complex, like the structure of citric acid.

Production of Natural Chemicals

It might be tempting to say that natural chemicals are chemicals that are not made by humans. But that statement is not true! The human body makes natural chemicals through natural processes all of the time. When you breathe, you release the natural chemical carbon dioxide. Your body also makes chemicals that are more complex, such as proteins and fats.

Natural chemicals are also made by other living things, such as plants, insects, and bacteria. For example, green plants can make chemicals called *carbohydrates* through the process of photosynthesis (FOHT oh SIN thuh sis). But some natural chemicals are made through natural processes that don't involve living things. Minerals and some gems form through processes involving the Earth.

Reading Check **Name three kinds of natural chemicals that your body makes.** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Social Studies

Natural Dyes Native Americans used natural dyes to color their clothing and artwork. Found in plants, these dyes are natural chemicals that can be removed from the plants by boiling or soaking plant parts in water. Native Americans used the bark, leaves, petals, and berries of various plants to produce different colors. Learn how to extract dyes from plants and color a cotton rag or T-shirt by using a natural dye that you made.

ACTIVITY

Synthetic Chemicals

The word *synthetic* usually refers to something that is made by humans or to something that is not natural. So, a *synthetic chemical* is a chemical that is not found in nature and that is not made by natural processes. Synthetic chemicals are very common in today's modern world. You probably use things made of synthetic chemicals every day.

Reading Check **What is a synthetic chemical?**

Kinds of Synthetic Chemicals

Take a look around you. Do you see things made from plastic? Perhaps you see a plastic bottle or the plastic housing of a computer monitor. Plastics are common synthetic chemicals. Different kinds of plastics have different properties. For example, some plastics are flexible, some are rigid, some are clear, and some are colored. Their different properties allow plastics to be used to make various things.

Many medicines are also examples of synthetic chemicals. The pain reliever that you might take when you have a headache and the allergy medicines that keep you from sneezing are synthetic chemicals.

You can also find synthetic chemicals in the food you eat and the clothes you wear. Although food is mostly made up of natural chemicals, synthetic chemicals are added to some foods. Examples of synthetic food additives are artificial sweeteners and food coloring. Similarly, many clothes are made from natural chemicals. But some clothing fabrics are partially or completely made of synthetic fibers. Polyester is a synthetic fiber, as is nylon, shown in **Figure 3.**

Figure 3 *The white rope being pulled out of the liquid is nylon. Nylon forms at the surface between the two chemicals in the beaker. Nylon is one of the most widely used synthetic chemicals.*

Production of Synthetic Chemicals

Synthetic chemicals are made during chemical reactions between natural chemicals, other synthetic chemicals, or both. Scientists develop ways to make synthetic chemicals through laboratory experiments. Often, scientists try to make chemicals that have specific properties or a specific combination and arrangement of atoms. For example, a scientist may try to make a strong, rigid plastic like that used in the helmet shown in **Figure 4.** Another scientist may try to make a medicine to treat a certain disease.

Sometimes, scientists produce useful synthetic chemicals by accident. For example, the synthetic chemical Teflon™ was first made by mistake. Now, Teflon is used to make nonstick cookware and to make fabrics stain resistant. Silly Putty™ is another example of a synthetic chemical that was made by accident. Silly Putty was first made when a scientist was trying to make a synthetic rubber. The putty did not have the properties of rubber but did have properties that made the putty a fun toy!

Figure 4 *This skateboarder's helmet is made from various synthetic chemicals. Both the rigid plastic cover and the cushioning foam will protect the skateboarder if he falls.*

SECTION Review

Summary

- Chemicals are substances that have defined compositions.
- Natural chemicals are found in nature or are made by natural processes.
- Synthetic chemicals are substances that are not formed by natural processes and that are made by humans.

Using Key Terms

1. Use the following term in a sentence: *chemical*.

Understanding Key Ideas

2. Which of the following is a synthetic chemical?
   - **a.** water
   - **b.** fructose
   - **c.** nylon
   - **d.** oxygen
3. What is the difference between natural chemicals and synthetic chemicals?
4. List four examples of natural chemicals and four examples of synthetic chemicals.

Math Skills

5. Aspartame is a synthetic chemical that is used as an artificial sweetener in many low-Calorie foods. Aspartame's chemical formula is $C_{14}H_{18}N_2O_5$. What percentage of the atoms in aspartame are oxygen, O?

Critical Thinking

6. **Applying Concepts** The chemical sodium chloride (table salt) can be found in seawater and can also be made by scientists in a laboratory. Is sodium chloride a natural or a synthetic chemical? Explain your answer.
7. **Expressing Opinions** How do synthetic chemicals affect your quality of life? Explain your answer with specific examples.

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Topic: Chemicals
SciLinks code: HSM0277

SECTION 2

Chemical Benefits

READING WARM-UP

Objectives

- Explain the beneficial effects of different kinds of medicines.
- Describe how food preservatives work and why they are useful.
- Describe two ways that chemicals help improve crop yield.
- Explain the role of chemicals in sanitation.

Terms to Learn

medicine
potency
dose

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Achoo! It's the morning of a big math test. You studied hard and are ready for the test, but you woke up feeling terrible. Your nose is running and you can't stop sneezing. You don't want to miss the test, but what can you do to feel better?

Perhaps your runny nose and sneezing are the result of a cold or allergies. In either case, you could take some medicine to relieve your symptoms. Medicines are just one example of the products in which chemicals are used to help people. Read on to learn about medicines and other benefits of chemicals.

Medicines

A **medicine** is a substance that is used to cure, prevent, or treat illness or discomfort. Medicines may be made of one chemical or a mixture of chemicals. All medicines improve a person's health or well-being by causing a change in the person's physical or psychological state. **Table 1** lists several kinds of medicines and their effects.

Some medicines are natural chemicals, but many medicines are synthetic chemicals. An example of a natural medicine is penicillin. Penicillin kills certain kinds of bacteria and is produced by a type of mold. An example of a synthetic medicine is the pain reliever aspirin. Aspirin is made by changing a naturally occurring acid through a chemical reaction.

medicine any drug that is used to cure, prevent, or treat illness or discomfort

Table 1 **Kinds of Medicines**

Kind	Example	Effect
Analgesic	acetaminophen	It relieves pain.
Antihistamine	diphenhydramine	It helps relieve minor allergy symptoms.
Antacid	aluminum hydroxide	It neutralizes stomach acid for relief from heartburn.
Antibiotic	penicillin	It kills some kinds of bacteria to help cure infections.
Hormone	insulin	Different hormones work differently; insulin helps treat diabetes.
Vaccine	chickenpox vaccine	It helps prevent infections in people exposed to the disease.

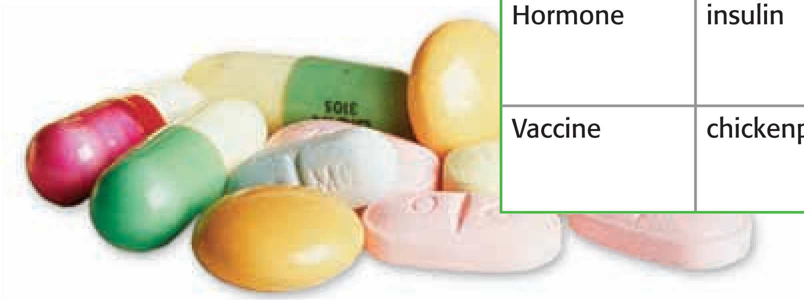


Figure 1 *A dose of this children's medicine depends on the weight of the child taking it.*

Medicines, Potency, and Side Effects

To be a good medicine, a medicine must be potent. The **potency** of a medicine is the power of a medicine to produce its desired effect. For example, penicillin is potent at killing certain kinds of bacteria. Good medicines also have to be safe. Penicillin wouldn't be very useful if it damaged the heart while it was killing bacteria. But penicillin doesn't damage the heart. So, for most people, penicillin is safe.

However, no medicine is perfectly safe for everyone. Most medicines cause effects that differ from the intended effect. These effects are called *side effects*. Good medicines have minor side effects, such as headaches or sleepiness. If a medicine has too many side effects or if the side effects are severe, the medicine may not be safe for everyone to use.

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

potency the power of a medicine to produce a desired effect

dose the quantity of medicine that needs to be taken over a period of time

Taking Medicines Properly

When you take a medicine, it is important to take the correct dose of the medicine. A **dose** is the amount of medicine that needs to be taken at one time. The amount of medicine that needs to be taken often depends on who is taking the medicine. For example, children take a smaller dose of a medicine than adults take. Also, small children take smaller doses than larger children take, as shown in **Figure 1.** Different doses are necessary because people are of different sizes. Adults are larger than children, so adults need a larger dose of medicine to have the correct concentration of medicine in their bodies.

SCHOOL to HOME

Reading Medicine Labels

Ask a parent to help you gather four or five medicines. Read the labels of the medicines. In your **science journal,** make a chart that shows the medicine names, the uses of each medicine, the proper dose for each medicine, and the side effects of each medicine. Ask your parent if he or she experienced any of the side effects, and make a note of his or her answers in the chart.

ACTIVITY

Food Preservatives

Chemicals are also beneficial when they are used as food preservatives. A *food preservative* is a chemical that can prevent or slow down the spoiling of food. Food preservatives are useful because they keep food fresh during the time it takes to transport the food to stores. They also allow you to store foods for longer periods of time and keep foods safe to eat.

How Preservatives Work

Food preservatives work in different ways. Some food preservatives prevent the growth of bacteria or mold. For example, antibiotics can be added to poultry, fish, or canned goods to kill bacteria. And sorbic acid can be added to fruit juice or dried fruit to prevent the growth of mold. If certain bacteria and molds are eaten, they can make people sick. So, food preservatives can keep you healthy.

Other food preservatives work by preventing chemical reactions that break down foods. For example, preservatives called *BHA* and *BHT* are added to foods such as margarine and cereals to prevent the foods from becoming rancid. When food becomes rancid, it smells and tastes bad. The chemical vitamin C can be added to fruits to prevent a chemical reaction that causes the fruits to turn brown. Rancid or browned foods may not make you sick, but you may not want to eat them.

Still other preservatives prevent foods from going stale. These preservatives are found in store-bought cookies. They are not used in homemade cookies, such as the ones shown in **Figure 2,** so eat your cookies soon after you bake them!

Quick Lab

Apple Brown Betty

1. Use a **knife** to cut four bite-sized pieces from an **apple.** Place a **toothpick** in each piece.
2. Dip one piece of apple in **water,** one in **vegetable oil,** and one in **lemon juice.** Coat all sides of each piece. Do not dip the fourth piece in anything. Place the pieces on a **paper towel.**
3. Record your observations of the pieces. Then, predict what will happen to the pieces. After 15 minutes, observe the apple pieces again and record your observations. How did the pieces change?
4. Suppose that you are making a fruit salad that has pieces of apple in it. What could you do to keep the pieces of apple looking appetizing?

Figure 2 *Although homemade cookies are fun to make, they do not contain preservatives and will not stay fresh as long as store-bought cookies will.*

Crop Yield

A third way in which chemicals are beneficial is in their use to improve crop yields in farming. Farmers use different chemicals to increase the amounts of fruits or vegetables that are grown on a given amount of land. Two groups of chemicals used by farmers are fertilizers and pesticides.

Figure 3 *No one wants to eat an ear of corn with an insect in it! Therefore, pesticides are sprayed on corn fields to kill insects and other pests before they get into the corn.*

Fertilizers

All plants, including fruit trees and vegetable plants, need certain elements to grow well. The most important elements for plant growth are nitrogen, phosphorus, and potassium. These elements can be found in soil, but the soil where crops are grown sometimes does not have enough of these elements. To overcome this problem, farmers put fertilizers in their fields. A *fertilizer* is a chemical that improves the quality of the soil to produce plants.

Most fertilizers are a mixture of chemicals that contain nitrogen, phosphorus, and potassium. Fertilizers help farmers grow large, healthy plants that produce large amounts of fruits and vegetables. Without fertilizers, world food production would be less than half of what it is today.

Reading Check **What three elements are most important for plant growth?**

Pesticides

When growing fruits and vegetables for people to eat, farmers often discover that other things like to eat the food, too! In North America, insects, such as the one shown in **Figure 3,** eat about 13% of all crops. Worldwide, pests destroy about 33% of the world's potential food harvest.

Insects are just one of several kinds of organisms that are considered pests. A pest is any organism that lives where it is not wanted or grows in large enough numbers to cause economic damage. Pests include certain rodents, fungi, bacteria, and plants. Plant pests are often called *weeds*.

To reduce the loss of crops to pests, farmers often use pesticides. A *pesticide* is a poison that is used to kill insects, weeds, and other crop pests. During the last 50 years, scientists have invented many new pesticides. The pesticides are very effective, and farmers can rely on these pesticides to almost completely protect their crops from pests. However, farmers must be careful not to use large amounts of pesticides because pesticides can be dangerous to human health and the environment.

Sanitation

Chemicals are also beneficial in sanitation. *Sanitation* is the practice of providing sewage and solid waste disposal, clean drinking water, and clean living conditions. Good sanitation helps prevent the spread of diseases and infections.

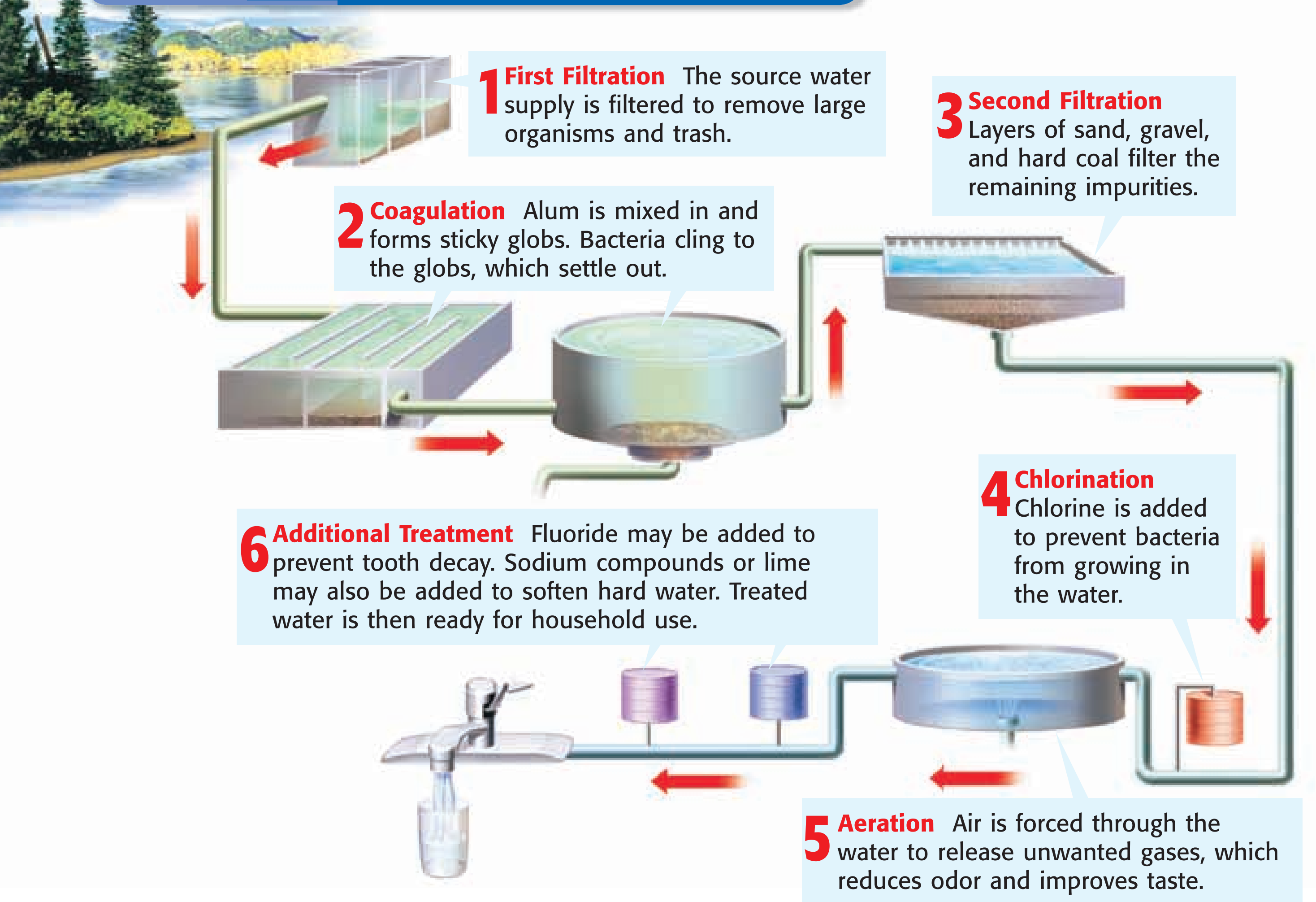
Chemicals and Large-Scale Sanitation

Some parts of good sanitation depend on the use of chemicals. For example, the chemical chlorine is used in the treatment of sewage wastewater. Wastewater is treated because it must be cleaned before it can be returned to a natural body of water. If the wastewater is not cleaned, the environment could be damaged by pollution. Chlorine helps clean wastewater by killing harmful bacteria and other microorganisms.

Chlorine and other chemicals are also used in the treatment of water for household use. **Figure 4** shows how water is treated to become safe drinking water.

Reading Check **How does chlorine help clean wastewater?**

Figure 4 **Drinking-Water Treatment**



Chemicals and Household Sanitation

Sanitation is also important in your home. Chemicals in household cleaners are needed to kill bacteria and other disease-causing microorganisms. For example, some kitchen and bathroom surface cleaners contain bleach. Bleach is a common name for the chemical sodium hypochlorite and is effective at killing bacteria and viruses. Another useful chemical is hydrogen peroxide. As shown in **Figure 5,** hydrogen peroxide can be applied to wounds to prevent infections.

Figure 5 *After a wound is washed with soap and water, using hydrogen peroxide on the wound can help prevent an infection.*

SECTION Review

Summary

- Medicines are substances that are used to cure, prevent, or treat illness or discomfort. Good medicines are potent and safe.
- Food preservatives are chemicals that can slow down or prevent the spoiling of food.
- Chemicals in fertilizers and pesticides help increase crop yields.
- Chemicals are used in sanitation to kill harmful bacteria and other microorganisms.

Using Key Terms

1. Use each of the following terms in a separate sentence: *medicine, potency,* and *dose*.

Understanding Key Ideas

2. Which of the following kinds of medicines should you take if you have a headache?
   a. hormone
   b. vaccine
   c. analgesic
   d. antacid
3. Pesticides can be used to kill
   a. insects.
   b. weeds.
   c. bacteria.
   d. All of the above
4. Describe the effects of antihistamines, antibiotics, and vaccines.
5. Why do children need smaller doses of medicine than adults need?
6. How do food preservatives work? What are two benefits of using food preservatives?
7. Describe two ways that chemicals can be used to improve crop yields.
8. Why are chemicals important in sanitation?

Math Skills

9. One spring, a farmer plants 70 acres of soybeans. Every year, she loses approximately 20% of her crop to pests. How many acres of soybeans can she expect to harvest? Suppose the farmer tries a new pesticide and reduces her crop loss to 10%. How many acres will she harvest?

Critical Thinking

10. **Making Inferences** Why is it important to read the directions every time you take a medicine?
11. **Applying Concepts** Suppose that you buy a loaf of bread and bake a loaf of bread on the same day. You store both loaves on the kitchen counter. Which loaf should you eat first? Explain.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Medicines from Plants; Food Preservation

SciLinks code: HSM0934; HSM0597

SECTION 3

Chemical Risks

Imagine that you and a friend are building a model airplane for a school project. As you pick up the tube of glue, your friend says, "Be careful—that's a dangerous chemical."

READING WARM-UP

Objectives

- List three ways that you can be exposed to dangerous chemicals.
- Identify chemicals that may contribute to certain human health conditions.
- Describe possible means to eliminate or reduce the effects of dangerous chemicals.

Terms to Learn

carcinogen

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Why is glue dangerous? One reason is that you can become dizzy if you inhale too many fumes from glue. But that doesn't mean that you shouldn't use glue. It just means that you have to use glue in a safe way.

Dangerous Chemicals and Exposure

Although many chemicals are safe, some chemicals can be dangerous to your health. Even useful chemicals, such as model-airplane glue, can be dangerous. Usually, health problems resulting from dangerous chemicals depend on a person's exposure to the chemicals. *Exposure* to a chemical means being in contact with the chemical. Greater exposure leads to greater risk of developing problems.

You can be exposed to dangerous chemicals in many ways. You can eat or drink dangerous chemicals. Alcohol and pesticides on fruits and vegetables are examples of chemicals that are eaten. You can touch dangerous chemicals. Some chemicals, such as mercury, can be absorbed through your skin if you touch them. And you can inhale dangerous chemicals, such as the fumes from model-airplane glue. The chemicals in cigarette smoke, shown in **Figure 1,** are also examples of dangerous chemicals that can be inhaled.

Health problems resulting from chemicals can also be due to a person's individual susceptibility. *Individual susceptibility* is a person's risk of being affected negatively by something dangerous. When exposed to a danger, some people are at greater risk than other people are. For example, penicillin is safe for many people, but some people are severely allergic to penicillin. For people who are highly allergic to penicillin, penicillin can be deadly.

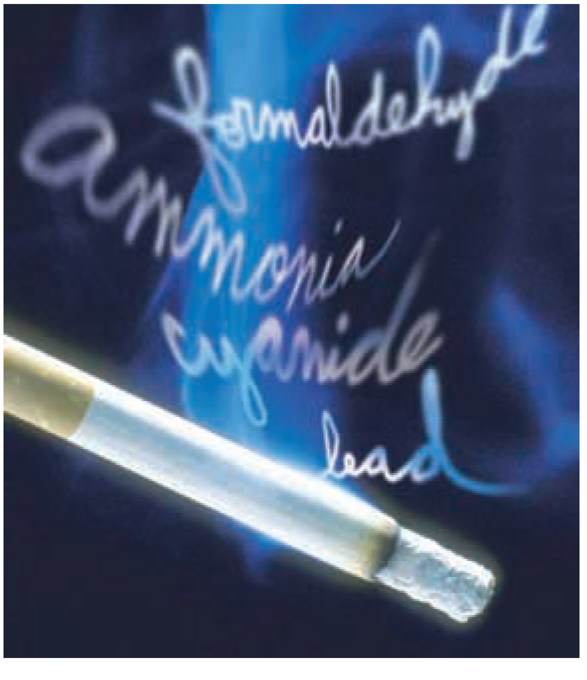

Figure 1 *Cigarette smoke contains many dangerous chemicals. Limit your exposure by choosing not to smoke and avoiding secondhand smoke.*

Diseases and Chemical Exposure

Some diseases can be caused by exposure to certain chemicals. Therefore, knowing what chemicals can be dangerous will help you reduce your risk of getting certain diseases. Read on to learn about some diseases that can be caused by chemical exposure.

Cancer

Cancer is a disease caused by uncontrolled cell growth. More than 1 million people in the United States are diagnosed with cancer every year, and cancer is the second leading cause of death in the United States. Cancer is caused by many things, including exposure to certain chemicals. Substances that cause cancer are called **carcinogens** (kahr SIN uh juhnz). **Table 1** shows a list of common chemical carcinogens.

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

Autoimmune Diseases

An autoimmune disease is a disease in which a person's immune system attacks certain cells, tissues, or organs of the body. The causes of autoimmune diseases are not well known, but some diseases may be caused by exposure to certain chemicals. For example, lupus is an autoimmune disease that may be triggered by certain antibiotics, certain drugs, and hormones.

***Table 1* Kinds of Carcinogens**

Carcinogen	Body parts that may be affected
Asbestos	lung, colon, larynx, and gastrointestinal system
Alcoholic beverages	mouth, pharynx, larynx, esophagus, liver, and breast
Arsenic	skin, lung, kidney, liver, and gastrointestinal system
Benzene	bone marrow
Coal tar	lung, mouth, skin, stomach, larynx, bladder, and bone marrow
Radon	lung
Soots	lung, esophagus, liver, and bone marrow
Environmental (second-hand) tobacco smoke	lung
Smokeless tobacco	mouth
Tobacco smoke	lung, bladder, mouth, pharynx, larynx, esophagus, and pancreas

MATH PRACTICE

Evaluating Statistics

The American Cancer Society estimated that 699,560 men in the United States would be diagnosed with cancer in 2004. Of these men, 13% would be diagnosed with lung cancer. From these statistics, calculate how many men were predicted to be diagnosed with lung cancer in 2004.

carcinogen a cancer-causing substance

Figure 2 *This little girl has fetal alcohol syndrome (FAS). Her condition causes her small size and distinct facial features. But the FAS affects her behavior and mental development the most.*

Birth Defects

Some birth defects are caused when a fetus is exposed to certain chemicals. For example, the child in **Figure 2** has fetal alcohol syndrome (FAS). FAS is a group of birth defects that a child may have because his or her mother drank large amounts of alcohol when pregnant. A child with FAS may be small at birth, have brain damage, and be mentally retarded. Other chemicals that are known to cause birth defects are thalidomide (a sedative) and isotretinoin (medicine for acne).

Diabetes

Diabetes is a disease that affects the body's ability to use sugar for energy. There are two main types of diabetes. In type 1 diabetes, the body produces little or no insulin. Insulin is a hormone that helps the body store glucose, or sugar. Insulin also enables cells to use glucose for energy. In type 2 diabetes, the body makes insulin but cannot use it properly. People who have type 1 diabetes and some people who have type 2 diabetes must receive daily insulin injections, as shown in **Figure 3.**

The causes of type 1 diabetes are not well known. Some people think that certain vaccines can trigger type 1 diabetes, but no scientific research currently supports this belief. The causes of type 2 diabetes are mostly related to a person's life-style. People who are overweight and do not exercise regularly are at greatest risk of developing type 2 diabetes. However, certain steroid medicines used to treat asthma and arthritis are known to trigger type 2 diabetes.

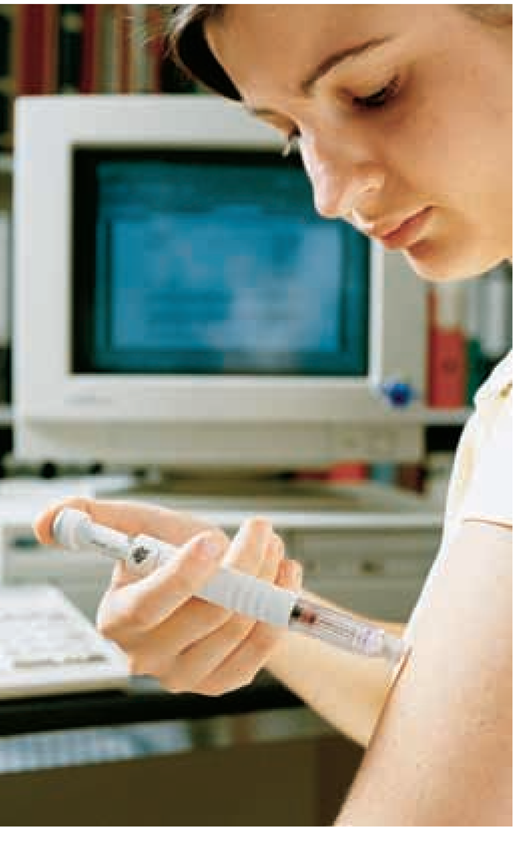

Figure 3 *This teen is giving herself an insulin injection to control her type 1 diabetes.*

Learning and Behavioral Disorders

Learning and behavioral disorders are caused by many things, including genetics. But some causes are related to chemical exposure. For example, lead poisoning can result in learning and behavioral disorders. Children may get lead poisoning if they eat paint chips from walls painted with lead-based paints. Thus, peeling paint should be removed from homes where young children live.

Kidney Disease

Kidneys are organs that filter water and wastes from the blood. Kidneys can be affected by a variety of diseases. These diseases cause the kidneys to function improperly or to fail completely. Some kidney diseases are caused by exposure to chemicals. For example, pain relievers, such as aspirin and ibuprofen, can cause kidney damage if they are used for long periods of time. Certain combinations of medicines, such as the combination of aspirin, acetaminophen, and caffeine, also can damage the kidneys.

Heart Disease

Heart disease is a general name for several diseases that affect the heart and the cardiovascular system. Strokes, heart attacks, and atherosclerosis (ATH uhr OH skluh ROH sis) are examples of heart diseases. Exposure to the chemicals in cigarette smoke can contribute to the development of heart disease. In addition, taking certain illegal drugs, such as cocaine and Ecstasy, can cause heart attacks.

Reading Check What are three examples of heart disease?

Asthma

The teen in **Figure 4** is using an inhaler to treat her asthma. Asthma is a disease that causes air passages in the lungs to narrow. Shortness of breath, wheezing, and coughing are symptoms of asthma. Allergies, respiratory infections, and chemicals in the air can cause asthma. Chemicals in cigarette smoke, air pollutants, and aerosol sprays can trigger asthma attacks.

Figure 4 *Asthma attacks can be triggered by certain chemicals but can be treated with other chemicals. The chemicals in an inhaler help restore normal breathing.*

CONNECTION TO Environmental Science

Ozone and Asthma Ozone is a chemical that can form near the surface of the Earth when air pollutants from cars and power plants react in the presence of heat and sunlight. Ground-level ozone can cause harmful health effects, including inflammation of the lungs and the aggravation of asthma. Research ground-level ozone, and make a pamphlet for teens who have asthma. In your pamphlet, explain the dangers of ozone and ways for teens to avoid having problems.

ACTIVITY

Figure 5 *Restaurants and other businesses often have rules that prohibit smoking in certain areas.*

Reducing Exposure to Dangerous Chemicals

Because some chemicals can be harmful to your health, reducing your exposure to them is important for reducing their effects. Luckily, laws and rules help reduce or eliminate the public's exposure to some dangerous chemicals. And you can do several things to reduce your personal exposure to other harmful chemicals.

Laws and Rules to Reduce Exposure

The federal government has passed a few laws to help reduce the amount of harmful chemicals released into the environment. Two such laws are the Clean Air Act, which was passed in 1970 and strengthened in 1990, and the Clean Water Act, which was passed in 1972. These acts set standards for acceptable levels of pollutants in the air and water. Since these acts were passed, some kinds of air pollution and water pollution in the United States have decreased.

Rules that ban smoking in certain public places help reduce people's exposure to the dangerous chemicals in cigarette smoke. In most restaurants, you can avoid secondhand smoke by choosing to sit in a nonsmoking area. You can also avoid secondhand smoke by eating at nonsmoking restaurants, such as the one shown in **Figure 5.** Smoking is also banned in most public areas of airports and government buildings.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5CMPW.**

Reading Check **Which two laws help reduce people's exposure to chemical pollutants?**

Reducing Your Exposure

Although dangerous chemicals are common, you can take many simple steps to reduce your exposure to them. For example, choosing not to smoke and avoiding people who are smoking can reduce or almost eliminate your exposure to cigarette smoke. Another way to reduce exposure is to work in a well-ventilated area when you are using chemicals that can produce dangerous fumes. Such chemicals include model-airplane glue and some household cleaners. Also, thoroughly washing fruits and vegetables, as shown in **Figure 6,** will keep you from accidentally eating pesticides that were sprayed on the plants during farming.

Figure 6 *Pesticides are often used on fruits and vegetables. Washing fruits and vegetables with water removes these chemicals.*

SECTION Review

Summary

- A person may be exposed to dangerous chemicals by eating, touching, or inhaling the chemicals.
- Some chemicals can contribute to certain human health conditions, including cancer, autoimmune diseases, birth defects, diabetes, learning and behavioral disorders, kidney disease, heart disease, and asthma.
- The effects of dangerous chemicals can be reduced or eliminated by reducing exposure to the chemicals.

Using Key Terms

1. In your own words, write a definition for the term *carcinogen*.

Understanding Key Ideas

2. Which of the following carcinogens can cause liver cancer?

a. asbestos
b. alcoholic beverages
c. coal tar
d. tobacco smoke

3. How can you be exposed to dangerous chemicals?

a. by touching the chemicals
b. by inhaling fumes from the chemicals
c. by eating the chemicals
d. All of the above

4. Why should pregnant women avoid drinking alcoholic beverages?

5. Name chemicals that may contribute to the following health conditions: autoimmune disease, diabetes, learning and behavioral disorders, heart disease, and asthma.

6. List three ways that you can reduce the effects of dangerous chemicals.

Math Skills

7. In one year, 272,810 women died from cancer. Of those women, 4% died from leukemia. How many women died from leukemia?

Critical Thinking

8. Predicting Consequences Suppose your aunt has severe back problems. She takes aspirin every day to relieve her pain. What health problems might she be in danger of developing?

9. Evaluating Conclusions Your friend tells you that he doesn't think that smoking is dangerous because many smokers live for a long time. Use the information that you learned in this section to evaluate your friend's belief.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Noninfectious Diseases; Smoking and Health

SciLinks code: HSM1042; HSM1403

Skills Practice Lab

Keep It Clean

One of the best ways to prevent the spread of bacterial and viral infections is to wash your hands frequently with soap and water. Many companies advertise that their soap contains chemicals that can destroy bacteria that are normally found on the body. These chemicals are called *antibacterial agents*. In this activity, you will investigate how effective antibacterial soaps are at killing bacteria.

OBJECTIVES

Investigate how well antibacterial soap works.

Practice counting bacterial colonies.

MATERIALS

- incubator
- pencil, wax
- Petri dishes, nutrient agar–filled, sterile (3)
- scrub brush, new
- soap, liquid, antibacterial
- stopwatch
- tape, transparent

SAFETY

Procedure

1. Keeping the agar plates closed at all times, use the wax pencil to label the bottom of each agar plate. Label one plate “Control,” one plate “No soap,” and one plate “Soap.”
2. Without washing your hands, carefully press several surfaces of your hands on the agar plate marked “Control.” Have your partner immediately put the cover back on the plate. After you touch the agar, do not touch anything with either hand.
3. Hold your right hand under running water for 2 min. Ask your partner to use the scrub brush to scrub all surfaces of your right hand throughout these 2 min. Be sure that your partner scrubs under your fingernails. After scrubbing, your partner should turn off the water and open the plate marked “No soap.” Touching only the agar, carefully press on the “No soap” plate with your right hand. Use the same surfaces that you used to press on the “Control” plate.
4. Repeat step 3, but use your left hand instead of your right hand. This time, ask your partner to scrub your left hand with liquid, antibacterial soap and the scrub brush. Use the plate marked “Soap” instead of the plate marked “No soap.”

5. Using transparent tape, secure the lid of each plate to its bottom half. Place the plates upside down in the incubator. Incubate overnight all three plates at 37°C.

6. Remove the plates from the incubator, and turn them right side up. Check each plate for the presence of bacterial colonies, and count the number of colonies present on each plate. Record this information. **Caution:** Do not remove the lids from any of the plates.

Analyze the Results

1. **Examining Data** Compare the bacterial growth on the plates. Which plate contained the most growth? Which contained the least?

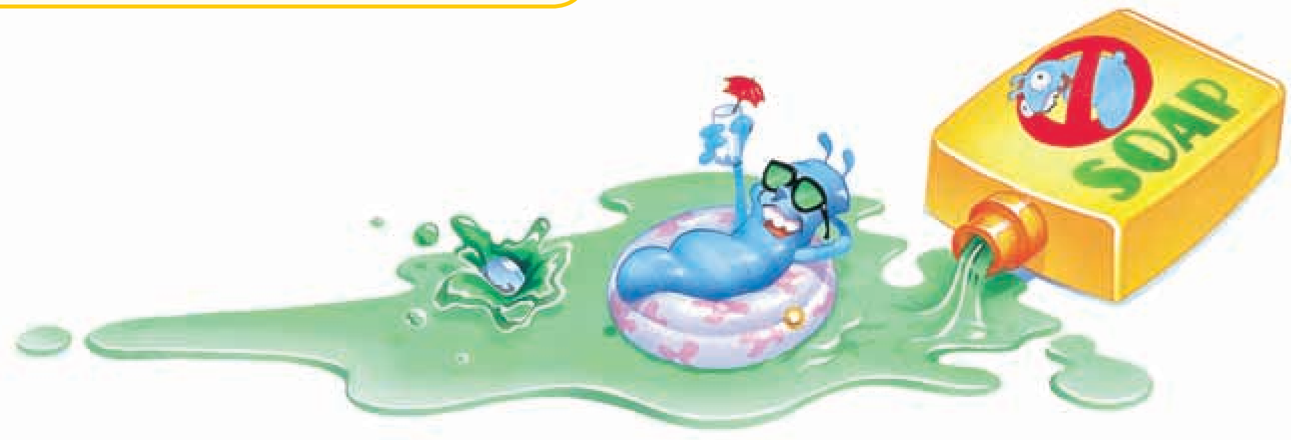
Draw Conclusions

2. **Drawing Conclusions** Does water alone effectively kill bacteria? Explain.

3. **Evaluating Results** How effective were the antibacterial chemicals? Explain.

Applying Your Data

Repeat this experiment, but use regular, not antibacterial, liquid soap. Describe how the results of the two experiments differ.



Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

chemical	carcinogen
medicine	dose
potency	

1. A chemical that is used to cure, prevent, or treat an illness is a ___.

2. The amount of medicine that you take at one time is a ___.

3. Radon is a ___ because it can cause several kinds of cancer.

4. Aspirin has a defined composition, so it is an example of a ___.

5. A medicine's ___ is a measure of how good the medicine is.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Which of the following is most likely a natural chemical?
   - **a.** the medicine acetaminophen
   - **b.** the food preservative BHT
   - **c.** the sugar sucrose
   - **d.** the plastic polystyrene

7. What kind of medicine could a doctor give you to prevent you from getting the measles?
   - **a.** hormone
   - **b.** antihistamine
   - **c.** antacid
   - **d.** vaccine

8. If a farmer did not use pesticides, his crops
   - **a.** probably would not grow very quickly.
   - **b.** could be eaten by insects.
   - **c.** could be poisonous to people.
   - **d.** probably would grow quickly.

9. Which of the following statements about natural chemicals is true?
   - **a.** All natural chemicals are made by natural processes.
   - **b.** All natural chemicals are made by the human body.
   - **c.** All natural chemicals have simple structures.
   - **d.** All natural chemicals are safe.

10. A child who has ___ should avoid going outside if the level of air pollution is high.
    - **a.** kidney disease
    - **b.** asthma
    - **c.** diabetes
    - **d.** birth defects

11. Which of the following statements about good medicines is true?
    - **a.** Good medicines are safe.
    - **b.** Good medicines are potent.
    - **c.** Good medicines have minor side effects.
    - **d.** All of the above

Short Answer

12 What are fertilizers, and why are they helpful?

13 Why are the Clean Air Act and the Clean Water Act important?

14 What is sanitation, and why is having good sanitation important?

Math Skills

15 Each 15 mL of a cold medicine contains 15 mg of a cough suppressant and 6.25 mg of an antihistamine. According to the medicine's label, adults should take 30 mL of the medicine every 6 h to relieve cold symptoms.

a. How much antihistamine is in one dose of the cold medicine?

b. How much cough suppressant should an adult take in a 24 h period?

CRITICAL THINKING

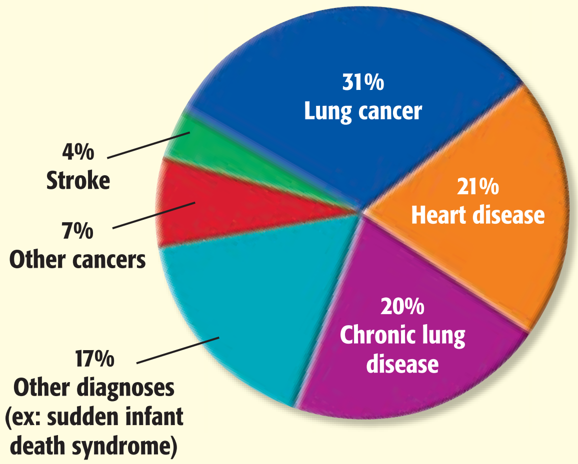
16 **Concept Mapping** Use the following terms to create a concept map: *natural, medicine, fertilizer, synthetic, chemical,* and *preservative*.

17 **Making Inferences** A warning on a can of spray paint says to use the product in a well-ventilated area. Why do you think such an instruction is on the paint?

18 **Forming Hypotheses** Medicines that you can buy in a store are called *over-the-counter medicines*. Over-the-counter medicines are considered to be safe to use without supervision by a doctor. However, many over-the-counter medicines have warnings on their labels. Why do you think these warnings are necessary?

INTERPRETING GRAPHICS

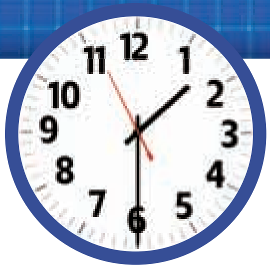
The graph below shows the causes of deaths due to cigarette smoking. Use the graph below to answer the questions that follow.



19 What is the total percentage of deaths due to smoking-related cancers?

20 Which cause of death affects the smallest number of smokers?

21 What percentage of smoking-related deaths result from damage to the lungs?



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Heart disease is the leading cause of death in the United States. Heart disease causes more than 900,000 deaths per year. These deaths <u>constitute</u> 40% of all deaths in the United States. Twenty-five percent of deaths due to heart disease occur in people under the age of 65. But death rates are improving. Death rates for the 10-year period ending in 1985 were 30% less than they were for the previous 10-year period. This decline in mortality is related to a decrease in risk factors for heart disease and improvements in diagnosis and treatment.

1. In the passage, what does *constitute* mean?

A to propose
B to make up
C to follow
D to concern

2. Which of the following can be inferred from the passage?

F The number of deaths due to heart disease is greater in the United States than in any other country in the world.
G The number of deaths due to heart disease has not changed since 1985.
H Changes in risk factors have decreased the number of deaths due to heart disease.
I Nothing can be done to prevent deaths from heart disease.

3. What percentage of deaths due to heart disease occur in people under the age of 65?

A 10%
B 25%
C 30%
D 40%

Passage 2 Your kidneys clean your blood. They also help regulate the amount of water in your body. When blood enters a kidney, the blood contains nutrients, gases, water, and waste products. The kidney must remove wastes and excess water from the blood while leaving other substances in the blood. Inside your kidneys are nephrons, which are microscopic filters that remove harmful products from your blood. The nephrons remove the wastes from the blood through the process of filtration. The waste products are then mixed with excess water to form a liquid called *urine*. The urinary system then removes the urine and excess water from your body.

1. What are the main functions of your kidneys?

A to make nephrons and mix water
B to remove urine and excess water from your body
C to remove blood from water and waste products
D to clean your blood and regulate the amount of water in your body

2. According to the passage, what are nephrons?

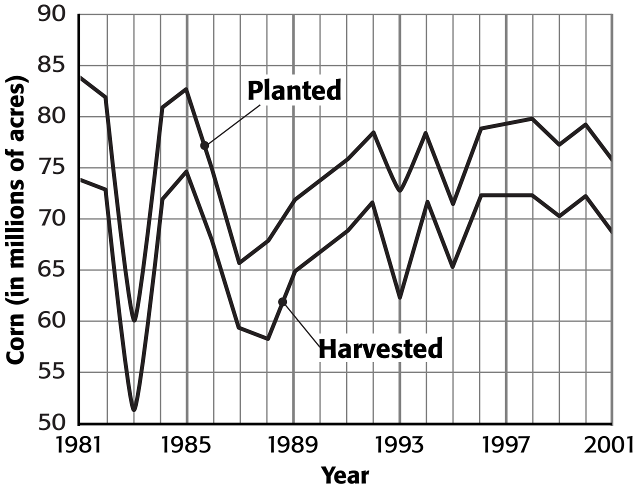
F nutrients in your blood
G microscopic filters in your kidneys
H waste products that must be removed from your blood
I parts of the urinary system

3. According to the passage, what kinds of chemicals can be found in your blood?

A water, gases, and nutrients
B urine and water
C nephrons and waste products
D poisons and medicines

INTERPRETING GRAPHICS

The graph below shows the number of acres of corn planted and harvested in the United States. Use the graph below to answer the questions that follow.



Source: U.S. Department of Agriculture.

1. In which year was the most corn planted?

A 1981
B 1983
C 1985
D 1998

2. How many acres of corn were planted in 1993?

F 60 million
G 64 million
H 73 million
I 79 million

3. Which of the following statements summarizes the data in the graph?

A The amount of corn harvested each year increased.
B The amount of corn harvested each year was less than the amount of corn planted in that year.
C The highest amount of corn was planted in the year when the amount harvested was lowest.
D The amount of corn planted decreased every year.

MATH

Read each question below, and choose the best answer.

1. A medicine that relieves nasal congestion is dispensed in tablets. Each tablet contains 30 mg of the medicine. A dose of the medicine for people who are more than 12 years old is two tablets every 6 h. How much medicine does a 15-year-old person take in a 24 h period?

A 30 mg
B 60 mg
C 120 mg
D 240 mg

2. Citric acid is a chemical found in citrus fruits. The chemical formula of citric acid is $C_6H_8O_7$. C is the symbol for carbon, O is the symbol for oxygen, and H is the symbol for hydrogen. The number after each symbol indicates how many atoms of the element are in one molecule of citric acid. What percentage of the atoms in citric acid are oxygen atoms?

F 0.33%
G 7%
H 33%
I 50%

3. Peter has a piece of nylon cloth that is 3 m long and 2 m wide. What is the area of the piece of cloth?

A 5 m^2
B 6 m^2
C 5 m^3
D 6 m^3

4. Every year, about 12% of a farmer's wheat crop is destroyed by insects. One spring, the farmer plants 60 acres of wheat. How much wheat can the farmer expect to harvest the following fall if no natural disaster strikes the farmer's crops?

F 7 acres
G 48 acres
H 53 acres
I 88 acres

Standardized Test Preparation

Science in Action

Science, Technology, and Society

Skunk-Spray Remedy

So, that pretty black cat with the white stripe down its back wasn't a cat after all? Well, hold off on dumping Fido into a tomato-juice bath. Chemistry has a much better way of conquering skunk spray.

Paul Krebaum has invented a new deskunking formula. The key ingredient in the formula is the chemical hydrogen peroxide. The hydrogen peroxide reacts with the smelly chemicals in a skunk's spray and changes them to odorless chemicals. The formula was tested on a skunk-sprayed dog. The result was one wet, unhappy, but much less smelly pet!

Language Arts ACTIVITY

WRITING SKILL Write a humorous story about a family pet that has a run-in with a skunk. Write the story from the pet's point of view.

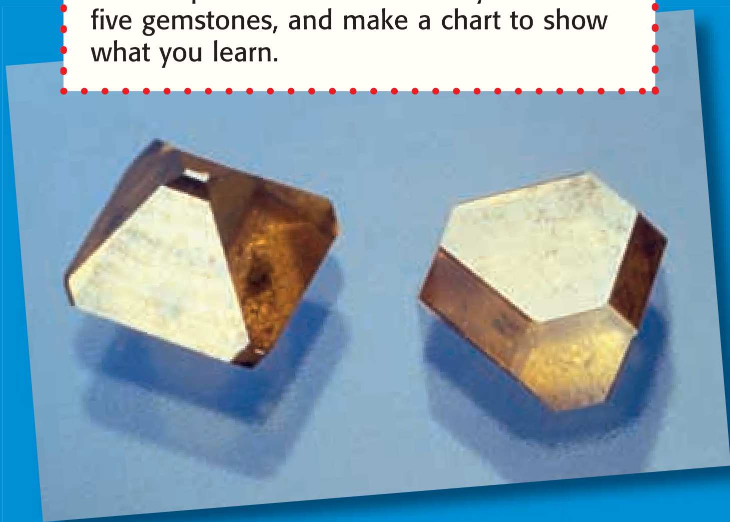
Scientific Discoveries

Synthetic Diamonds

For some people, diamonds are the ultimate luxury. But what makes the shiny little stones so special and so expensive? One reason that diamonds are so valuable is that they are very rare. Diamonds are made deep underground by a natural process that requires high temperatures and pressures. For this reason, gem-quality diamonds, unlike other gemstones, such as rubies and sapphires, could not be grown in a laboratory—until now. Today, two companies are growing gem-quality diamonds in labs. Unfortunately, the synthetic diamonds are still expensive, but they are not as pricey as natural diamonds.

Social Studies ACTIVITY

In many cultures, gemstones, such as diamonds, have specific meanings or represent certain qualities. Research the symbolism of five gemstones, and make a chart to show what you learn.



Flossie Wong-Staal

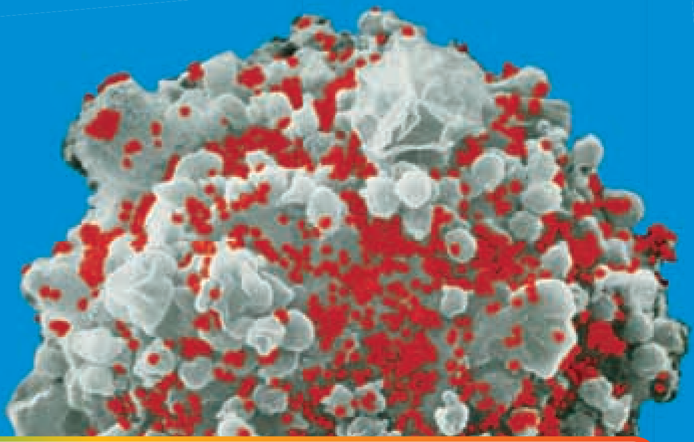
Molecular Biologist Flossie Wong-Staal is a molecular biologist, a person who studies the structures of various chemicals in living things. Wong-Staal has dedicated her career to fighting HIV, the virus that causes AIDS. AIDS is a disease that causes the human immune system to fall apart. HIV enters a body's healthy cells and uses the cells' DNA to multiply itself and spread through the body.

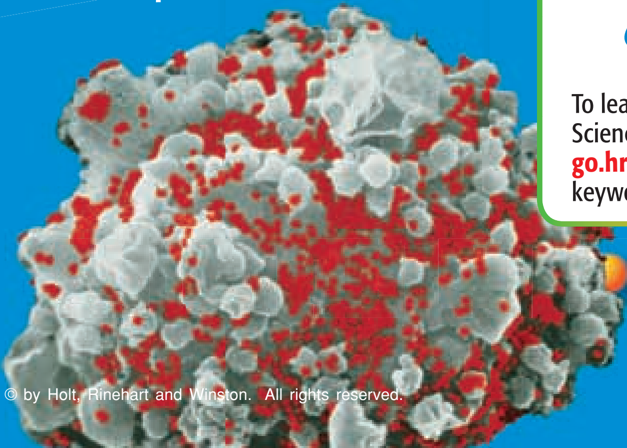
In 1983, Wong-Staal and scientist Robert Gallo were the first researchers in the United States to discover HIV. Two years later, Wong-Staal successfully cloned the virus. Cloning is the process of making a genetic copy of an organism or virus in a laboratory. Cloning HIV gives researchers more opportunities to study the virus. With more copies of the virus, scientists can do different experiments, which will help in creating a vaccine or a cure for AIDS.

Today, Wong-Staal continues to try to find ways to treat patients who have HIV and AIDS and ways to prevent other people from becoming infected with HIV.

Math ACTIVITY

A recent study estimated that 940,000 North Americans have HIV or AIDS. If the population of North America at the time of the study was 316 million, what percentage of the population was infected with HIV or AIDS?





The white blobs are white blood cells. The red dots on the cells are HIV particles.

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TIMELINE

The Evolution of Technology

Can you imagine a world without computers, motors, or even telephones? Your life would be very different indeed without technology. In this unit, you will learn how technology has evolved, and how electronic technology has revolutionized the world in a relatively short amount of time. This timeline shows some events and discoveries that have occurred throughout history and that have contributed to the evolution of technology.

1751

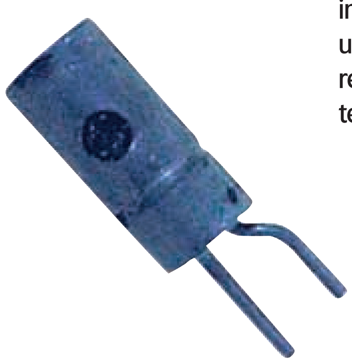
Benjamin Franklin flies a kite to which a key is attached in a thunderstorm to demonstrate that lightning is a form of electricity.

1903

Dutch physician Willem Einthoven develops the first electrocardiograph machine to record the tiny electric currents that pass through the body's tissues.

1947

The transistor is invented.



1958

The invention of the integrated circuit, which uses millions of transistors, revolutionizes electronic technology.

1773

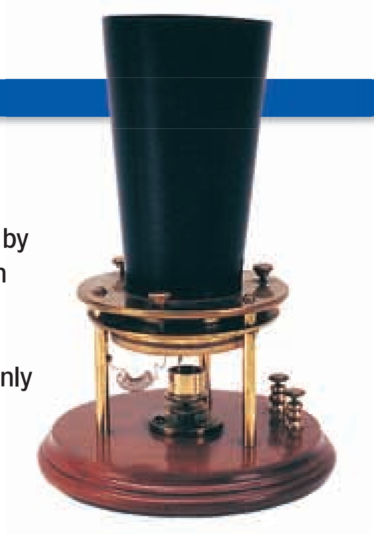
American colonists hold the "Boston Tea Party" and dump 342 chests of British tea into Boston Harbor.

1831

British scientist Michael Faraday and American physicist Joseph Henry separately demonstrate the principle of electromagnetic induction in which magnetism is used to generate electricity.

1876

The telephone is officially invented by Alexander Graham Bell, who beats Elisha Gray to the patent office by only a few hours.



1911

Superconductivity is discovered. Superconductivity is the ability some metals and alloys have to carry electric current without resistance under certain conditions.

1945

Grace Murray Hopper, a pioneer in computers and computer languages, coins the phrase "debugging the computer" after removing from the wiring of her computer a moth that caused the computer to fail.

1984

The first portable CD player is introduced.

1997

Garry Kasparov, reigning world chess champion, loses a historic match to a computer named Deep Blue.

2003

One of the largest electricity blackouts in North American history started in the afternoon on August 14, 2003. The blackout left several large cities, including New York City; Detroit, Michigan; and Toronto, Canada, in the dark. Several days passed before electrical energy was fully restored to the millions of people affected in eight U.S. states and Canada.

12

Heat Technology

About the PHOTO

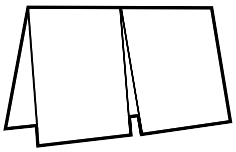
Roasting marshmallows while warming yourself by a campfire is fun and cozy. But imagine what your life would be like if the only way that you could warm yourself on a cold winter night was to huddle around an open fire. It probably wouldn't be much fun at all! Luckily, many kinds of more-effective heating systems have been developed for use in homes and buildings. So, you only need to sit by a campfire when you want some s'mores!

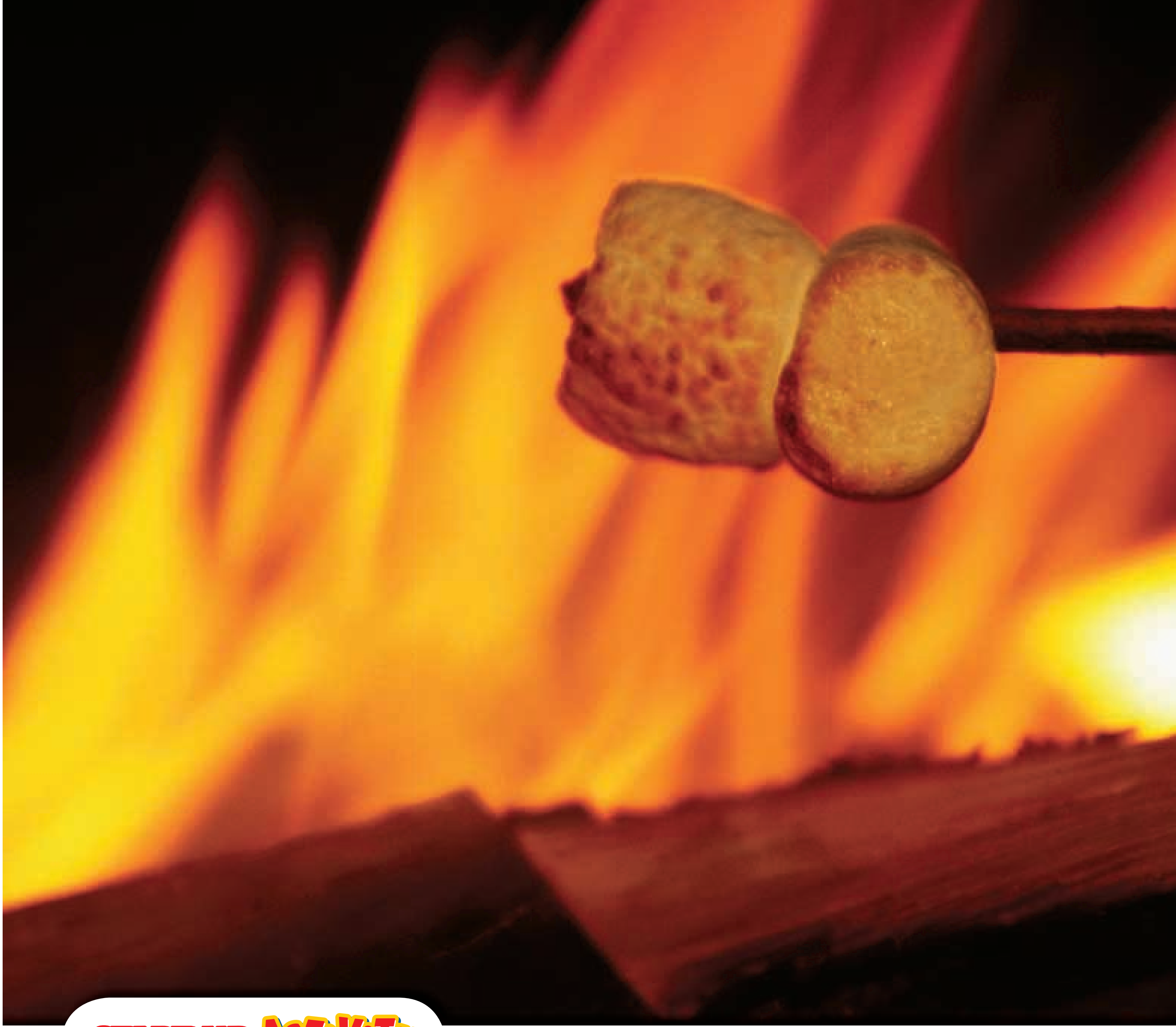
PRE-READING ACTIVITY

FOLDNOTES

Two-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Two-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the two-panel flip chart with "Heating and Cooling Systems" and "Heat Engines." As you read the chapter, write information you learn about each category under the appropriate flap.





START-UP ACTIVITY

Solar Solutions

Solar heating systems work by absorbing energy from the sun. In this activity, you will make two model solar heating systems to determine the better color for a solar panel.

Procedure

1. Wrap one **150 mL beaker** in **white paper** and another **150 mL beaker** with **black paper.** Put 100 mL of **water** in each beaker and place a **thermometer** in each beaker.
2. Place the beakers about 15 cm away from an **incandescent lamp** and turn on the lamp
3. Record the temperature of each beaker every 15 s for 3 min. Be sure to also write down the times that you took the temperature. You may wish to record your data in a table.

Analysis

1. Make a line graph with your data. Put time on the *x*-axis and temperature on the *y*-axis. Plot the data for both beakers on the graph. Use a different colored pencil or marker for each beaker's data.
2. What color is better for a solar panel? Use your graph to explain your answer.

SECTION 1

Heating and Cooling Systems

READING WARM-UP

Objectives

- Analyze several kinds of heating systems.
- Describe how an air conditioner works.
- Explain how a refrigerator keeps food cold.
- Describe how a heat pump works.

Terms to Learn

insulation

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

It's a hot summer day, and you eagerly go inside your cool, air-conditioned house. But what if you had lived a hundred years ago? Then, cooling off was a lot more difficult.

You can cool off in the summer, stay warm in the winter, and keep your food cold all because of heat technology.

Heating Systems

Many homes and buildings have a central heating system that controls the temperature in every room. Central heating systems were first developed by ancient Greeks and Romans but were not adopted for use again until the 19th century.

Hot-Water Heating

Hot-water heating systems first became popular around 1830. Hot-water heating is still the favored heating system in Europe. A hot-water heating system is shown in **Figure 1.** A hot-water heater raises the temperature of water, which is pumped through pipes that lead to radiators in each room. The hot water in the radiators then heats the colder room air. The cooled water returns to the hot-water heater to be heated again.

Figure 1 **A Hot-Water Heating System**

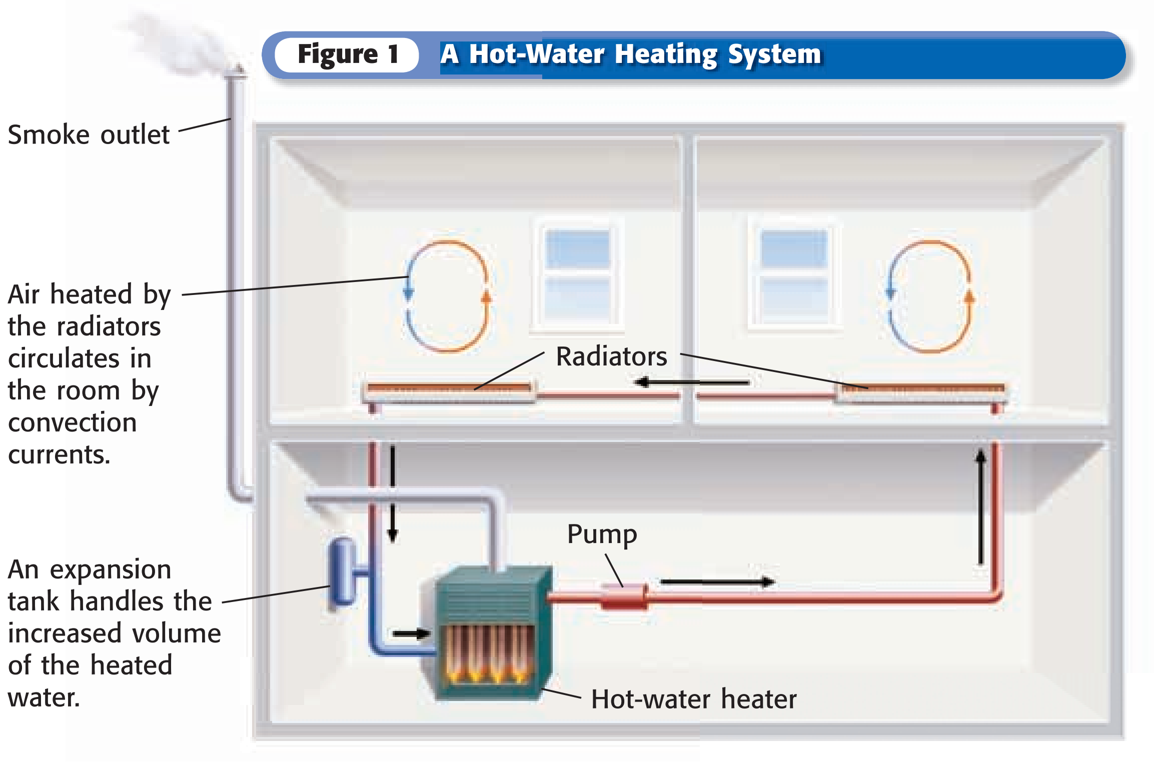
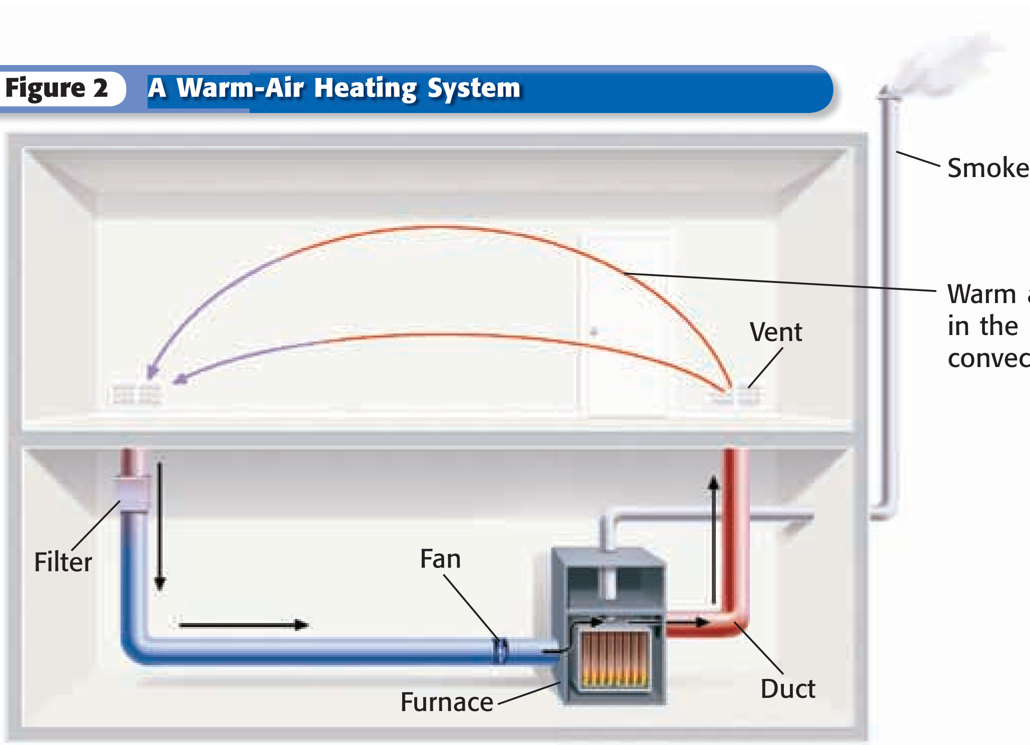


Figure 2 A Warm-Air Heating System



Warm-Air Heating

Ancient Romans built a complex warm-air heating system called the *hypocaust* system. But the modern warm-air heating systems used in many buildings in the United States were developed around 1930. In a modern warm-air system, shown in **Figure 2,** air is heated by burning fuel in a furnace. The warm air travels through ducts to different rooms. The warm air heats air in the rooms. Cooler air sinks below the warm air and enters a vent near the floor. Then, a fan forces the cooler air into the furnace. The air is heated and returned to the ducts. An air filter cleans the air as it moves through the system.

insulation a substance that reduces the transfer of electricity, heat, or sound

Heating and Insulation

Heat may quickly escape out of a house during cold weather, and during hot weather a house may heat up. To keep the house comfortable, a heating system must run much of the time during the winter. Air conditioners often must run most of the time in the summer to keep a house cool. This almost constant running can be wasteful. Insulation can help reduce the energy needed to heat and cool buildings. Fiberglass insulation is shown in **Figure 3. Insulation** is a material that reduces the transfer of thermal energy. When insulation is used in walls, ceilings, and floors, less heat passes into or out of the building. Insulation helps a house stay warm in the winter and cool in the summer.

Figure 3 *Millions of tiny air pockets in this insulation help prevent thermal energy from flowing into or out of a building.*

Reading Check **How does insulation help reduce energy costs?** (*See the Appendix for answers to Reading Checks.*)

Solar Heating

Solar heating systems use the sun's energy to heat buildings. A *passive solar heating system* does not have moving parts. It relies on a building's structural design and materials to use energy from the sun as a means of heating. An *active solar heating system* has moving parts. It uses pumps and fans to distribute the sun's energy throughout a building. Passive solar heating systems have been around for centuries, but active systems did not gain popularity until the energy crisis of the 1970s.

Look at the house in **Figure 4.** The large windows on the south side of the house are part of the passive solar heating system. These windows receive a large amount of sunlight, and this energy enters the rooms through the windows. Thick concrete walls absorb energy and keep the house warm at night or during cloudy days. In an active solar heating system, water is pumped to the solar collector, where the water is heated. The hot water is pumped through pipes and transfers its energy to them. A fan blowing over the pipes helps the pipes transfer their thermal energy to the air. Warm air is then sent into rooms through vents. The cooled water returns to the water storage tank to be pumped back through the solar collector.

SCHOOL to HOME

WRITING SKILL **Home Heating and Cooling**

Find out from an adult what kinds of systems are used in your home for heating and cooling. In your **science journal,** describe how these systems work. Also, describe any energy-saving methods used in your home.

ACTIVITY

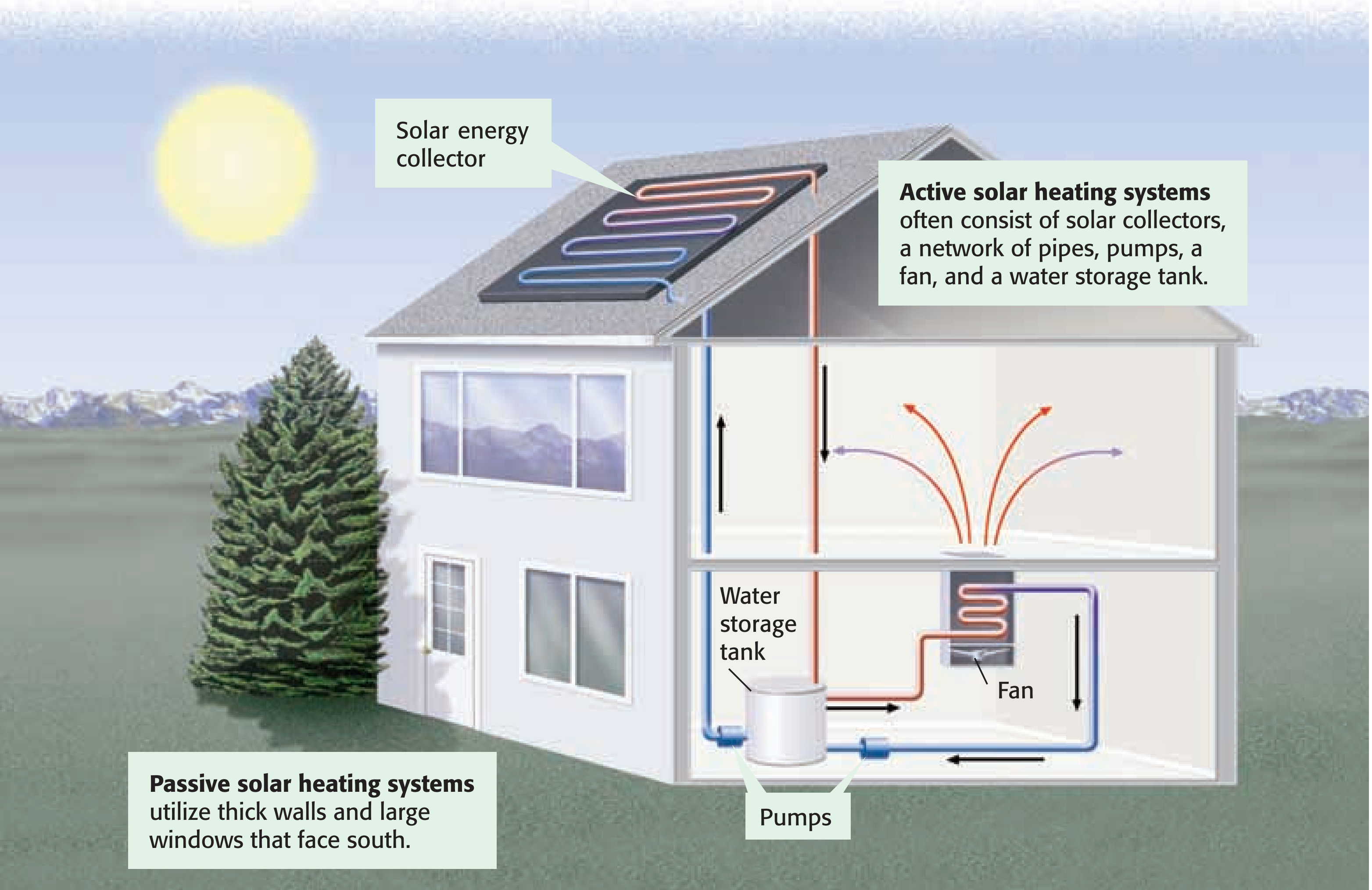


Figure 4 *Passive and active solar heating systems work together to use the sun's energy to heat an entire house.*

Cooling Systems

When the weather is hot, an air-conditioned room can feel very refreshing. Cooling systems are used to transfer thermal energy out of an area so that the area feels cooler. An air conditioner, shown in **Figure 5,** is a cooling system that transfers thermal energy from a warm area inside a building or car to an area outside. The first fully air-conditioned office building was built in the late 1920s. Thermal energy naturally moves from areas of higher temperature to areas of lower temperature. So, to transfer thermal energy from the cooler inside to the warm outside, the air-conditioning system must do work.

Figure 5 *This air-conditioning unit keeps a building cool by moving thermal energy from inside the building to the outside.*

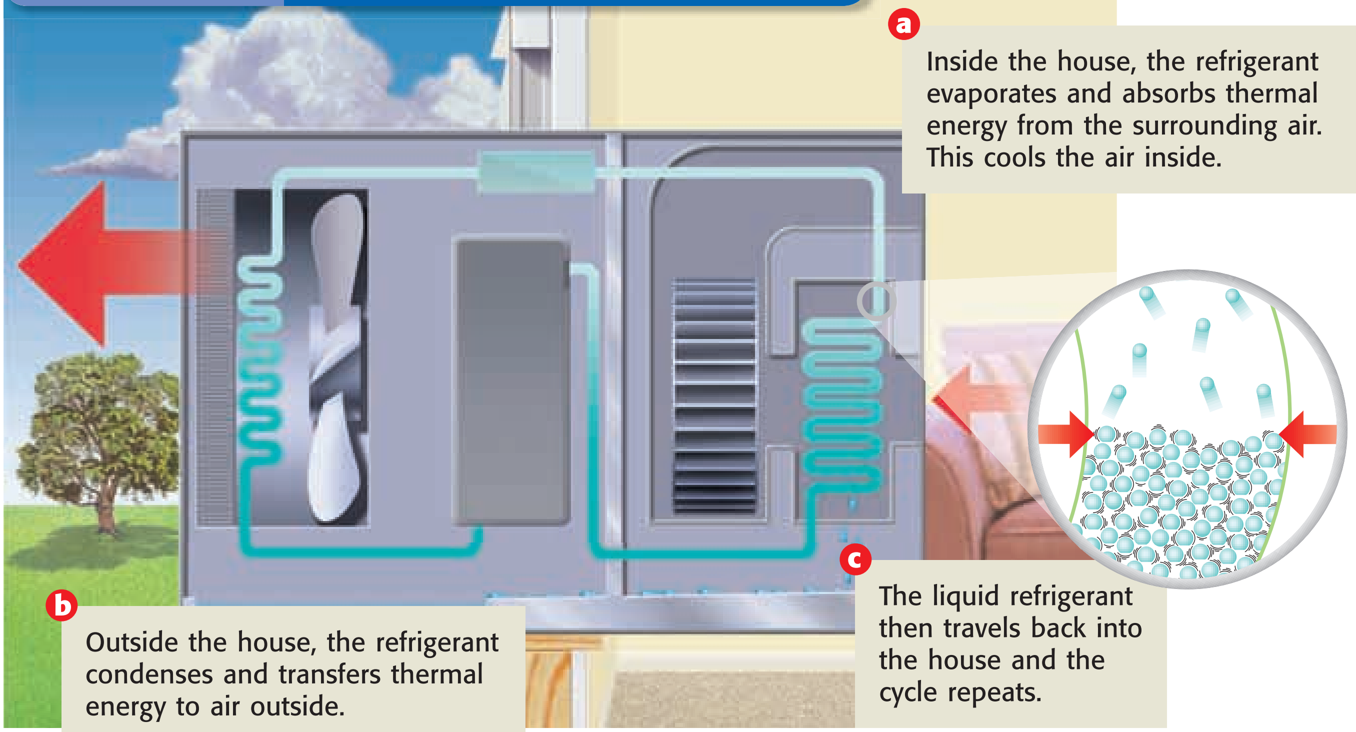
Refrigerants

Most cooling systems use a refrigerant to transfer thermal energy. A *refrigerant* is a substance that condenses and evaporates easily. Within a cooling system, the refrigerant continually evaporates and condenses. That means that the refrigerant is always changing between a liquid state and gas state. This process is shown in the air conditioner in **Figure 6.**

When the refrigerant in an air conditioner evaporates, it absorbs thermal energy from the surrounding air. So, the air around the refrigerant is cooled. When the refrigerant condenses, it releases thermal energy. Air conditioners release this thermal energy outside.

Reading Check **What is a refrigerant?**

Figure 6 **How an Air Conditioner Works**

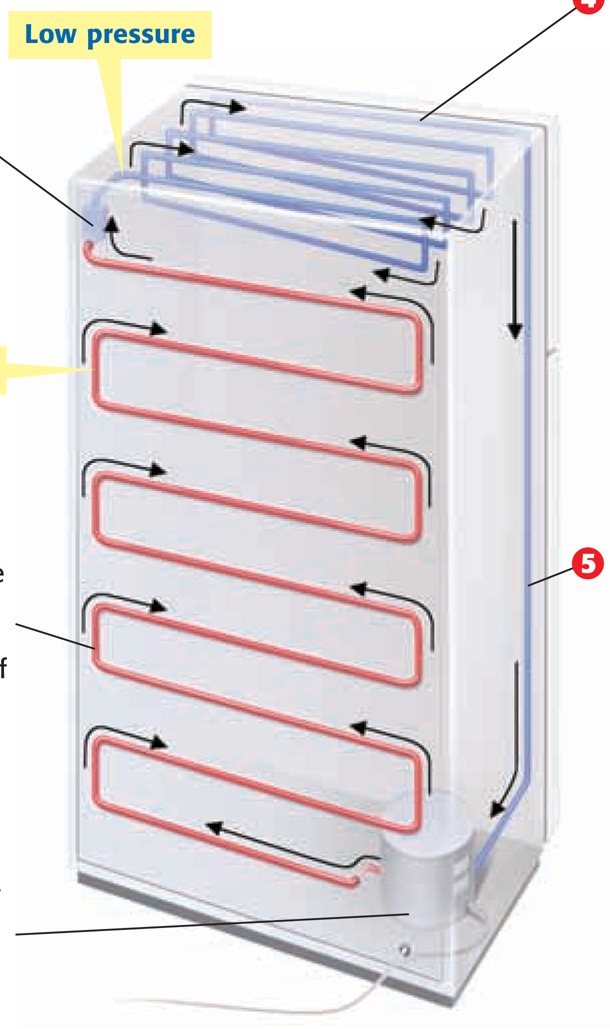


a Inside the house, the refrigerant evaporates and absorbs thermal energy from the surrounding air. This cools the air inside.

b Outside the house, the refrigerant condenses and transfers thermal energy to air outside.

c The liquid refrigerant then travels back into the house and the cycle repeats.

Figure 7 **How a Refrigerator Works**



❸ When the liquid passes through the expansion valve, it goes from a high-pressure area to a low-pressure area. As a result, the temperature of the liquid decreases.

❹ As the cold liquid refrigerant moves through the evaporating coils, it absorbs thermal energy from the refrigerator compartment, making the inside of the refrigerator cold. As a result, the temperature of the refrigerant increases, and it changes into a gas.

❷ The hot gas flows through the condenser coils on the outside of the refrigerator. The gas condenses into a liquid, transferring some of its thermal energy to the coils.

❺ The gas is then returned to the compressor, and the cycle repeats.

❶ The compressor uses electrical energy to compress the refrigerant gas. This compression increases the pressure and temperature of the gas.

Cooling and Energy

Most cooling systems require electrical energy to do the work of cooling. The electrical energy is used by a device called a compressor. The *compressor* does the work of compressing the refrigerant. Compressors are found in both air conditioners and refrigerators.

To keep many foods fresh, you store them in a refrigerator. A refrigerator is another example of a cooling system. **Figure 7** shows how a refrigerator continuously transfers thermal energy from inside the refrigerator to the condenser coils on the outside of the refrigerator. That's why the area near the back of a refrigerator feels warm.

Reading Check **How does the inside of a refrigerator stay at a temperature that is cooler than the temperature outside the refrigerator?**

Heat Pumps

The *heat pump* shown in **Figure 8** works both as a heating system and a cooling system. Heat pumps use the evaporation and condensation of a refrigerant to provide heating in winter and cooling in summer.

In winter, the refrigerant absorbs thermal energy from outside air and evaporates. Work is done on the refrigerant gas by a compressor, which compresses the gas and increases the refrigerant's temperature. The hot gas then moves through inside coils and transfers thermal energy to inside air. This transfer of energy warms inside air and causes the refrigerant to condense. In summer, a heat pump works like an air conditioner.

Figure 8 *Heat pumps are refrigeration units in which the cooling cycle can be reversed by flipping a switch.*

SECTION Review

Summary

- Central heating systems include hot-water heating systems and warm-air heating systems.
- Solar heating systems can be passive or active. In passive solar heating, a building takes advantage of the sun's energy without the use of moving parts. Active solar heating uses moving parts to aid the flow of solar energy throughout a building.
- A cooling system transfers thermal energy from cooler temperatures to warmer temperatures by doing work.
- A heat pump works as both a heating system and a cooling system.

Using Key Terms

1. Use the following term in a sentence: *insulation.*

Understanding Key Ideas

2. Which of the following describes how cooling systems transfer thermal energy?
   a. Thermal energy naturally flows from cooler areas to warmer areas.
   b. Thermal energy naturally flows from warmer areas to cooler areas.
   c. Work is done to transfer thermal energy from warmer areas to cooler areas.
   d. Work is done to transfer thermal energy from cooler areas to warmer areas.
3. Compare a hot-water heating system with a warm-air heating system.
4. How does an air conditioner work?
5. Describe how thermal energy is transferred when a refrigerant evaporates and condenses.
6. What is a heat pump? How does a heat pump work?

Math Skills

7. People generally feel best when the temperature of the air around them is in the range of 21°C–25°C. What is this range in degrees Fahrenheit? (Hint: The equation for converting between degrees Celsius and degree Fahrenheit is $°F = (9/5 \times °C) + 32$.)

Critical Thinking

8. **Identifying Relationships** How are changes of state important in how a refrigerator works?
9. **Expressing Opinions** Describe the advantages and disadvantages of solar heating systems. What do you think the overall benefits of solar heating systems are?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Heating Systems
SciLinks code: HSM0733

SECTION 2

Heat Engines

Did you know that automobiles work because of heat? In fact, motor scooters, airplanes, and even rockets all work because of heat.

READING WARM-UP

Objectives

- Explain the difference between an external combustion engine and an internal combustion engine.
- Explain how a simple external combustion engine works.
- Describe how a four-stroke internal combustion engine works.

Terms to Learn

heat engine

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

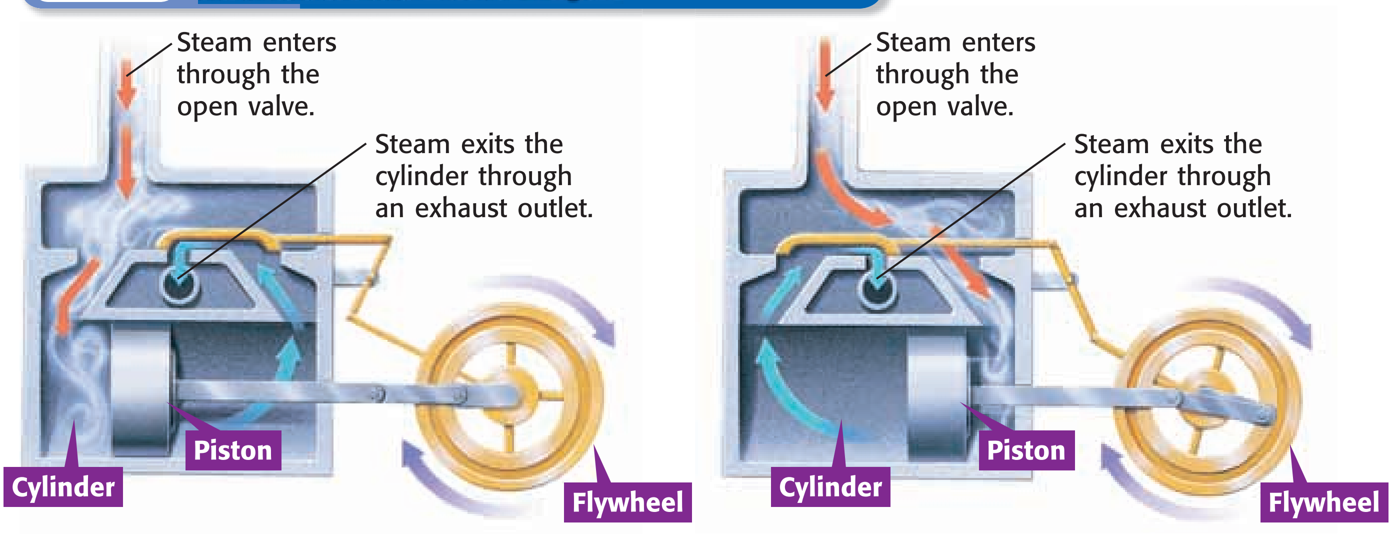
All these forms of transportation have a **heat engine,** a machine that uses heat to do work. Heat engines burn fuel through a process called *combustion*. Heat engines that burn fuel outside the engine are called *external combustion engines*. Heat engines that burn fuel inside the engine are called *internal combustion engines*. In both types of engines, fuel is burned to release thermal energy that can be used to do work.

External Combustion Engines

The first heat engines were steam engines. Heron of Alexandria built steam engines in the 1st century CE. A simple steam engine, shown in **Figure 1,** is an example of an external combustion engine. Coal is burned to heat water in a boiler and change the water to steam. The steam expands, which pushes a piston. The piston can be attached to other parts of the machine that do work.

Modern steam engines, such as those used to generate electrical energy at a power plant, drive turbines instead of pistons. In the case of generators that use steam to do work, thermal energy is converted into electrical energy.

Figure 1 **An External Combustion Engine**



1. The expanding steam enters the cylinder from one side. The steam does work on the piston, forcing the piston to move.

2. As the piston moves to the other side, a second valve opens, and steam enters. The steam does work on the piston and moves it back. The motion of the piston turns a flywheel.

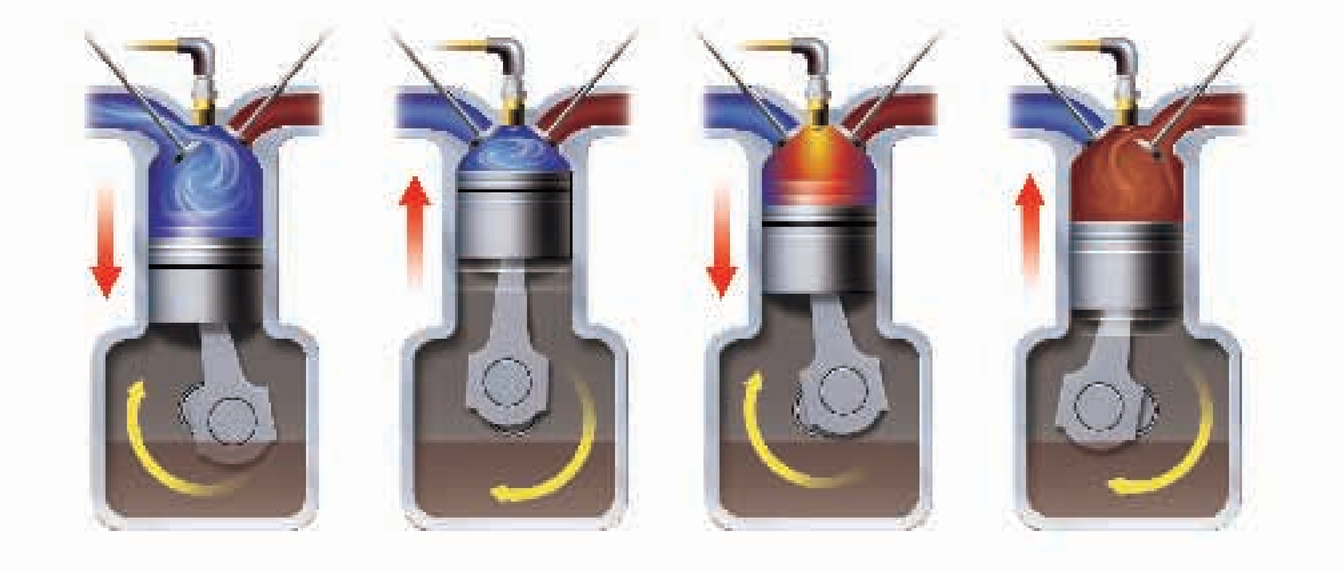
Figure 2 How a Four-Stroke Engine Works

a In the *intake* stroke, a mixture of fuel vapor and air is brought into the cylinder as the piston moves down.

b In the *compression* stroke, the piston moves up and compresses the fuel-air mixture.

c At the beginning of the *power* stroke, a spark from the spark plug ignites the compressed mixture and forces the piston down.

d The *exhaust* stroke takes place when the piston moves up again and forces the waste products to move out of the exhaust valve.



Internal Combustion Engines

In an internal combustion engine, fuel is burned in cylinders within the engine. There are pistons inside the cylinders. The up and down movements, or strokes, of the pistons cause a device called a *crankshaft* to turn. The crankshaft changes the up-and-down motion into circular motion. The motion of the crankshaft can be transferred to the wheels of a car or truck.

heat engine a machine that transforms heat into mechanical energy, or work

Four-Stroke Engines

Car engines are four-stroke engines, because four strokes take place for each cycle of the piston. **Figure 2** shows how a four-stroke engine works. First, a mixture of gasoline and air enters each cylinder as the piston moves down. This step is called the *intake stroke*. Next, the crankshaft turns and pushes the piston up, compressing the fuel mixture. This step is called the *compression stroke*. Next comes the *power stroke,* in which the spark plug uses electrical energy to ignite the compressed fuel mixture. As the mixture of fuel and air burns, it expands and forces the piston down. Finally, during the *exhaust stroke,* the crankshaft turns, and the piston is forced back up, pushing exhaust gases out of the cylinder.

Reading Check **What are the four strokes of an internal combustion engine called?** (*See the Appendix for answers to Reading Checks.*)

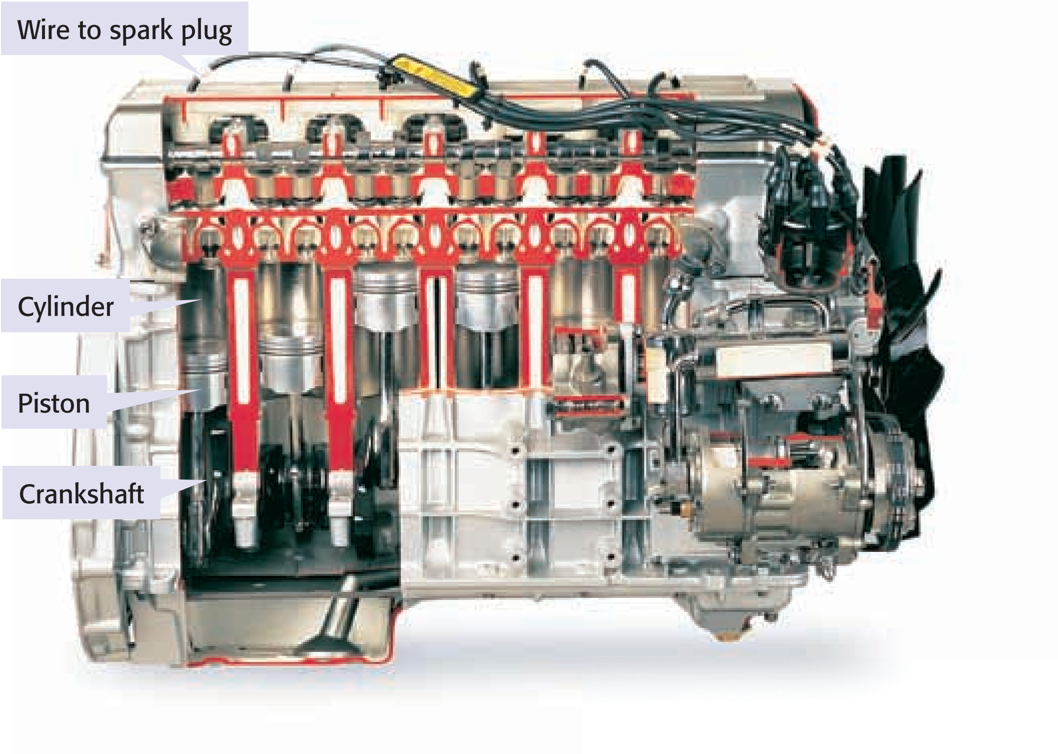


Figure 3 *The continuous cycling of the four strokes in the cylinders converts thermal energy into the kinetic energy needed to make a car move.*

Internal Combustion Engines Vary in Number of Pistons

Most automobile engines have four, six, or eight cylinders. The car engine shown in **Figure 3** is a six-cylinder engine. You can easily see four of the pistons, but the other two are partially hidden by other parts of the engine. Notice that the positions of the pistons are different. The positions are different because each piston is in a different stage of the four-stroke cycle. Because of the four-stroke cycle, a four-cylinder engine can run efficiently with each piston at a different stroke of the cycle. However, engines with six or eight cylinders have more power than four-piston engines. So, larger cars and sports cars tend to have either six or eight cylinders.

CONNECTION TO Social Studies

Engine Development through History Many scientists and engineers from different countries and backgrounds contributed to the development of the engines that are used today. For example, Thomas Newcomen, a British blacksmith and engineer, built the first steam engine to use a cylinder and piston in 1712. And in 1862, a Belgian inventor named Etienne Lenoir built the first car to have an internal combustion engine. Research the history of engine development and make a timeline showing important events.

ACTIVITY

Differences in Internal Combustion Engines

Not all internal combustion engines work in the same way. Diesel engines are also internal combustion engines, but the way that diesel engines work differs from the way that regular car engines do. A diesel engine has no spark plugs. Instead, the fuel-air mixture is compressed so much that it becomes hot enough to ignite without a spark from a spark plug.

Motorcycles, such as the one shown in **Figure 4,** have two-stroke internal combustion engines. Two-stroke engines do not have valves that allow fuel and gases to move in and out of the cylinders. Instead, two-stroke engines have openings in the side of the cylinders called *ports*. The ports open and close as the pistons move up and down.

Reading Check **How do diesel engines differ from regular car engines?**

Figure 4 *Two-stroke engines, such as the one on this motorcycle, are very noisy. Two-stroke engines also power lawn mowers, chain saws, and radio-controlled model airplanes.*

SECTION Review

Summary

- Heat engines use heat to do work.
- External combustion engines burn fuel outside the engine. Internal combustion engines burn fuel inside the engine.
- Car engines are four-stroke internal combustion engines.

Using Key Terms

1. In your own words, write a definition for the term *heat engine*.

Understanding Key Ideas

2. During which stroke of a four-stroke engine cycle is the fuel mixture ignited?
   a. intake
   b. compression
   c. power
   d. exhaust
3. How does a simple external combustion engine work?
4. Describe what happens in each of the strokes of a four-stroke internal combustion engine.

Math Skills

5. Sara has an after-school lawn-mowing business. She buys 2.5 gal of gasoline to use in her lawn mower. How many liters of gasoline did she buy? (Hint: 1 gal = 3.8 L)

Critical Thinking

6. **Expressing Opinions** A car comes with a four-cylinder engine or a six-cylinder engine. The six-cylinder version is more powerful, but uses more gasoline. Which car would you buy? Explain.
7. **Making Comparisons** Compare an external combustion engine with an internal combustion engine. Where could you find an example of each?

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Topic: Heat Engines
SciLinks code: HSM0728

Using Scientific Methods

Skills Practice Lab

OBJECTIVES

Measure the temperature change when hot and cold objects come into contact.

Compare materials for their ability to hold thermal energy.

MATERIALS

- balance, metric
- cups, plastic-foam, 9 oz (2)
- cylinder, graduated, 100 mL
- nails (10 to 12)
- string, 30 cm length
- paper towels
- rubber band
- thermometer
- water, cold
- water, hot

SAFETY

Feel the Heat

Heat is the energy transferred between objects at different temperatures. Energy moves from objects at higher temperatures to objects at lower temperatures. If two objects are left in contact for a while, the warmer object will cool down and the cooler object will warm up until they eventually reach the same temperature. In this activity, you will combine equal masses of water and nails at different temperatures to determine which has a greater effect on the final temperature.

Ask a Question

1. When you combine substances at two different temperatures, will the final temperature be closer to the initial temperature of the warmer substance or of the colder substance, or halfway in between?

Form a Hypothesis

2. Write a prediction that answers the question in item 1.

Test the Hypothesis

3. Copy the table below onto a separate sheet of paper.
4. Use the rubber band to bundle the nails together. Find and record the mass of the bundle. Tie a length of string around the bundle, leaving one end of the string 15 cm long.
5. Put the bundle of nails into one of the cups, letting the string dangle outside the cup. Fill the cup with enough hot water to cover the nails, and set it aside for at least 5 min.

Data Collection Table

Trial	Mass of nails (g)	Volume of water that equals mass of nails (mL)	Initial temp. of water and nails (°C)	Initial temp. of water to which nails will be transferred (°C)	Final temp. of water and nails combined (°C)
1					
2					

6. Use the graduated cylinder to measure enough cold water to exactly equal the mass of the nails (1 mL of water = 1 g). Record this volume in the table.
7. Measure and record the temperature of the hot water with the nails and the temperature of the cold water.
8. Use the string to transfer the bundle of nails to the cup of cold water. Use the thermometer to monitor the temperature of the water-nail mixture. When the temperature stops changing, record this final temperature in the table.
9. Empty the cups, and dry the nails.
10. For Trial 2, repeat steps 4 through 9, but switch the hot and cold water. Record all of your measurements.

Analyze the Results

1. **Analyzing Results** In Trial 1, you used equal masses of cold water and nails. Did the final temperature support your initial prediction? Explain.
2. **Analyzing Results** In Trial 2, you used equal masses of hot water and nails. Did the final temperature support your initial prediction? Explain.
3. **Explaining Events** In Trial 1, which material—the water or the nails—changed temperature the most after you transferred the nails? What about in Trial 2? Explain your answers.

Draw Conclusions

4. **Drawing Conclusions** The cold water in Trial 1 gained energy. Where did the energy come from?
5. **Evaluating Results** How does the energy gained by the nails in Trial 2 compare with the energy lost by the hot water in Trial 2? Explain.
6. **Applying Conclusions** Which material seems to be able to hold energy better? Explain your answer.
7. **Interpreting Information** Specific heat is a property of matter that indicates how much energy is required to change the temperature of 1 kg of a material by 1°C. Which material in this activity has a higher specific heat (changes temperature less for the same amount of energy)?
8. **Making Predictions** Would it be better to have pots and pans made from a material with a high specific heat or a low specific heat? Explain your answer.

Communicating Your Data

Share your results with your classmates. Discuss how you would change your prediction to include your knowledge of specific heat.

Chapter Review

USING KEY TERMS

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

1. *heat engine* and *insulator*

UNDERSTANDING KEY IDEAS

Multiple Choice

2. Which of the following is NOT part of a warm-air heating system?
   - **a.** vent
   - **b.** furnace
   - **c.** filter
   - **d.** hot-water heater

3. What does the compressor of a refrigerator do?
   - **a.** increases the temperature and pressure of the refrigerant
   - **b.** decreases the temperature and increases the pressure of the refrigerant
   - **c.** causes the refrigerant to change from a liquid to a gas
   - **d.** causes the refrigerant to change from a gas to a liquid

4. What type of internal combustion engine does not have a spark plug?
   - **a.** two-stroke engine
   - **b.** four-stroke engine
   - **c.** diesel engine
   - **d.** gasoline engine

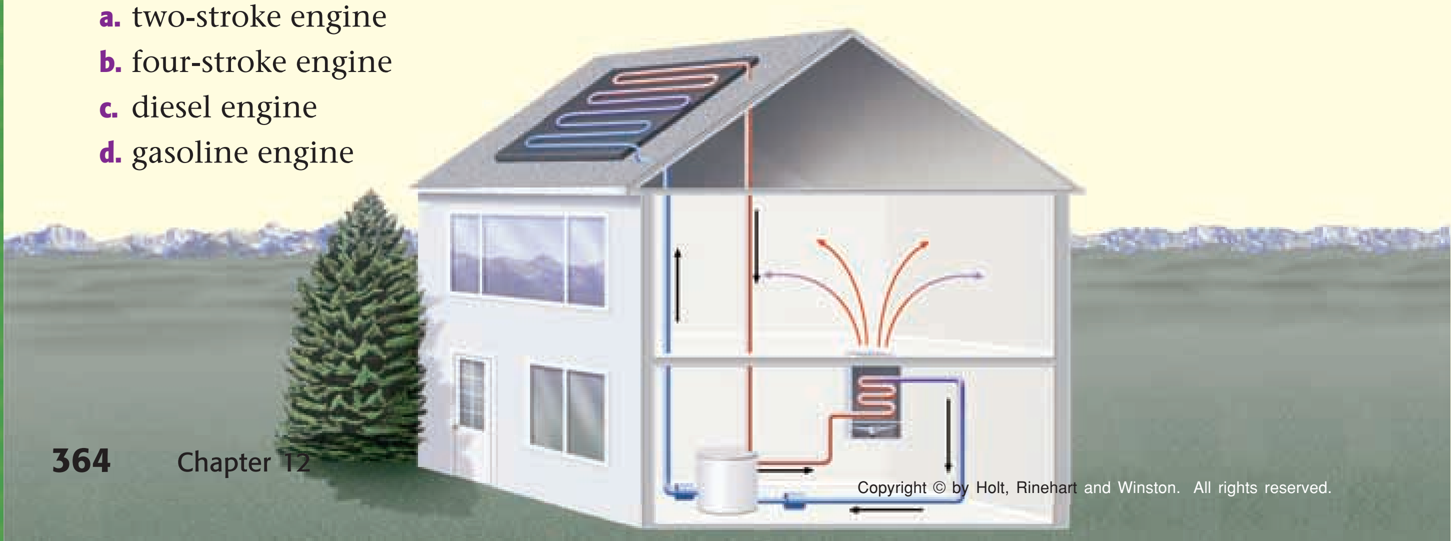
5. How do the pistons in a four-cylinder engine work together?
   - **a.** All the pistons are in the same stroke of the four-stroke cycle.
   - **b.** Each of the pistons is in a different stroke of the four-stroke cycle.
   - **c.** The pistons work in pairs, and the two cylinders of a pair are in the same stroke of the four-stroke cycle.
   - **d.** The pistons work completely independently of each other.

6. In an air conditioner, thermal energy is
   - **a.** transferred from areas of higher temperatures to areas of lower temperatures.
   - **b.** transferred from areas of lower temperatures to areas of higher temperatures.
   - **c.** used to do work.
   - **d.** transferred into the building.

Short Answer

7. What does insulation do when used in buildings?

8. Describe how a passive solar heating system works.



Math Skills

9. Leonardo needs to put insulation in part of his attic. The attic space is 4 m long and 3 m wide. One roll of insulation covers 2.5 m^2. How many rolls of insulation should Leonardo buy?

CRITICAL THINKING

10. **Concept Mapping** Create a concept map using the following terms: *heat engine, external combustion, internal combustion, four-stroke,* and *two-stroke.*

11. **Making Comparisons** Compare a passive solar heating system with an active solar heating system.

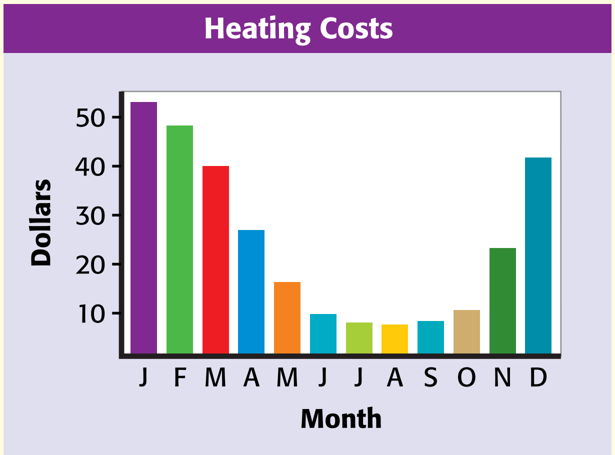
12. **Evaluating Conclusions** Supposed that on one hot, summer day, the air conditioner in your home breaks down. Your brother says, "A refrigerator is a cooling system that works in a similar way to an air conditioner. So, we should be able to open the refrigerator to cool the kitchen down." Do you think your brother's suggestion will work? Explain your answer.

13. **Making Comparisons** Compare an air conditioner with a heat pump.

14. **Predicting Consequences** Suppose that someone accidentally installed a window air conditioner backwards so that the part that belongs inside the house is on the outside of the house. What do you think would happen?

INTERPRETING GRAPHICS

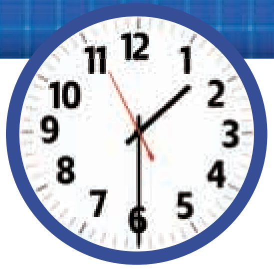
Look at the graph below. It shows the cost of heating a certain house month by month over the course of a year. Use the graph to answer the questions that follow.



15. During which three months is the most energy used for heating?

16. During which three months is the least energy used for heating?

17. Why do you think the heating costs follow the trend shown in the graph?



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 All matter is made up of particles. Temperature is a measure of the average kinetic energy of these particles. The colder a substance gets, the less kinetic energy its particles have, and the slower the particles move. In theory, at absolute zero (–273°C), all movement of particles should stop. Scientists are working in laboratories to cool matter so much that the temperature approaches absolute zero.

1. What is the purpose of this text?
- **A** to entertain
- **B** to influence
- **C** to express
- **D** to inform

2. What does information in the passage suggest?
- **F** Matter at absolute zero no longer exists.
- **G** No one knows what would happen to matter at absolute zero.
- **H** It is currently not possible to cool matter to absolute zero.
- **I** Scientists have cooled matter to absolute zero.

3. What information does the passage give about the relationship between kinetic energy and temperature?
- **A** The higher the temperature, the more kinetic energy a substance has.
- **B** There is no relationship between temperature and kinetic energy.
- **C** The higher the temperature, the less kinetic energy a substance has.
- **D** No one knows what the relationship between kinetic energy and temperature is.

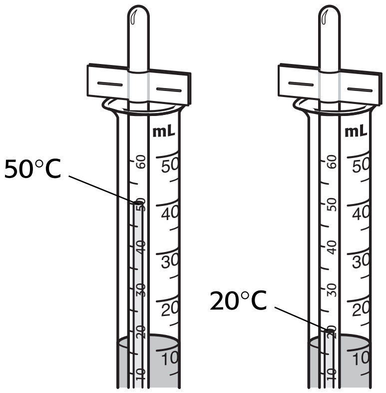
Passage 2 Birds and mammals burn fuel to maintain body temperatures that are usually greater than the air temperature of their surroundings. A lot of energy is necessary to maintain a high body temperature. Tiny animals such as shrews and hummingbirds maintain high body temperatures only during the day. At night or when the air temperature falls significantly, these tiny creatures go into a state called torpor. When an animal is in torpor, its respiration and heart rate are slow. Circulation continues primarily to major organs. Body temperature drops. Because their body processes are slowed, animals in torpor use much less energy than they usually need.

1. Which of the following would be the **best** summary of this passage?
- **A** Some animals use less energy than other animals.
- **B** Some animals use more energy than other animals.
- **C** Some animals maintain high body temperatures only during the day, going into torpor at night.
- **D** Going into torpor at night is necessary for some animals to maintain high body temperatures.

2. What happens when an animal goes into torpor?
- **F** Respiration and heart rate slow, and body temperature drops.
- **G** Normal respiration and heart rate are maintained, and body temperature drops.
- **H** Respiration and heart rate increase, and body temperature drops.
- **I** Respiration and heart rate increase, and body temperature rises.

INTERPRETING GRAPHICS

The figure below shows a thermometer in each of two graduated cylinders holding water. Use the figure below to answer the questions that follow.



1. Which graduated cylinder contains more water?

A The cylinder on the left contains more.
B The cylinder on the right contains more.
C The cylinders contain equal amounts.
D There is not enough information to determine the answer.

2. The thermal energy of a substance increases as the temperature of the substance increases. The thermal energy also increases as the amount of substance increases. In which cylinder is the thermal energy of the water greater?

F The cylinder on the left contains water that has greater thermal energy.
G The cylinder on the right contains water that has greater thermal energy.
H The thermal energies of the water in the two cylinders are equal.
I There is not enough information to determine the answer.

3. If the water in the graduated cylinders is mixed together, which of the following will most likely be the temperature of the mixture?

A 25°C
B 35°C
C 50°C
D 70°C

MATH

Read each question below, and choose the best answer.

1. Elena has a bag containing 4 blue marbles, 6 red marbles, and 3 green marbles. She picks 1 marble at random. What is the probability of her picking a blue marble?

A 1 in 13
B 1 in 4
C 4 in 13
D 9 in 13

2. If $8 - 2n = -30$, what is the value of n?

F 7
G 19
H 68
I 120

3. A rectangle has sides of 4 cm and 10 cm. If the lengths of each of its sides are reduced by half, what will the change in the area of the rectangle be?

A 1/4 as much area
B 1/2 as much area
C 2 times as much area
D 4 times as much area

4. The specific heat of copper is 387 J/kg•°C. If the temperature of 0.05 kg of copper is raised from 25°C to 30°C, how much heat was put into the copper?

F 96.8 J
G 484 J
H 581 J
I 96,800 J

5. A change in temperature of 1°C is equal to a change in temperature of 1 K. The temperature 0°C is equal to the temperature 273 K. If the temperature is 300 K, what is the temperature in degrees Celsius?

A –27°C
B 27°C
C 54°C
D 73°C

Science in Action

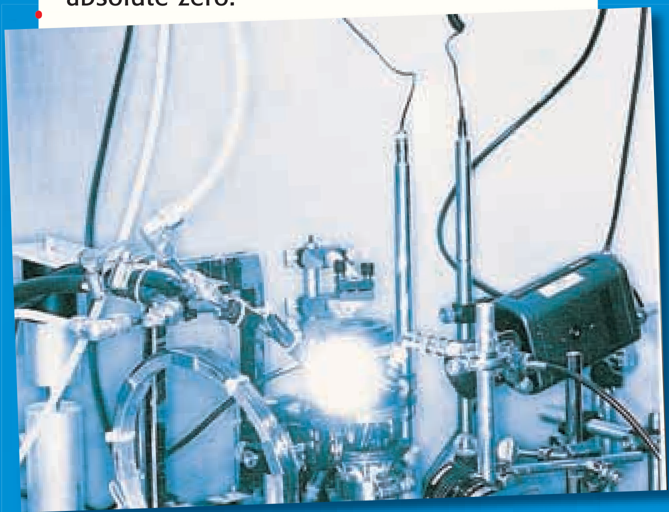
Scientific Discoveries

The Deep Freeze

All matter is made up of tiny, constantly vibrating particles. Temperature is a measure of the average kinetic energy of particles. The colder a substance gets, the slower its particles move. Scientists are interested in how matter behaves when it is cooled to almost absolute zero, the absence of all thermal energy, which is about –273°C. In one method, scientists aim lasers at gas particles, holding them so still that their temperature is less than one-millionth of a degree from absolute zero. It's like turning on several garden hoses and pointing each from a different angle at a soccer ball so that the ball won't move in any direction.

Math ACTIVITY

Think of the coldest weather you have ever been in. What was the temperature? Convert this temperature to kelvins. Compare this temperature with absolute zero.



Science, Technology, and Society

Deep-Sea Air Conditioning

Deep beneath the ocean, about half a mile down, sunlight barely penetrates the still waters. Scientists at Makai Ocean engineering in Hawaii are now using that pitch-dark area as a resource for air conditioning.

In tropical locations, there are some air-conditioning systems that operate with cold water. The water moves through pipes in a building's walls, and the water absorbs thermal energy from the room. But instead of using compressors to cool the water, the new systems designed by Makai use frigid water from the ocean's depths. To use this water, engineers must install long pipelines and powerful pumps to move the water out of the ocean and into the building.

Language Arts ACTIVITY

WRITING SKILL Imagine that air-conditioning systems were never invented. Write a story describing what you would do to cool off on a hot summer day.

Michael Reynolds

Earthship Architect Would you want to live in a house without a heating system? You could if you lived in an Earthship! Earthships are the brainchild of Michael Reynolds, an architect in Taos, New Mexico. These houses are designed to make the most of our planet's most abundant source of energy, the sun.

Each Earthship takes full advantage of passive solar heating. For example, large windows face south in order to maximize the amount of energy the house receives from the sun. Each home is partially buried in the ground. The soil helps keep the energy that comes in through the windows inside the house.

To absorb the sun's energy, the outer walls of Earthships are massive and thick. The walls may be made with crushed aluminum cans or stacks of old automobile tires filled with dirt. These materials absorb the sun's energy and naturally heat the house. Because an Earthship maintains a temperature around 15°C (about 60°F), it can keep its occupants comfortable through all but the coldest winter nights.

Social Studies ACTIVITY

Find out more about Michael Reynolds and other architects who have invented unique ways of building houses that are energy-efficient. Present your findings.

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HT5R8HTTF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS10.

13

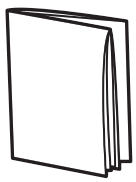
Electronic Technology

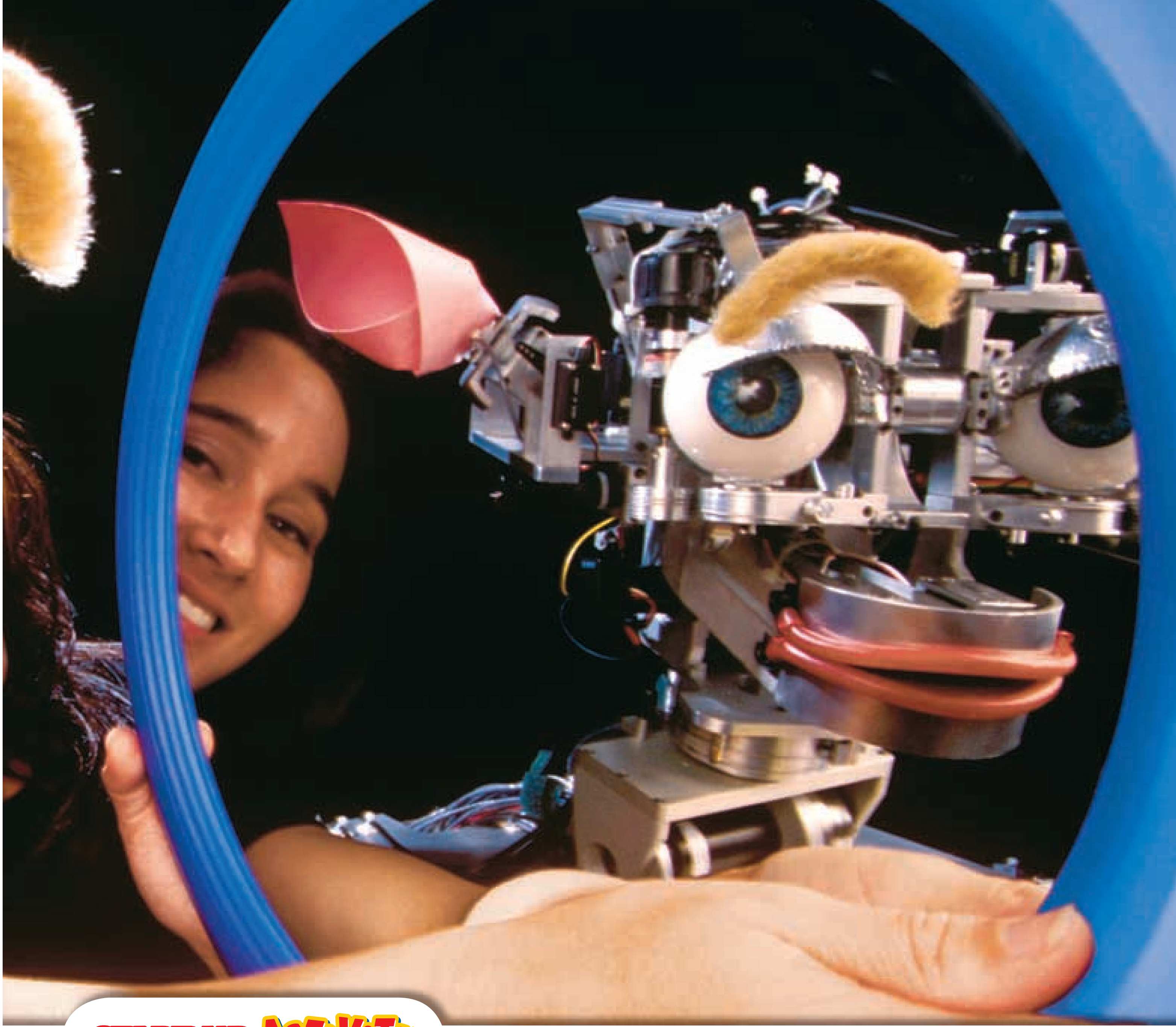
About the PHOTO

Can you read the expression on Kismet's face? This robot's expression can be sad, happy, angry, interested, surprised, disgusted, or just plain calm. Kismet was developed by MIT researchers to interact with humans. Electronic devices in cameras, motors, and computers allow Kismet to change its expression as it responds to its surroundings.

PRE-READING ACTIVITY

FOLDNOTES **Booklet** Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.





START-UP ACTIVITY

Talking Long Distance

In this activity, you'll build a model of a telephone.

Procedure

1. Thread one end of a **piece of string** through the hole in the bottom of one **empty food can.**
2. Tie a knot in the end of the string inside the can. The knot should be large enough to keep the string in place. The rest of the string should come out of the bottom of the can.
3. Repeat steps 1 and 2 with **another can** and the other end of the string.
4. Hold one can, and have a classmate hold the other. Walk away from each other until the string is fairly taut.
5. Speak into your can while your classmate holds the other can at his or her ear. Switch roles.

Analysis

1. Describe what you heard.
2. Compare your model with a real telephone.
3. How are signals sent back and forth along the string?
4. Why do you think it was important to pull the string taut?

SECTION 1

Communication Technology

What electronic devices do you use to send or receive information? Your answer might include telephones, radios, or televisions.

In this section, you'll study these and other electronic devices that are used for communication. You'll also learn about two kinds of signals used to send and store information.

READING WARM-UP

Objectives

- Identify how signals transmit information.
- Describe analog signals and their use in telephones and records.
- Describe digital signals and their use in compact discs.
- Describe how information is transmitted and received in radios and televisions.

Terms to Learn

analog signal
digital signal

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Communicating with Signals

One of the first electronic communication devices, the telegraph, was invented in the 1830s. It used an electric current to send messages in Morse code through wires joining two places. **Table 1** shows the patterns of dots and dashes that stand for each letter and number in Morse code. The message was sent by tapping a telegraph key, like the one in **Figure 1.** This tapping closed a circuit, causing "clicks" at the receiving end of the telegraph. New technologies, such as the telephone, have since evolved. So, now you can communicate using your own voice instead of just a series of clicks.

Signals and Carriers

Electronic communication devices, including the telegraph, send information by using signals. A *signal* is anything, such as a movement, a sound, or a set of numbers and letters, that can be used to send information. Often, one signal is sent using another signal called a *carrier*. Electric current is the carrier of the signals made by tapping a telegraph key. Two kinds of signals are analog signals and digital signals.

Figure 1 *By tapping this telegraph key in the right combinations of short taps (dots) and long taps (dashes), people could send messages over long distances.*

***Table 1* International Morse Code**

A	•–	G	––•	Q	––•–	1	•––––
B	–•••	H	••••	R	•–•	2	••–––
C	–•–•	I	••	S	•••	3	•••––
D	–••	J	•–––	T	–	4	••••–
E	•	K	–•–	U	••–	5	•••••
F	••–•	L	•–••	V	•••–	6	–••••
		M	––	W	•––	7	––•••
		N	–•	X	–••–	8	–––••
		O	–––	Y	–•––	9	––––•
		P	•––•	Z	––••	0	–––––

Analog Signals

An **analog signal** (AN uh LAWG SIG nuhl) is a signal whose properties change without a break or jump between values. Think of a dimmer switch on a light. You can continuously change the brightness of the light using the dimmer switch.

The changes in an analog signal are based on changes in the original information. For example, when you talk on the phone, the sound of your voice is changed into changing electric current in the form of a wave. This wave is an analog signal that is similar to the original sound wave. But remember that sound waves do not travel down your phone line!

analog signal a signal whose properties can change continuously in a given range

CONNECTION TO Geology

Seismograms A *seismograph* is a device used by scientists to record waves made by earthquakes. It makes a *seismogram*—wavy lines on paper that record ground movement. Draw an example of a seismogram that shows changes in the wave, and explain why this is an example of an analog signal.

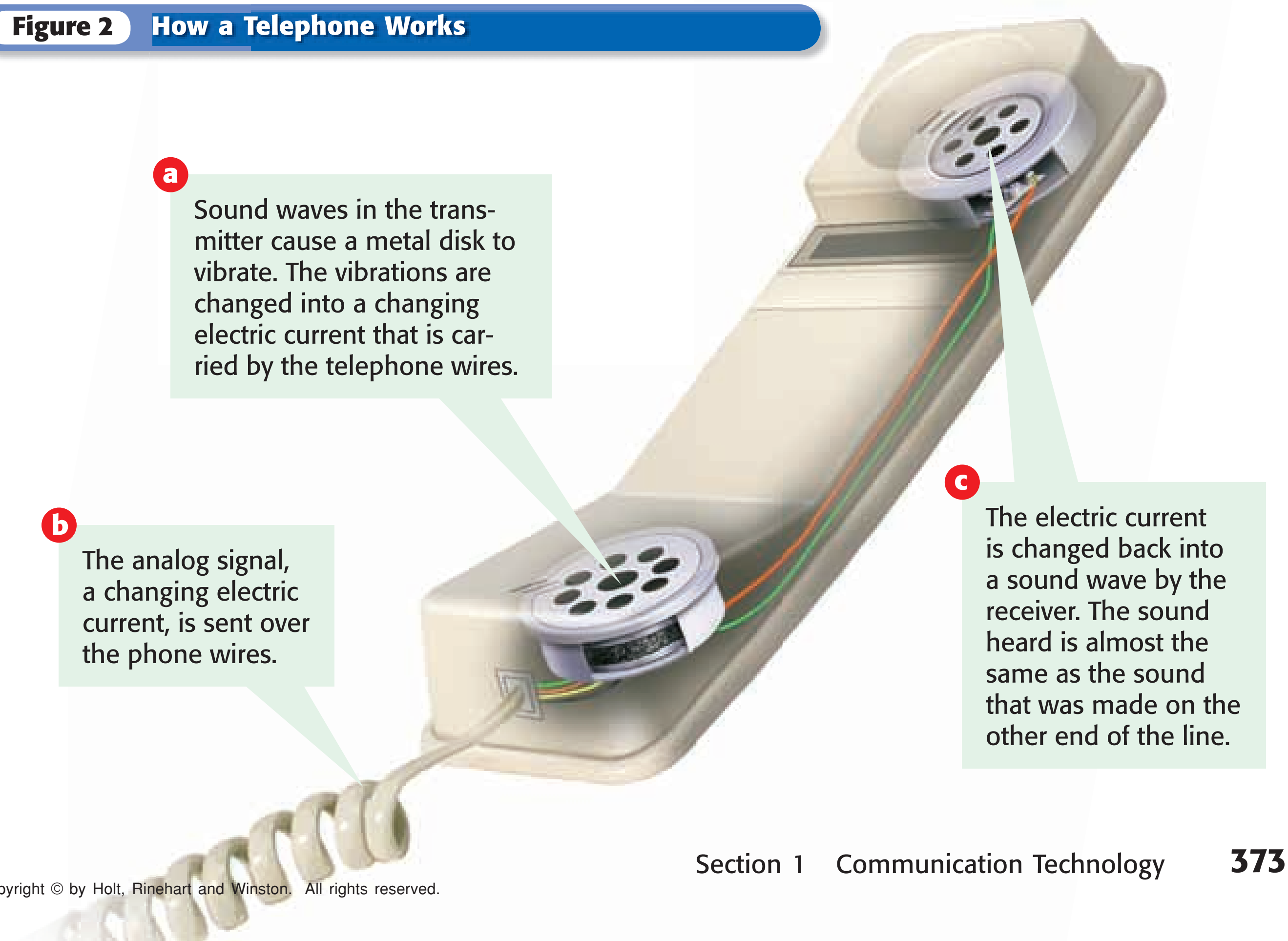
ACTIVITY

Reading Check **What is an analog signal?** (*See the Appendix for answers to Reading Checks.*)

Talking on the Phone

Look at the telephone in **Figure 2.** You talk into the transmitter. You listen to the receiver. The transmitter changes the sound waves made when you speak into an analog signal. This signal moves through phone wires to the receiver of another phone. The receiver changes the analog signal back into the sound of your voice. Sometimes, the analog signals are changed to digital signals and back again before they reach the other person. You will learn about digital signals later in this section.

Figure 2 **How a Telephone Works**



Analog Recording

Early recordings of sounds were stored as analog signals by making grooves in wax or metal. More durable vinyl records were later developed. A sound's properties are represented by the number and depth of the contours made in a plastic disk.

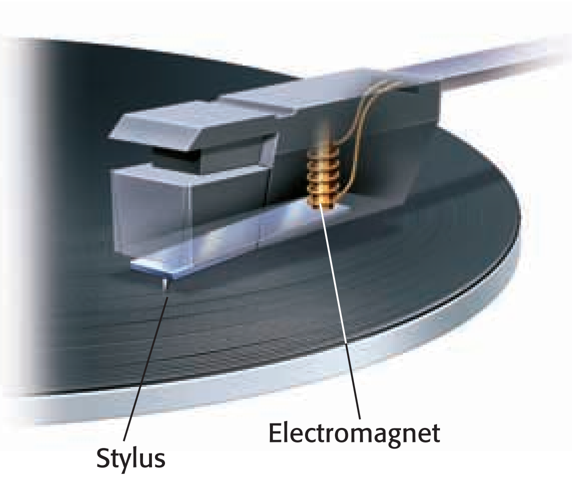


Figure 3 *As the stylus rides in the record's grooves, it causes an electromagnet to vibrate.*

Playing a Record

Figure 3 shows a record being played. The stylus (STIE luhs), or needle, makes an electromagnet vibrate. The vibrating electromagnet induces an electric current that is used to make sound. Analog recording makes sound that is very close to the original. But unwanted sounds are sometimes recorded and are not easy to remove. Also, the stylus touches the record to play it. So, the record wears out, and the sound changes over time.

Digital Signals

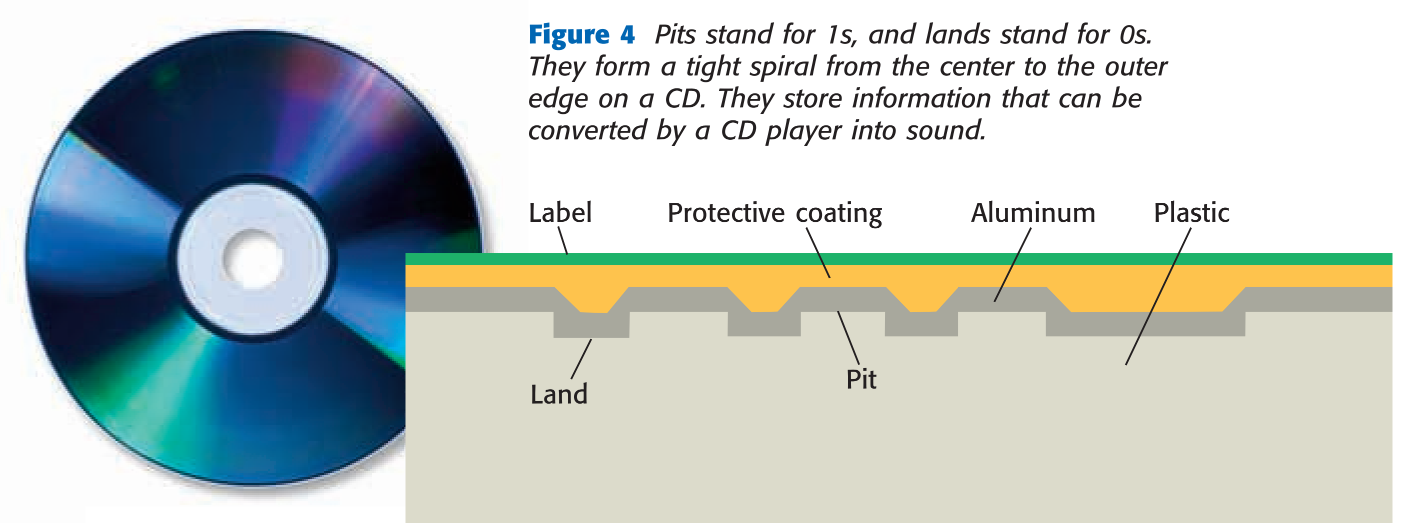
A **digital signal** is a signal that is represented as a sequence of separate values. It does not change continuously. Think of a regular light switch. It can be either on or off. Information in a digital signal is represented as binary (BIE nuh ree) numbers. *Binary* means "two." Numbers in binary are made up of only two digits, 1 and 0. Each digit is a *bit,* which is short for *binary digit*. Computers process digital signals that are in the form of a pattern of electric pulses. Each pulse stands for a 1. Each missing pulse stands for a 0.

digital signal a signal that can be represented as a sequence of discrete values

Digital Storage on a CD

Processes for recording sound evolved further and led to the compact disc, or CD. Sound is recorded to a CD by means of a digital signal. A CD stores the signals in a thin layer of aluminum. Look at **Figure 4.** When looking at the pits and lands, keep in mind that a CD is read from the bottom.

Figure 4 *Pits stand for 1s, and lands stand for 0s. They form a tight spiral from the center to the outer edge on a CD. They store information that can be converted by a CD player into sound.*



Digital Recording

In a digital recording, the sound wave is measured many times each second. **Figure 5** shows how these sample values represent the original sound. These numbers are then changed into binary values using 1s and 0s. The 1s and 0s are stored as pits and lands on a CD.

In digital recording, the sample values don't exactly match the original sound wave. So, the number of samples taken each second is important to make sure the recording sounds the way it should sound. Taking more sample values each second makes a digital sound that is closer to the original sound.

Reading Check **How can a digital recording be made to sound more like the original sound?**

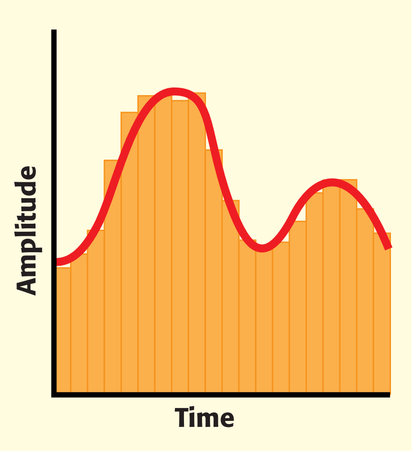


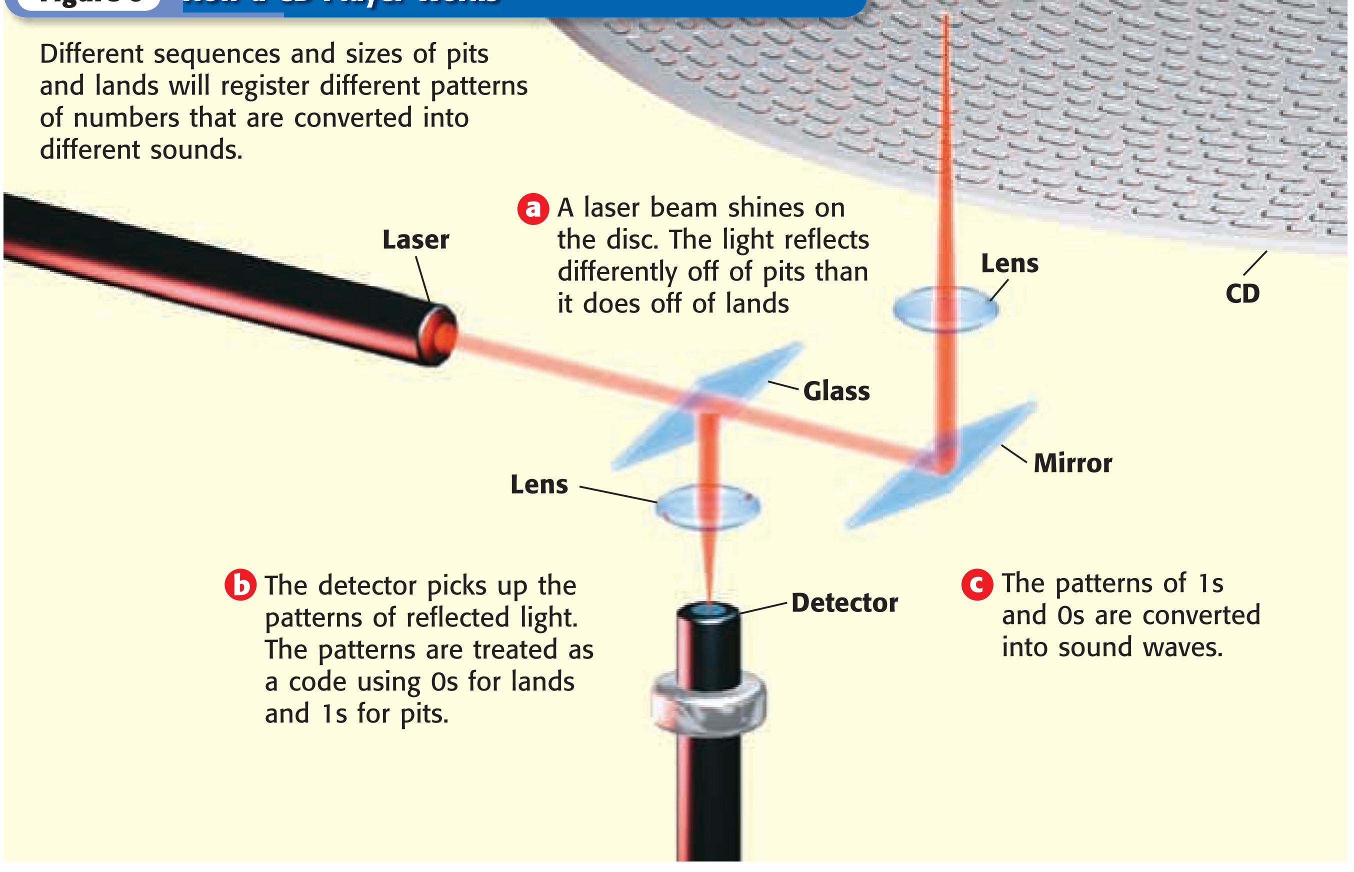
Figure 5 *Each of the bars represent a digital sample of the sound wave.*

Playing a CD

In a CD player, the CD spins around while a laser shines on the CD from below. As shown in **Figure 6,** light reflected from the CD enters a detector. The detector changes the pattern of light and dark into a digital signal. The digital signal is changed into an analog signal, which is used to make a sound wave. Because only light touches the CD, the CD doesn't wear out. But errors can happen from playing a dirty or scratched CD.

Figure 6 **How a CD Player Works**

Different sequences and sizes of pits and lands will register different patterns of numbers that are converted into different sounds.



Radio and Television

You hear or see shows on your radio or television that are broadcast from a station that may be many kilometers away. The radio and TV signals can be either analog or digital. An *electromagnetic* (EM) *wave* is a wave that consists of changing electric and magnetic fields. EM waves are used as carriers.

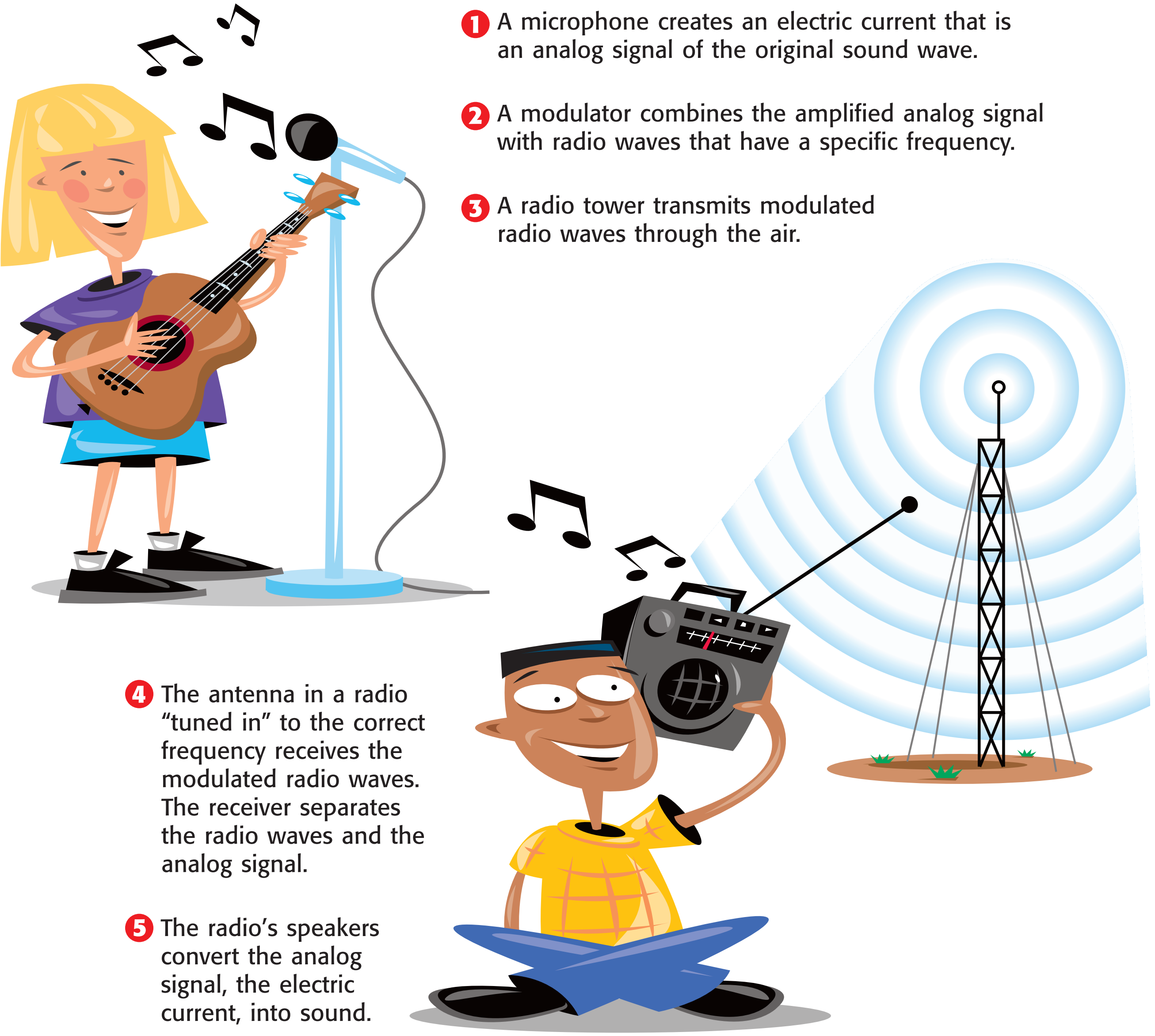
INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5ELTW.**

Radio

Radio waves are one kind of EM wave. Radio stations use radio waves to carry signals that represent sound. Look at **Figure 7.** Radio waves are transmitted by a radio tower. They travel through the air and are picked up by a radio antenna.

Figure 7 **How a Radio Works**



1. A microphone creates an electric current that is an analog signal of the original sound wave.
2. A modulator combines the amplified analog signal with radio waves that have a specific frequency.
3. A radio tower transmits modulated radio waves through the air.
4. The antenna in a radio "tuned in" to the correct frequency receives the modulated radio waves. The receiver separates the radio waves and the analog signal.
5. The radio's speakers convert the analog signal, the electric current, into sound.

Television

The pictures you see on your television are made by beams of electrons hitting the screen, as described in **Figure 8.** Video signals hold the information to make a picture. Audio signals hold the information to make the sound. These signals can be sent as analog or digital signals to your television. The signals can be broadcast using EM waves as carriers. The signals can be sent through cables or from satellites or broadcast towers.

The technological evolution of television has led to more and more programs going digital. This means that they are filmed using digital cameras and transmitted as digital signals. You can watch digital shows on an analog TV. However, on a digital display, the images and sound are much clearer than on a television made for analog broadcasts.

Reading Check **What kinds of signals can be picked up by a color television?**

SCHOOL to HOME

TV Screen

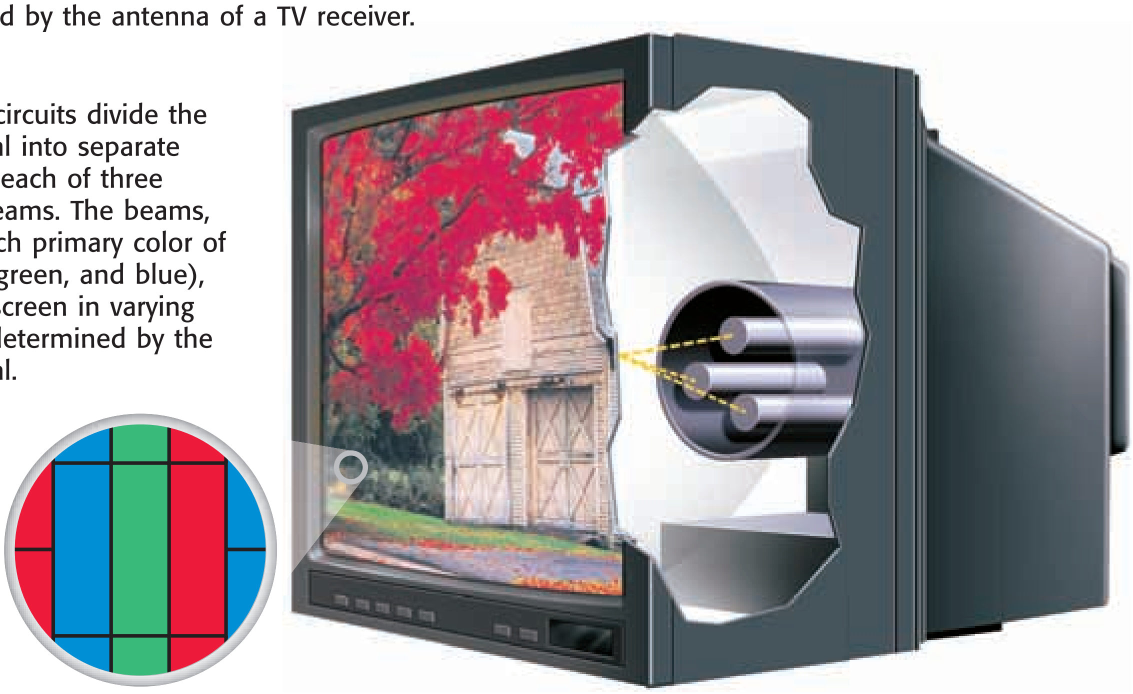
With an adult, use a magnifying lens to look at a television screen. How are the fluorescent materials arranged? Hold the lens at various distances from the screen. What effects do you see? How does the screen's changing picture affect what you see?

ACTIVITY

Figure 8 **Images on a Color Television**

1 Video signals transmitted from a TV station are received by the antenna of a TV receiver.

2 Electronic circuits divide the video signal into separate signals for each of three electron beams. The beams, one for each primary color of light (red, green, and blue), strike the screen in varying strengths determined by the video signal.



3 The screen has stripes or dots of three fluorescent (FLOO uh RES uhnt) materials. These materials glow when hit by electrons. The electron beams sweep the screen 30 times every second and activate the fluorescent materials. These materials then emit colored light that is viewed as a picture.

Plasma Display

Standard televisions must be deep enough so that the electron beams can reach all parts of the screen. So, televisions are bulky and heavy. Technological evolution has led to a newer kind of screen, called a *plasma display*. It can be as thin as 15 cm. So, it is not much thicker than a painting on the wall!

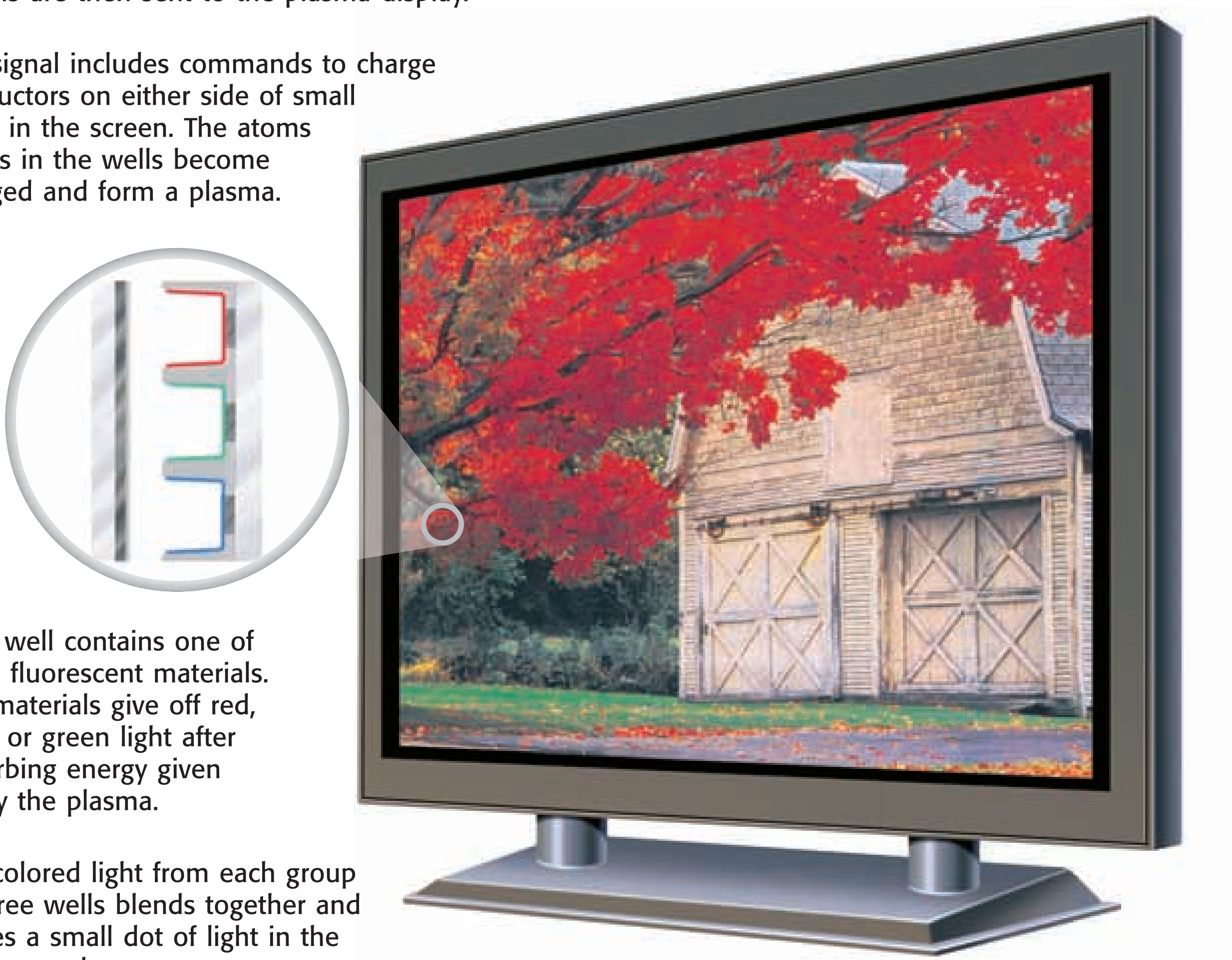
Figure 9 shows how a plasma display works. Plasma displays do not use electron tubes. Instead, they have thousands of tiny cells with gases in them. A computer charges the cells, making a current in the gases. The current generates colored lights. Each light can be red, green, blue, or a combination. As in a regular television, these three colors are combined to make every picture on the screen.

Reading Check **Why is a plasma display thinner than a regular television?**

Figure 9 **How a Plasma Display Works**

1. Video signals transmitted from a TV station are received by a device, such as a VCR, that has a television tuner in it. The signals are then sent to the plasma display.

2. The signal includes commands to charge conductors on either side of small wells in the screen. The atoms of gas in the wells become charged and form a plasma.



3. Each well contains one of three fluorescent materials. The materials give off red, blue, or green light after absorbing energy given off by the plasma.

4. The colored light from each group of three wells blends together and makes a small dot of light in the picture on the screen.

SECTION Review

Summary

- Signals transmit information in electronic devices. Signals can be transmitted using a carrier. Signals can be analog or digital.
- Analog signals have continuous values. Telephones, record players, radios, and regular TV sets use analog signals.
- In a telephone, a transmitter changes sound waves to electric current. The current is sent across a phone line. The receiving telephone converts the signal back into a sound wave.
- Analog signals of sounds are used to make vinyl records. Changes in the groove reflect changes in the sound.
- Digital signals have discrete values, such as 0 and 1. CD players use digital signals.
- Radios and televisions use electromagnetic waves. These waves travel through the atmosphere. In a radio, the signals are converted to sound waves. In a television, electron beams convert the signals into images on the screen.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *analog signal* and *digital signal*.

Understanding Key Ideas

2. Which of the following objects changes sound waves into an electric current in order to transmit information?

a. telephone
b. radio
c. television
d. telegraph

3. Why are carriers used to transmit signals?

4. What is an early example of an electrical device used for sending information over long distances? How did this device work?

Critical Thinking

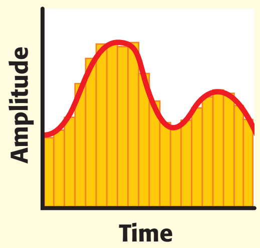
5. Applying Concepts Is Morse code an example of an analog signal or a digital signal? Explain your reasoning.

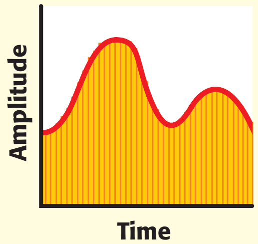
6. Making Comparisons Compare how a telephone and a radio tower transmit information.

7. Making Inferences Does a mercury thermometer provide information in an analog or digital way? Explain your reasoning.

Interpreting Graphics

8. Look at the graphs below. They represent a sound wave that is being changed into a digital signal. Each bar represents a digital sample of the sound wave. Which graph represents the digital signal that is closer to the original sound wave? Explain your reasoning.





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Topic: Telephone Technology; Television Technology

SciLinks code: HSM1499; HSM1501

SECTION 2

Computers

Did you use a computer to wake up this morning?

You might think of a computer as something you use to send e-mail or to surf the Internet. But computers are around you all the time. Computers are in automobiles, VCRs, and telephones. Even an alarm clock is an example of a simple computer!

READING WARM-UP

Objectives

- List a computer's basic functions, and describe its development.
- Identify the main components of computer hardware.
- Explain how information can be stored on CD-Rs and CD-RWs.
- Describe what computer software allows a computer to do.
- Describe computer networks.

Terms to Learn

computer
microprocessor
hardware
software
Internet

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

What Is a Computer?

A **computer** is an electronic device that performs tasks by following instructions given to it. A computer does a task when it is given a command and has the instructions necessary to carry out that command. Computers can do tasks very quickly.

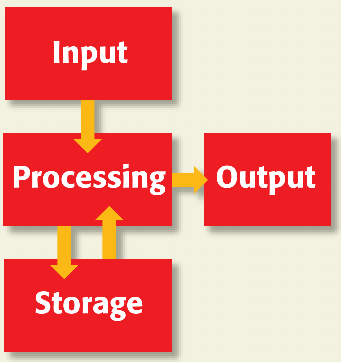
Basic Functions

The basic functions of a computer are shown in **Figure 1.** The information you give to a computer is called *input.* The computer *processes* the input. Processing could mean adding a list of numbers, making a drawing, or even moving a piece of equipment. Input doesn't have to be processed right away. It can be stored until it is needed. The computer *stores* information in its memory. *Output* is the final result of the job done by the computer.

Reading Check **What are the basic functions of a computer?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 Basic Computer Functions

The Functions of a Computer



An Alarm Clock as a Computer

Input You set the time you need to wake up.

Processing Clock compares wake-up time to actual time.

Storage Clock remembers your wake-up time.

Output Buzzer or music sounds to wake you up.

The First Computers

Your pocket calculator is a simple computer. But computers were not always so small and easy to use. The first computers were huge! They were made up of large pieces of equipment that could fill a room. The first general-purpose computer is shown in **Figure 2.** This is the ENIAC. ENIAC stands for Electronic Numerical Integrator and Computer. It was made in 1946 by the U.S. Army. The ENIAC was made up of thousands of vacuum tubes. As a result, it had to be cooled while in use. It also cost a lot to build and to run.

Figure 2 *Fast for its time, the ENIAC could add 5,000 numbers per second.*

Modern Computers

Computers have become much smaller because of the evolution of technological processes and theories that led to the development of integrated circuits. Computers today use microprocessors. A **microprocessor** is a single chip that controls and carries out a computer's instructions. The first widely available microprocessor had only 4,800 transistors. But microprocessors made today may have more than 40 million transistors. This evolution of technology has resulted in smaller and faster computers. Computers are now made so small that we can carry them around like a book!

computer an electronic device that can accept data and instructions, follow the instructions, and output the results

microprocessor a single semiconductor chip that controls and executes a microcomputer's instructions

Reading Check **What is a microprocessor?**

Quick Lab

The Speed of a Simple Computer

1. With a partner, use a **clock** to measure the time it takes each of you to solve the following items by hand.
   a. $(108 \div 9) + 231 - 19$
   b. $1 \times 2 \times 3 \times 4 \times 5$
   c. $(4 \times 6 \times 8) \div 2$
   d. $3 \times (5 + 12) - 2$
2. Repeat step 1 using a **calculator.**
3. Which method was faster?
4. Which method was more accurate?
5. Will the calculator always give you the correct answer? Explain.

hardware the parts or pieces of equipment that make up a computer

Computer Hardware

Different parts of a computer do different jobs. **Hardware** is the parts or pieces of equipment that make up a computer. As you read about each piece of hardware, look at **Figure 3** and **Figure 4** to see what the hardware looks like.

Input Devices

An *input device* gives information, or input, to the computer. You can enter information into a computer using a keyboard, a mouse, a scanner, or a digitizing pad and pen. You can even enter information using a microphone.

Central Processing Unit

A computer does tasks in the *central processing unit,* or CPU. In a personal computer, the CPU is a microprocessor. Input goes through the CPU for processing on the spot or for storage in memory. In the CPU, the computer does calculations, solves problems, and carries out instructions given to it.

Reading Check What does *CPU* stand for?

CONNECTION TO Social Studies

WRITING SKILL **ENIAC** ENIAC was developed for use by the U.S. Army during World War II. Research what ENIAC was to be used for in the war and what plans were made for ENIAC after the war. Write a one-page report in your **science journal** to report your findings.

Figure 3 Computer Hardware

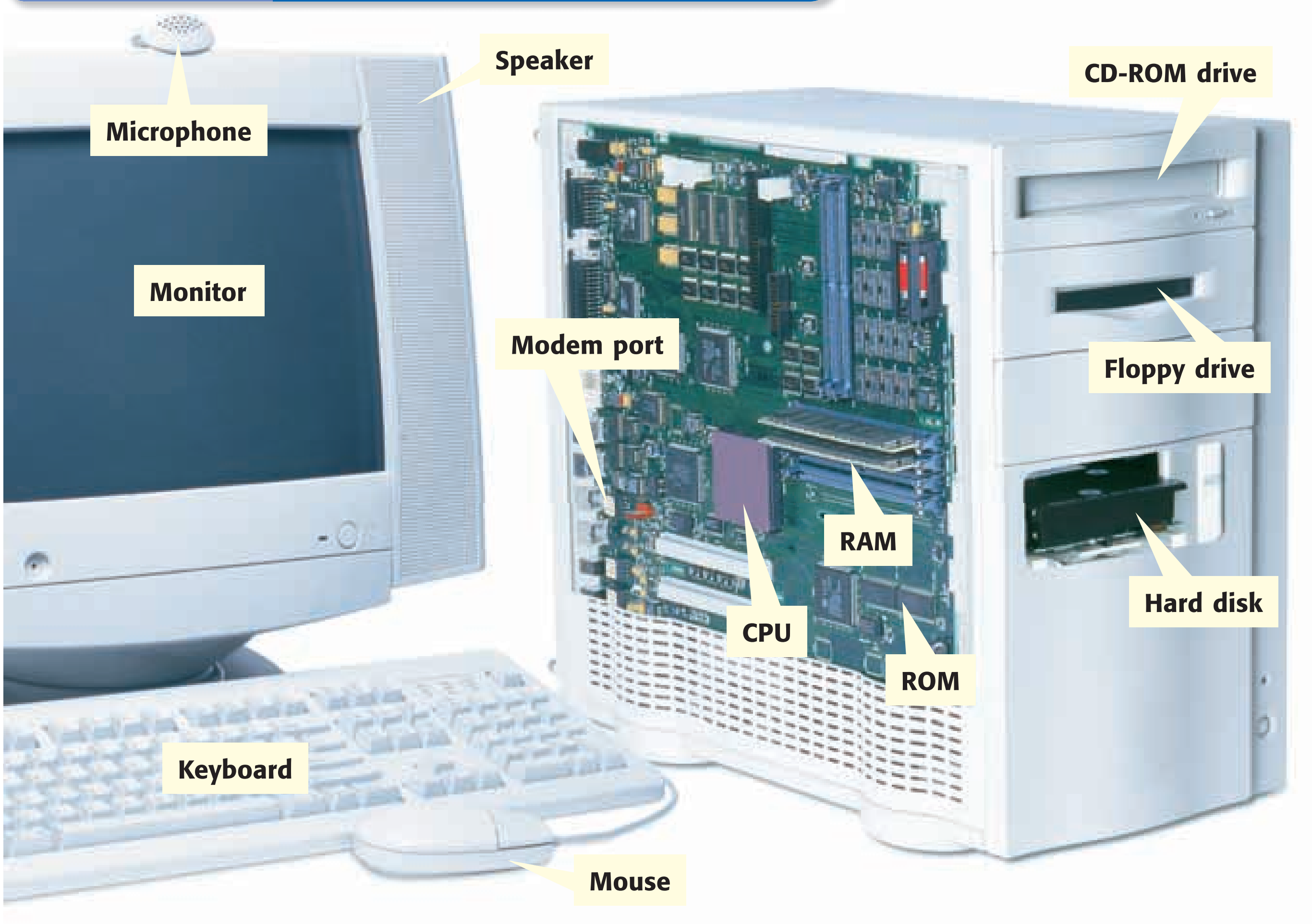
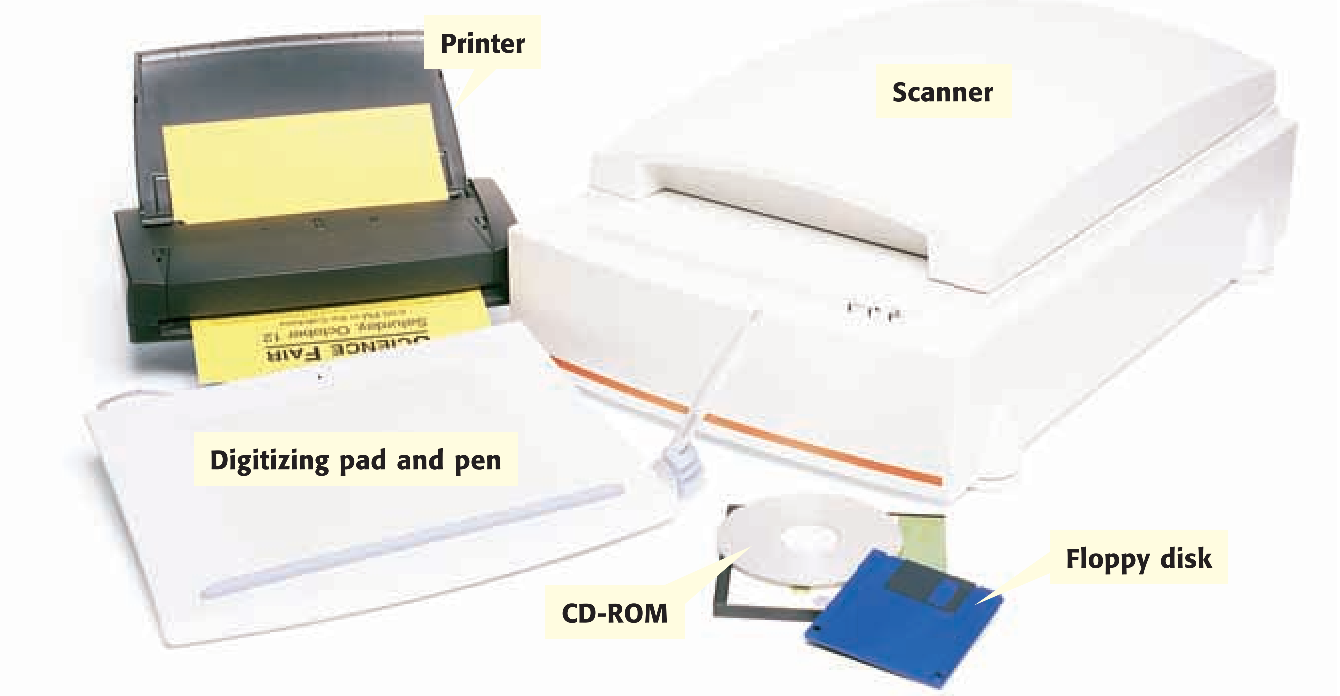


Figure 4 Additional Computer Hardware



Memory

Information can be stored in the computer's memory until it is needed. Hard disks inside a computer and floppy disks or CDs that are put into a computer have memory to store information. Two other types of memory are *ROM* (read-only memory) and *RAM* (random-access memory).

ROM is permanent. It handles jobs such as start-up, maintenance, and hardware management. ROM normally cannot be added to or changed. It also cannot be lost when the computer is turned off. RAM is temporary. RAM stores information only while it is being used. RAM is sometimes called *working memory.* Information in RAM is lost if the power is shut off. So, it is a good habit to save your work to a hard drive or to a disk every few minutes.

Output Devices

Once a computer does a job, it shows the results on an *output device*. Monitors, printers, and speaker systems are all examples of output devices.

Modems and Interface Cards

Computers can exchange information if they are joined by modems or interface cards. Modems send information through telephone lines. Modems convert information from a digital signal to an analog signal and vice versa. Interface cards use cables or wireless connections.

MATH PRACTICE

Computer Memory

Suppose you download a document from the Internet that uses 25 kilobytes of memory. How many of those documents could you fit on a disk that has 1 gigabyte of memory? A kilobyte is 1,024 bytes, and a gigabyte is 1,073,741,824 bytes.

Compact Discs

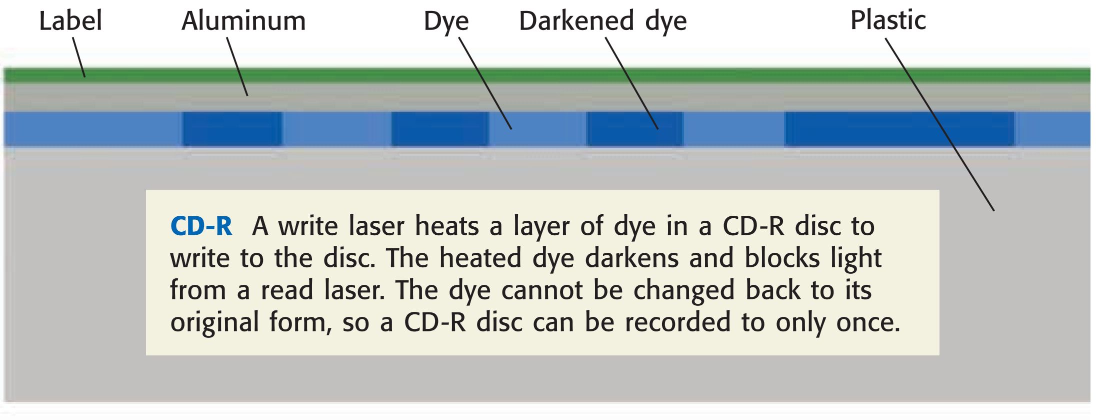
Today, CD technology has evolved so that you can use a CD burner to make your own compact discs. A CD holds about 500 times more information than a floppy disk. It can store digital photos, music files, and any other type of computer file.

Burning and Erasing CDs

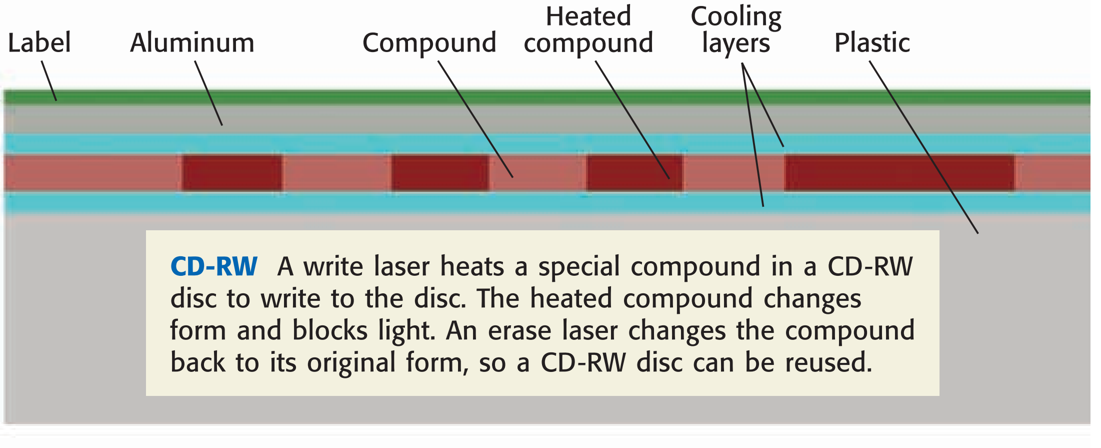
The first kind of CD that you could put information onto, or "burn," is a CD-recordable (CD-R) disc. CD-R discs use a dye to block light. When the dye is heated, light cannot pass through to reflect off the aluminum. To burn a CD, a special laser heats some places and not others. This burning creates a pattern of "on" and "off" spots on the CD-R. These spots store information just as the pits and lands do on a regular CD. You can burn a CD-R disc only once.

A CD-rewritable (CD-RW) disc can be used more than once. CD-RW discs use a special compound that can be erased and written over again. CD-RW discs cost more than CD-R discs. But CD-RW discs cannot be read by all CD players. Look at **Figure 5** to see how CD-R and CD-RW discs work.

Figure 5 **How CD-R and CD-RW Discs Work**



CD-R A write laser heats a layer of dye in a CD-R disc to write to the disc. The heated dye darkens and blocks light from a read laser. The dye cannot be changed back to its original form, so a CD-R disc can be recorded to only once.



CD-RW A write laser heats a special compound in a CD-RW disc to write to the disc. The heated compound changes form and blocks light. An erase laser changes the compound back to its original form, so a CD-RW disc can be reused.

Computer Software

Computers need instructions before they can do any given task. **Software** is a set of instructions or commands that tells a computer what to do. A computer program is software.

software a set of instructions or commands that tells a computer what to do; a computer program

Kinds of Software

Software can be split into two kinds: operating-system software and application software. Operating-system software handles basic operations needed by the computer. It helps the software and hardware communicate. It also handles commands from an input device. It can find programming instructions on a hard disk to be loaded into memory.

Application software tells the computer to run a utility, such as the ones shown in **Figure 6.** The pages in this book were made using many kinds of application software!

Reading Check What are the two main kinds of software?

Figure 6 Common Types of Computer Software

Computer Networks

Internet a large computer network that connects many local and smaller networks all over the world

By using modems and software, many computers can be connected, which allows them to communicate with one another. The **Internet** is a huge computer network made up of millions of computers that can all share information.

The Internet

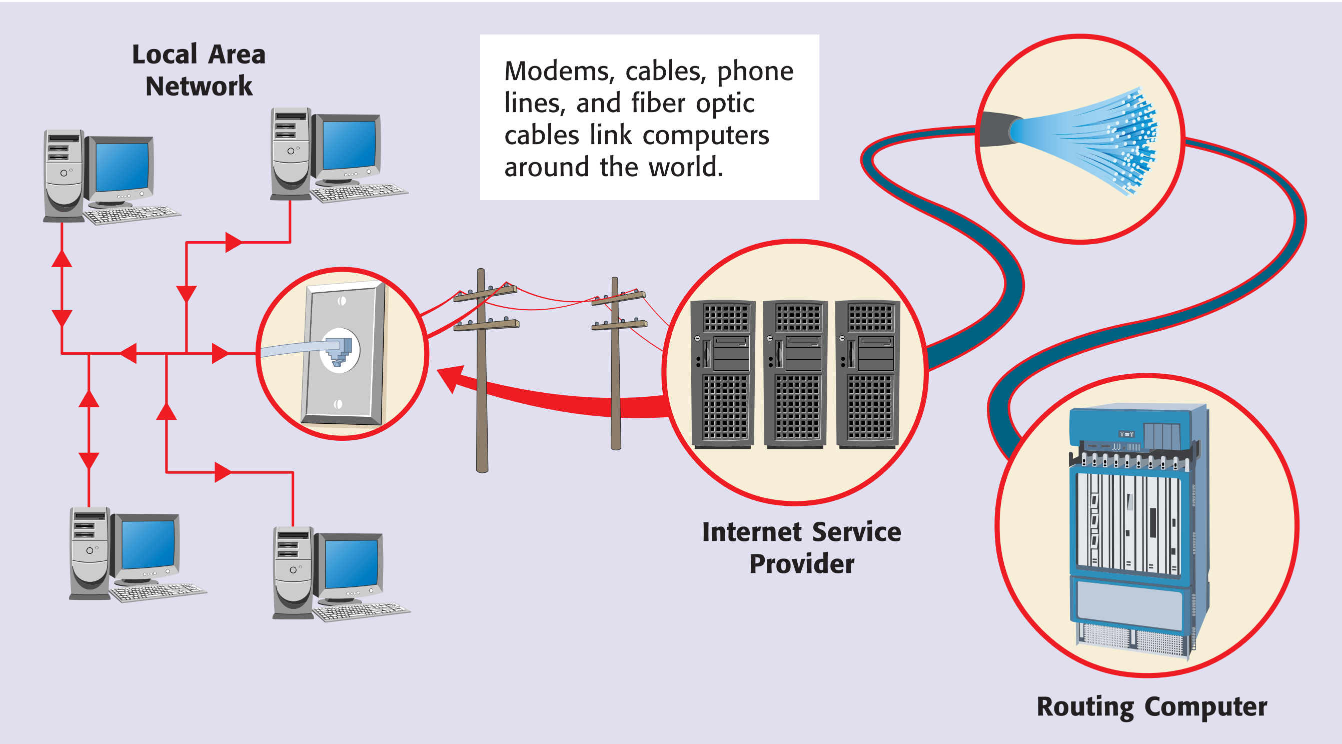
Figure 7 shows some ways computers can be connected. Computers can connect on the Internet by using modems to dial into an Internet Service Provider, or ISP. A home computer often connects to an ISP over a phone or cable line. Computers in a school or business can be joined in a Local Area Network, or LAN. These computers connect to an ISP through only one line. ISPs around the world are connected by fiber optic cables.

The World Wide Web

The part of the Internet that people know best is called the *World Wide Web*. When you use a Web browser to look at pages on the Internet, you are on the World Wide Web. Web pages share a format that is simple enough that any computer can view them. They are grouped into Web sites. Clicking on a link takes you from one page or site to another. You can use a search engine to find Web pages on a topic for a report or to find out about your favorite movie!

Reading Check **Describe the World Wide Web.**

Figure 7 *Internet Service Providers allow computers in your home or school to connect to large routing computers that are linked around the world.*



SECTION Review

Summary

- All computers have four basic functions: input, processing, storage, and output.
- The first general-purpose computer, ENIAC, was made of thousands of vacuum tubes and filled an entire room. Microprocessors have made it possible to have computers the size of notebooks.
- Computer hardware includes input devices, the CPU, memory, output devices, and modems.
- CD burners can store information on recordable CDs, or CD-Rs. Rewritable CDs, or CD-RWs, can be erased and reused. Both use patterns of light and dark spots.
- Computer software is a set of instructions that tell a computer what to do. The two main types are operating systems and applications. Applications include word processors, spreadsheets, and games.
- The Internet is a huge network that allows millions of computers to share information.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. A word-processing application is an example of <u>hardware</u>.

2. An ISP allows you to connect to the <u>microprocessor</u>.

Understanding Key Ideas

3. Which of the following is an example of hardware used for input?

a. monitor
b. keyboard
c. printer
d. speaker

4. How are modern computers different from ENIAC? How are they the same?

5. What is the difference between hardware and software?

6. Explain how a CD burner works.

7. What is the Internet?

Critical Thinking

8. Applying Concepts Using the terms *input, output, processing,* and *store,* explain how you use a pocket calculator to add numbers.

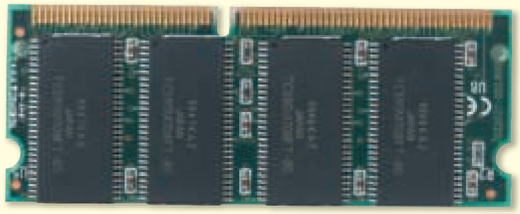
9. Predicting Consequences If no phone lines were working, would there be any communication on the Internet? Explain.

Math Skills

10. How many 800 KB digital photos could you burn onto a CD-R disc that can hold 700 MB of information? (Note: 1,024 KB = 1 MB)

Interpreting Graphics

11. Look at the image of a RAM module below. Each of the black rectangles on the module is 32 MB of RAM. Each side of the module has the same number of rectangles. How much total RAM does the module have?



SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Computer Technology; Internet
SciLinks code: HSM0334; HSM0808

Skills Practice Lab

Sending Signals

With a telegraph, you can use electric current to send signals between two telegraph keys connected by wires. In this lab, you will build a model of a telegraph that allows you to use Morse code to transmit messages to a friend.

OBJECTIVES

Build a working model of a telegraph key.

Send a message in Morse code by using your model.

Receive a message in Morse code by using your model.

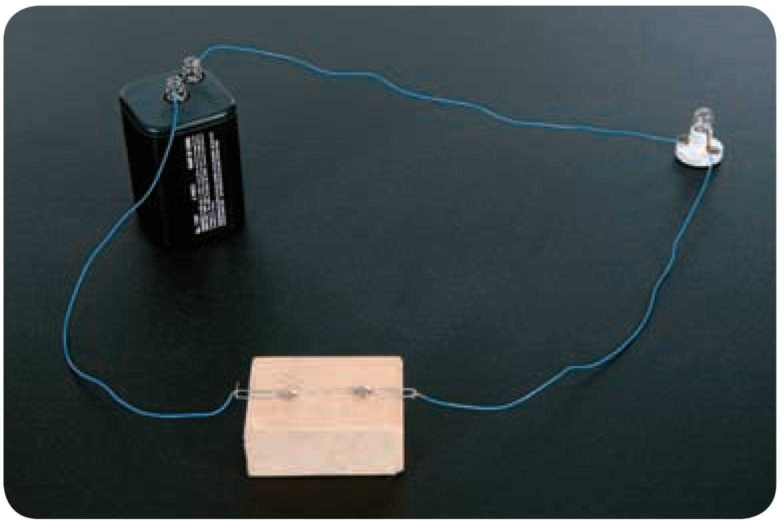
MATERIALS

- battery, 6 V
- flashlight bulb with bulb holder
- paper clip (3)
- thumbtack (2)
- wire, insulated, with ends stripped, 15 cm (4)
- wood block, small

SAFETY

Procedure

1. Build a switch on the wood block, as shown below. Use a thumbtack to tack down a paper clip so that one end of the paper clip hangs over the edge of the wood block.
2. Unfold a second paper clip so that it looks like an *s*. Use the second thumbtack to tack down one end of the open paper clip on top of the remaining paper clip. The free end of the closed paper clip should hang off of the edge of the wood block opposite the first paper clip. The free end of the open paper clip should touch the thumbtack below it when pushed down.
3. Build the rest of the circuit, as shown below. Use a wire to connect one terminal of the battery to one of the paper clips that hangs over the edge of the wood block.
4. Use a second wire to connect the other paper clip that hangs over the edge of the wood block to the bulb holder.
5. Use a third wire to connect the other side of the bulb holder with the second terminal of the battery.



6. Test your circuit by gently pressing down on the open paper clip so that it touches the thumbtack below it. The light bulb should light. This is your model of a telegraph key.
7. Connect your model to another team's model. Use the remaining wire in each team's materials to connect the bulb holders, as shown on the next page. Test your circuit by closing each switch one at a time.

8. Write a short, four- or five-word message in Morse code. Take turns sending messages to the other team using the telegraph. To send a dot, press the paper clip down for two seconds. To send a dash, hold the clip down for four seconds. Decode the message you receive, and check to see if you got the correct message.

9. Remove one of the batteries. Test your circuit again by closing each switch one at a time.

Analyze the Results

1. **Describing Events** When both batteries are attached, what happens to the flashlight bulbs when you close your switch?

2. **Describing Events** When both batteries are attached, what happens to the flashlight bulbs when the other team closes their switch?

3. **Describing Events** How does removing one of the batteries change the way you can send or receive messages on the telegraph?

4. **Analyzing Results** Did you receive the correct message from the other team? If not, what problems did you have?

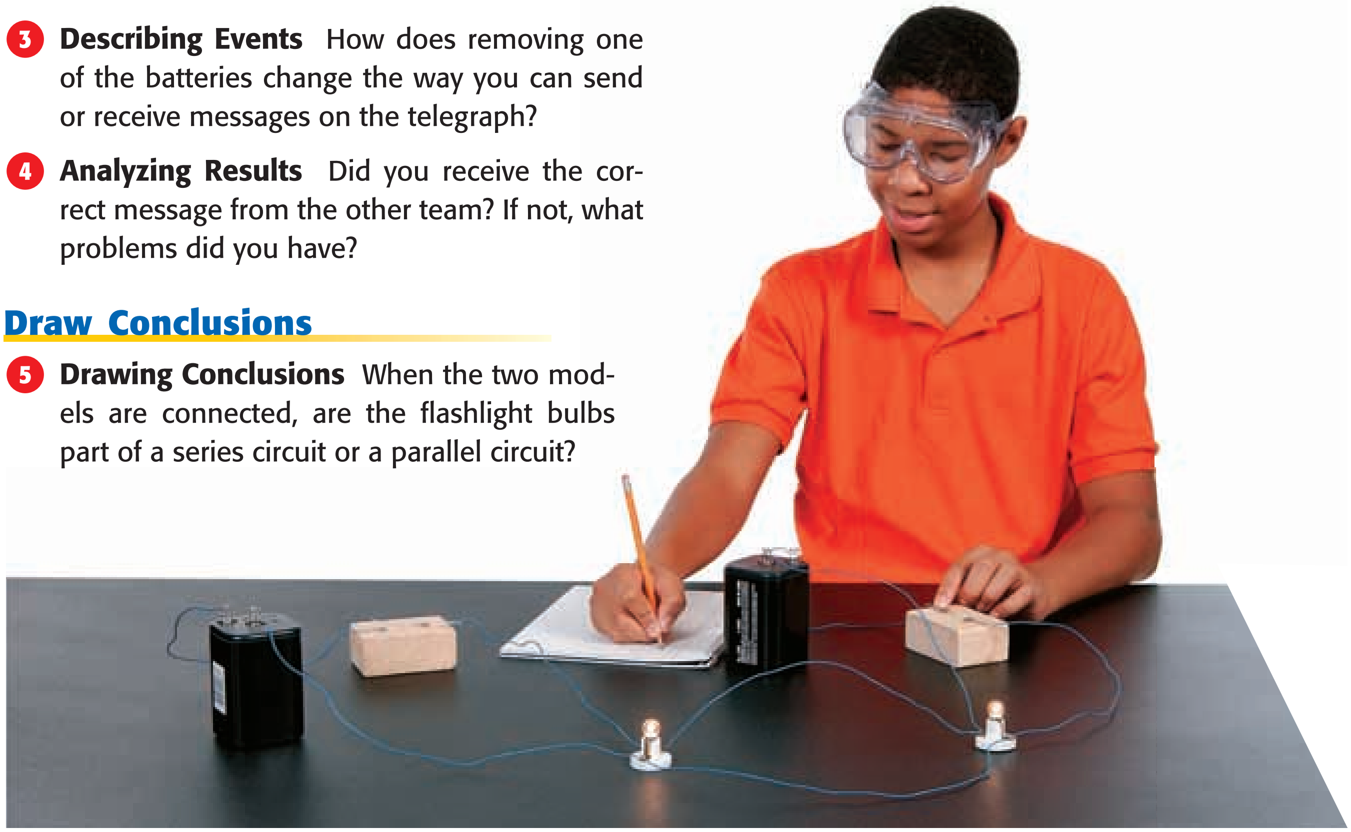
Draw Conclusions

5. **Drawing Conclusions** When the two models are connected, are the flashlight bulbs part of a series circuit or a parallel circuit?

6. **Making Predictions** How might using a telegraph to transmit messages overseas be difficult?

Table 1 International Morse Code

A •–	J •–––	S •••	2 ••–––
B –•••	K –•–	T –	3 •••––
C –•–•	L •–••	U ••–	4 ••••–
D –••	M ––	V •••–	5 •••••
E •	N –•	W •––	6 –••••
F ••–•	O –––	X –••–	7 ––•••
G ––•	P •––•	Y –•––	8 –––••
H ••••	Q ––•–	Z ––••	9 ––––•
I ••	R •–•	1 •––––	0 –––––



Chapter Review

USING KEY TERMS

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

1. *analog signal* and *digital signal*

2. *computer* and *microprocessor*

3. *hardware* and *software*

UNDERSTANDING KEY IDEAS

Multiple Choice

4. All communication devices transmit information by using
   - **a.** signals.
   - **b.** electromagnetic waves.
   - **c.** radio waves.
   - **d.** modems.

5. Memory in a computer that is temporary and that stores information only while the information is being used is called
   - **a.** RAM.
   - **b.** ROM.
   - **c.** CPU.
   - **d.** None of the above

6. Which of the following is an example of a telecommunication device?
   - **a.** vacuum tube
   - **b.** telephone
   - **c.** radio
   - **d.** Both (b) and (c)

7. A monitor, a printer, and a speaker are examples of
   - **a.** input devices.
   - **b.** memory.
   - **c.** computers.
   - **d.** output devices.

8. Record players play sounds that were recorded in the form of
   - **a.** digital signals.
   - **b.** electric currents.
   - **c.** analog signals.
   - **d.** radio waves.

9. Memory in a computer that is permanent and cannot be changed is called
   - **a.** RAM.
   - **b.** ROM.
   - **c.** CPU.
   - **d.** None of the above

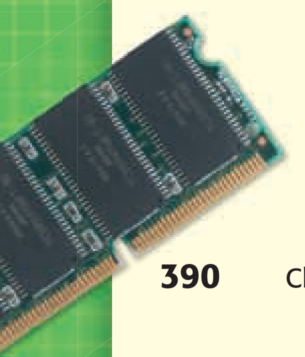
10. Beams of electrons that shine on fluorescent materials are used in
    - **a.** telephones.
    - **b.** telegraphs.
    - **c.** televisions.
    - **d.** radios.

Short Answer

11. How has computer technology evolved since ENIAC was made?

12. In one or two sentences, describe how a television works.

13. Give three examples of how computers are used in your everyday life.



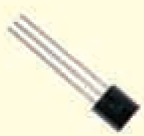
Math Skills

14 How many bits can be stored on a 20 GB hard disk? (Hint: 1 GB = 1,073,741,824 bytes; 1 byte = 8 bits)

CRITICAL THINKING

15 **Concept Mapping** Use the following terms to create a concept map: *electronic devices, radio waves, electric current, signals,* and *information*.

16 **Applying Concepts** While preparing an oral report on the evolution of computer technology, you discover the photos shown below. One photo shows a vacuum tube like the ones used in ENIAC. The other photo shows a much smaller device—a transistor—that was developed to do the same job that the vacuum tube did. How would you use these photos to correlate the evolution of technological designs and processes that led from large, slow computers in the 1940s to the smaller, more powerful computers today?

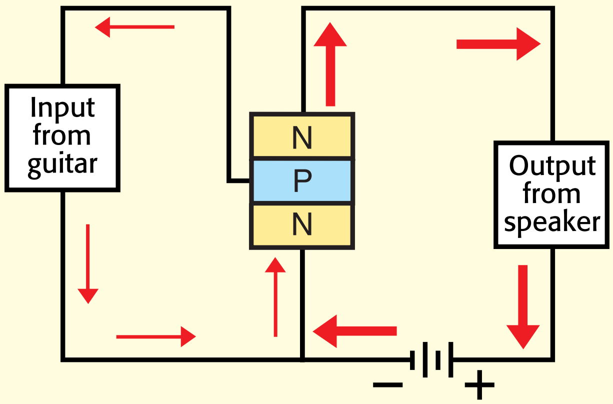


17 **Making Comparisons** Using what you know about the differences between analog signals and digital signals, compare the sound from a record player to the sound from a CD player.

18 **Making Comparisons** What do Morse code and digital signals have in common?

INTERPRETING GRAPHICS

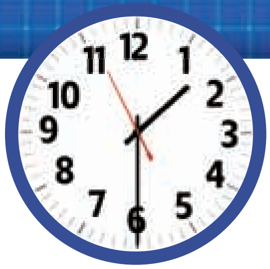
The diagram below shows a circuit that contains an NPN transistor. The red arrows represent electric current. Use the diagram below to answer the questions that follow.



19 The transistor is acting as an amplifier in the circuit. What is being amplified in the circuit?

20 Compare the electric current in the left side of the circuit with the electric current in the right side of the circuit.

21 Compare the sound from the speaker with the sound from the guitar.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The first televisions hit the market in the 1940s. At about $625 each, they were too expensive for most families to afford. Although the sets were large and bulky, the screens were small, and images were fuzzy and in black and white. Today's televisions have bigger screens and sharper pictures—in full color. Modern televisions are also generally less expensive. A typical television today costs less than half what it cost in the 1940s, and that cost is not accounting for inflation. Many modern televisions are cable ready and have remote controls. You can buy televisions with built-in DVD or videotape players. You could even install theater-quality surround sound. But even these improvements may seem out of date in 20 years.

1. Which of the following can be inferred from the passage?

- **A** Color movies are better than black-and-white movies.
- **B** In the 1940s, television sets did not have remote controls.
- **C** Today's televisions are not much better than the TVs made in the 1940s.
- **D** Televisions are much more expensive today than they were in the past.

2. Which of the following statements is a fact in the passage?

- **F** The first television sets had small screens with fuzzy, black-and-white images.
- **G** Televisions with built-in videotape players are very expensive.
- **H** Television screens are too large.
- **I** Although televisions are improving, the quality of TV programming is getting worse.

Passage 2 One of the first electronic communication devices was the telegraph, which was invented in the 1830s. The telegraph used an electric current to send messages between two distant places linked by wires. Telegraph operators sent messages in Morse code, which uses combinations of short taps and long taps to represent numbers and letters. When operators tapped the telegraph key, this closed a circuit, causing "clicks" at the receiving end of the telegraph. Although telegraphs are not used much today, they were an important step in the development of electronic <u>telecommunication</u>.

1. What is the meaning of the word *telecommunication* in this passage?

- **A** using telephones to communicate
- **B** sending messages to someone within hearing distance
- **C** trying to decipher codes without a key
- **D** communicating with someone over a long distance

2. What happens first when an operator sends a telegraph message?

- **F** A circuit opens and closes with the pattern of short and long taps.
- **G** There are short and long clicks on the receiving end.
- **H** The operator taps the telegraph key with a pattern of short and long taps.
- **I** The message is deciphered and interpreted by the receiver.

INTERPRETING GRAPHICS

The table below gives the cost of parts to build your own personal computer. Use the table below to answer the questions that follow.

Cost of Computer Parts

Part	Cost
Case	\$50–\$200
Power supply (300–400 W)	\$30–\$50
CPU (1.7–2.26 GHz)	\$80–\$250
Cooling equipment (may come with case)	\$0–\$50
Motherboard	\$50–\$200
RAM (256–512 MB)	\$50–\$150
Floppy drive	\$20
Hard drive (60–100 GB)	\$80–\$125
CD-ROM drive or DVD-ROM drive or CD-RW/DVD combo	\$35–\$120
Video card	\$40–\$175
Sound card (may be optional)	\$0–\$200
Speakers	\$10–\$150
Microphone (optional)	\$0–\$50
Keyboard and mouse	\$50–\$80
Monitor	\$200–\$600

1. Which of the following items is optional when building a computer?
- **A** a CPU
- **B** a hard drive
- **C** RAM
- **D** a microphone

2. What is the total cost to purchase the most expensive CPU, the most expensive motherboard, and the least expensive monitor?
- **F** \$330
- **G** \$650
- **H** \$730
- **I** \$1,050

MATH

Read each question below, and choose the best answer.

1. A plasma television is 15 cm thick. What is this value in inches? (1 in. = 2.5 cm)
- **A** 6 in.
- **B** 12 in.
- **C** 17.5 in.
- **D** 37.5 in.

2. The radius of a compact disc is about 6 cm. What is the approximate area of a compact disc? (Estimate the value of π to be 3.)
- **F** 36 cm
- **G** 36 cm^2
- **H** 108 cm
- **I** 108 cm^2

3. When sound is recorded digitally onto a CD, the sound waves are converted to electric current. The current is sampled about 44,000 times per second to make a digital signal. About how many samples would be taken in 1 min?
- **A** 733
- **B** 264,000
- **C** 733,000
- **D** 2,640,000

4. The first general-purpose computer, ENIAC, was made of 18,000 vacuum tubes. ENIAC used about 180,000 W of power. About how much power was consumed by each vacuum tube?
- **F** 0.1 W
- **G** 1.8 W
- **H** 10 W
- **I** 18 W

Science in Action

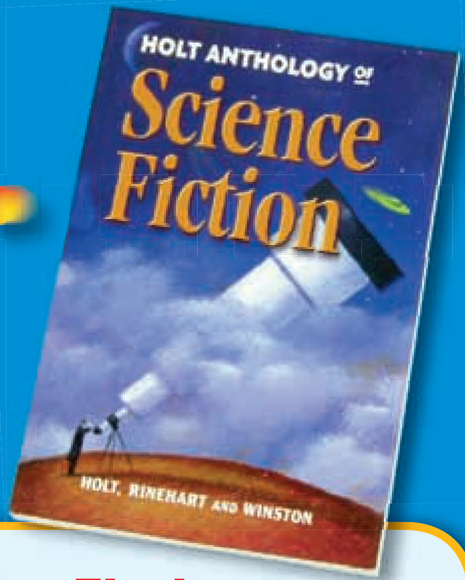
Science, Technology, and Society

Wearable Computers

Today's thin, portable laptop computers are extremely tiny compared to the first general-purpose computer, ENIAC, which filled an entire room. But today's laptops may look bulky next to the computers of tomorrow. In the future, you might wear your computer! A wearable computer is always with you, like clothing or eyeglasses. It is easy to operate. You can even use it while moving around. You might use a wearable computer to take notes in class, look up a phone number, check e-mail, or browse the Internet. These computers are already being used today by a number of companies. As the technology evolves, wearable computers will become even easier to use and more advanced in the types of tasks they perform.

Math ACTIVITY

One wearable computer that is available today can operate from 0°C to 50°C. You can convert temperature measurements from Celsius to Fahrenheit with this equation: Fahrenheit temperature = (9/5 × Celsius temperature) + 32. What is the operating range of this computer in degrees Fahrenheit?



Science Fiction

"There Will Come Soft Rains" by Ray Bradbury

Ticktock, seven o'clock, time to get up, seven o'clock. The voice clock in the living room sent out the wake-up message, gently calling to the family to get up and begin their new day. A few minutes later, the automatic stove in the kitchen began the family breakfast. A soft rain was falling outside, so the weather box by the front door suggested that raincoats were necessary today.

But no family sounds come from the house. The house goes on talking to itself as if it were keeping itself company. Why doesn't anyone answer? Find out when you read Ray Bradbury's "There Will Come Soft Rains" in the *Holt Anthology of Science Fiction*.

Language Arts ACTIVITY

WRITING SKILL The story described above takes place in 2026. The author has imagined how the future world might be. Write a short story about how you think life will be different in the year 2050.

Agnes Riley

Computer Technician Some people take it for granted how smoothly a computer works—until it breaks down. When that happens, you may need to call in an expert, such as Agnes Riley. Agnes is a computer technician from Budapest, Hungary. When a computer isn't working properly, she will take it apart, find the problem, and fix it.

Many people go to school to learn about computer repair, but Agnes taught herself. In Hungary, the company she worked for had a set of old, run-down computers. Agnes started experimenting, trying to repair them. The more she tinkered, the more she learned.

When Agnes moved to New York City in 1999, she wanted to become a computer technician. She started out as a computer salesperson. Eventually, she got the technician training materials. Her earlier experimenting and her studying paid off. She passed the exam to become a licensed technician. Agnes enjoys solving problems and likes helping people. If you are the same type of person, you might want to become a computer technician, too!

Social Studies ACTIVITY

WRITING SKILL Agnes Riley is from Budapest, Hungary. What might you see if you visited Budapest? Do some research to find out, and then design a travel brochure to encourage tourists to visit the city. You might include information about local points of interest or Budapest's history.

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Current Science

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UNIT 5

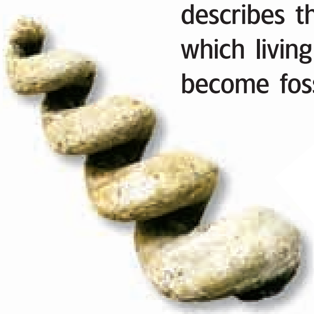
TIMELINE

The Dynamic Earth

The ground beneath your feet is a treasure-trove of interesting materials, some of which are very valuable. Secrets of Earth's history are also hidden within the ground's depths. In this unit, you will learn some of the ways that scientists study this dynamic planet. This timeline shows some of the events that have occurred through human history as scientists have come to understand more about our planet.

1669

Nicolaus Steno accurately describes the process by which living organisms become fossils.



1904

Roald Amundsen determines the position of the magnetic north pole.

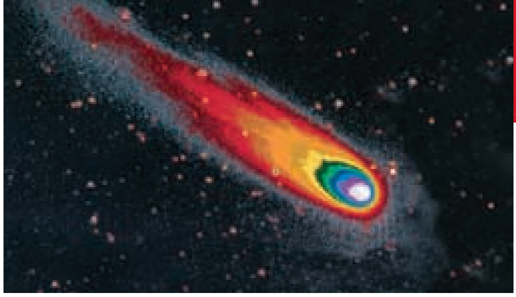
1922

Roy Chapman Andrews discovers fossilized dinosaur eggs in the Gobi Desert. They are the first such eggs to be found.

fossilized dinosaur eggs in the Gobi Desert

1962

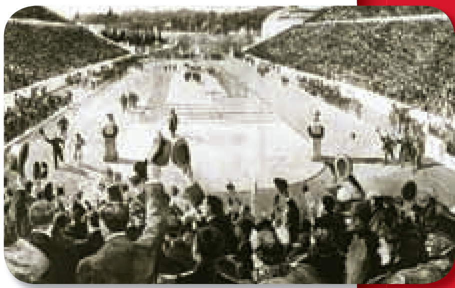
By reaching an altitude of over 95 km, the *X-15* becomes the first fixed-wing plane to reach space.



1758
Halley's comet makes a reappearance, which confirms Edmond Halley's 1705 prediction. The comet reappeared 16 years after Halley's death.

1799
The Rosetta stone is discovered in Egypt. It enables scholars to decipher Egyptian hieroglyphics.

1896
The first modern Olympic Games are held in Athens, Greece.



1943
The volcano Paricutín grows more than 200 m tall during its first two weeks of eruption.

Paricutín Volcano

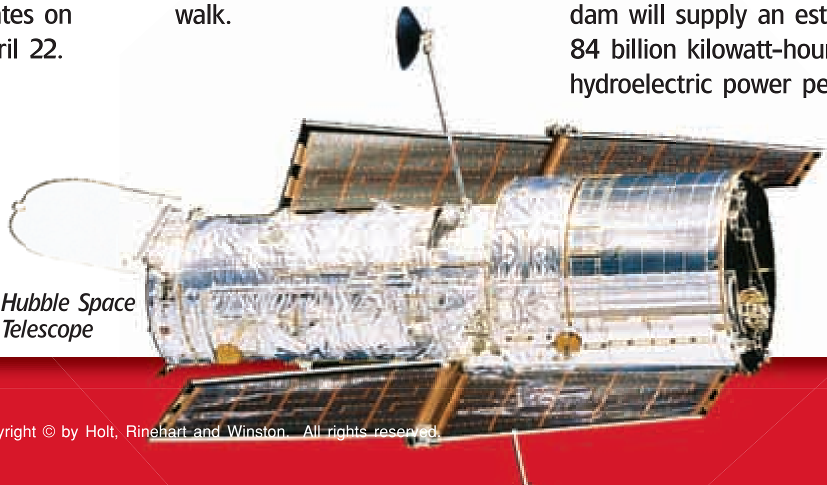
1960
The first weather satellite, *TIROS I*, is launched by the United States.

1970
The first Earth Day is celebrated in the United States on April 22.

1990
The Hubble Space Telescope is launched into orbit. Three years later, faulty optics are repaired during a space walk.

1994
China begins construction of Three Gorges Dam, the world's largest dam. Designed to control the Yangtze River, the dam will supply an estimated 84 billion kilowatt-hours of hydroelectric power per year.

2002
A new order of insects—*Mantophasmatodea*—is found both preserved in 45 million-year-old amber and living in southern Africa.



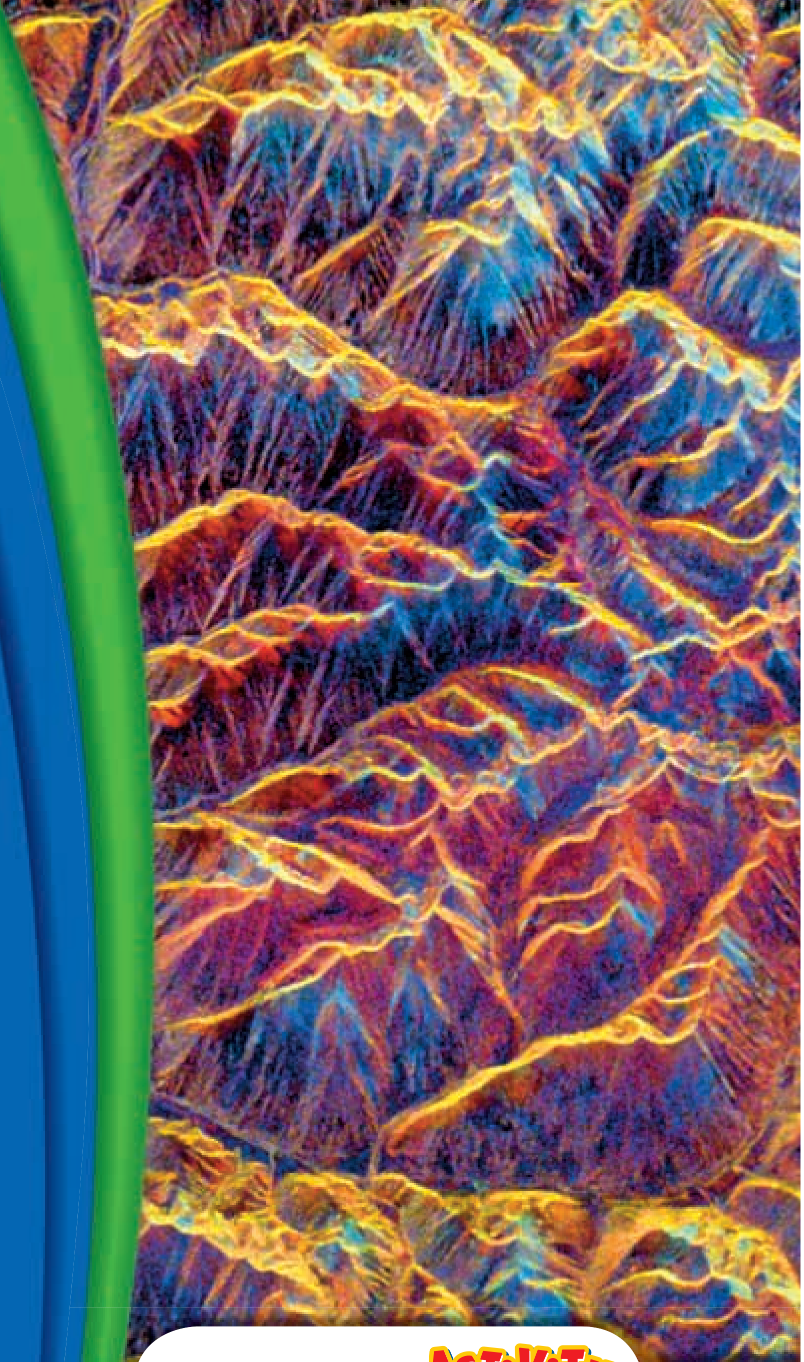
Hubble Space Telescope

14

Maps as Models of the Earth

About the PHOTO

No ordinary camera took this picture! In fact, a camera wasn't used at all. This image is a radar image of a mountainous area of Tibet. It was taken from the space shuttle. Radar imaging is a method that scientists use to map areas of the Earth from far above the Earth's surface.

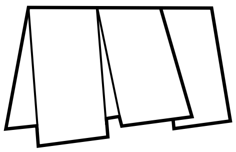


PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "Cylindrical projection," "Conical projection," and "Azimuthal projection." As you read the chapter, write information you learn about each category under the appropriate flap.



START-UP ACTIVITY

Follow the Yellow Brick Road

In this activity, you will not only learn how to read a map but you will also make a map that someone else can read.

Procedure

1. Use a **computer drawing program or colored pencils and paper** to draw a map that shows how to get from your classroom to another place in your school, such as the gym. Make sure you include enough information for someone unfamiliar with your school to find his or her way.
2. After you finish drawing your map, switch maps with a partner. Examine your classmate's map, and try to figure out where the map is leading you.

Analysis

1. Is your map an accurate picture of your school? Explain your answer.
2. What could you do to make your map better? What are some limitations of your map?
3. Compare your map with your partner's map. How are your maps alike? How are they different?

SECTION 1

You Are Here

Have you ever noticed the curve of the Earth's surface? You probably haven't. When you walk across the Earth, it does not appear to be curved. It looks flat.

Over time, ideas about Earth's shape have changed. Maps reflected how people saw the world and what technology was available. A **map** is a representation of the features of a physical body such as Earth. If you look at Ptolemy's (TAHL uh meez) world map from the second century, as shown in **Figure 1,** you might not know what you are looking at. Today, satellites give us more-accurate images of the Earth. In this section, you will learn how early scientists knew Earth was round long before pictures from space were taken. You will also learn how to find location and direction on Earth's surface.

READING WARM-UP

Objectives

- Explain how a magnetic compass can be used to find directions on Earth.
- Explain the difference between true north and magnetic north.
- Compare latitude and longitude.
- Explain how latitude and longitude is used to locate places on Earth.

Terms to Learn

map, true north, magnetic declination, latitude, equator, longitude, prime meridian

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

What Does Earth Really Look Like?

The Greeks thought of Earth as a sphere almost 2,000 years before Christopher Columbus made his voyage in 1492. The observation that a ship sinks below the horizon as it sails into the distance supported the idea of a spherical Earth. If Earth were flat, the ship would not sink below the horizon.

Eratosthenes (ER uh TAHS thuh NEEZ), a Greek mathematician, wanted to know the size of Earth. In about 240 BCE, he calculated Earth's circumference using math and observations of the sun. There were no satellites or computers back then. We now know his calculation was wrong by only 6,250 km!

map a representation of the features of a physical body such as Earth

Figure 1 *This map shows what explorers thought the world looked like 1,800 years ago.*

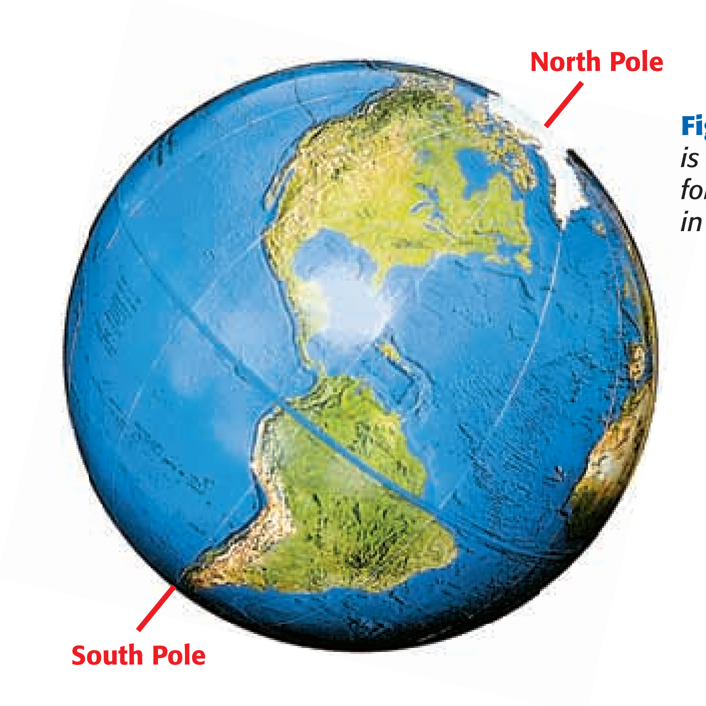


Figure 2 *The North Pole is a good reference point for describing locations in North America.*

SCHOOL to HOME

WRITING SKILL **Columbus's Voyage**

Did Christopher Columbus discover that Earth was a sphere only after he completed his voyage in 1492? Or did he know before he left? With a parent, use the Internet or the library to find out more information about Columbus's voyage. Then, write a paragraph describing what you learned.

ACTIVITY

Finding Direction on Earth

When giving directions to your home, you might name a landmark, such as a grocery store, as a reference point. A *reference point* is a fixed place on the Earth's surface from which direction and location can be described.

The Earth is spherical, so it has no top, bottom, or sides for people to use as reference points for determining locations on its surface. However, the Earth does rotate, or spin, on its axis. The Earth's axis is an imaginary line that runs through the Earth. At either end of the axis is a geographic pole. The North and South Poles are used as reference points when describing direction and location on the Earth, as shown in **Figure 2.**

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

Cardinal Directions

A reference point alone will not help you give good directions. You will need to be able to describe how to get to your home from the reference point. You will need to use the directions north, south, east, and west. These directions are called *cardinal directions*. Using cardinal directions is much more precise than saying "Turn left," "Go straight," or "Turn right." So, you may tell a friend to walk a block north of the gas station to get to your home. To use cardinal directions properly, you will need a compass, shown in **Figure 3.**

Figure 3 *A compass shows the cardinal directions north, south, east and west, as well as combinations of these directions.*

Using a Compass

A magnetic compass will show you which direction is north. A *compass* is a tool that uses the natural magnetism of the Earth to show direction. A compass needle points to the magnetic north pole. Earth has two different sets of poles—the geographic poles and the magnetic poles, as shown in **Figure 4.**

True North and Magnetic Declination

Remember that the Earth's geographic poles are on either end of the Earth's axis. Earth has its own magnetic field, which produces magnetic poles. Earth's magnetic poles are not lined up exactly with Earth's axis. So, there is a difference between the locations of Earth's magnetic and geographic poles. **True north** is the direction to the geographic North Pole. When using a compass, you need to make a correction for the difference between the geographic North Pole and the magnetic north pole. The angle of correction is called **magnetic declination.**

true north the direction to the geographic North Pole

magnetic declination the difference between the magnetic north and the true north

Reading Check **What is true north?**

Figure 4 *Unlike the geographic poles, which are always in the same place, the magnetic poles have changed location throughout the history of the Earth.*

Quick Lab

Making a Compass

1. Do this lab outside. Carefully rub a **steel sewing needle** against a **magnet** in the same direction 40 times.
2. Float a **1 cm × 3 cm piece of tissue paper** in a **bowl of water.**
3. Place the needle in the center of the tissue paper.
4. Compare your compass with a **regular compass.** Are both compasses pointing in the same direction?
5. How would you improve your compass?

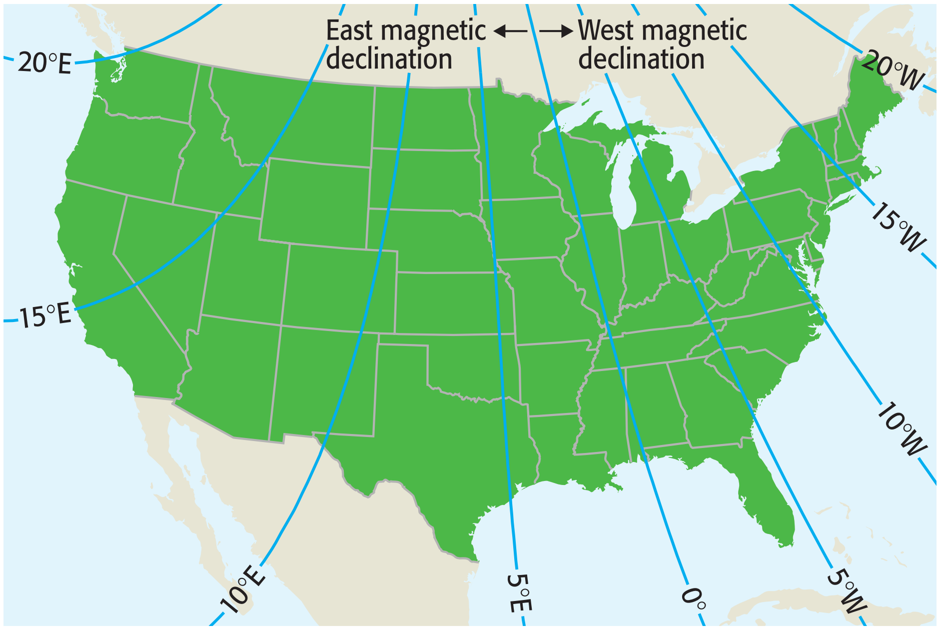


Figure 5 *The blue lines on the map connect points that have the same magnetic declination.*

Using Magnetic Declination

Magnetic declination is measured in degrees east or west of true north. Magnetic declination has been determined for different points on the Earth's surface. Once you know the declination for your area, you can use a compass to determine true north. This correction is like the correction you would make to the handlebars of a bike with a bent front wheel. You have to turn the handlebars a certain amount to make the bicycle go straight. **Figure 5** shows a map of the magnetic declination of the United States. What is the approximate magnetic declination of your city or town?

latitude the distance north or south from the equator; expressed in degrees

equator the imaginary circle halfway between the poles that divides the Earth into the Northern and Southern Hemispheres

Finding Locations on the Earth

All of the houses and buildings in your neighborhood have addresses that give their location. But how would you find the location of something such as a city or an island? These places can be given an "address" using *latitude* and *longitude*. Latitude and longitude are shown by intersecting lines on a globe or map that allow you to find exact locations.

Latitude

Imaginary lines drawn around the Earth parallel to the equator are called lines of latitude, or *parallels*. **Latitude** is the distance north or south from the equator. Latitude is expressed in degrees, as shown in **Figure 6.** The **equator** is a circle halfway between the North and South Poles that divides the Earth into the Northern and Southern Hemispheres. The equator represents 0° latitude. The North Pole is 90° north latitude, and the South Pole is 90° south latitude.

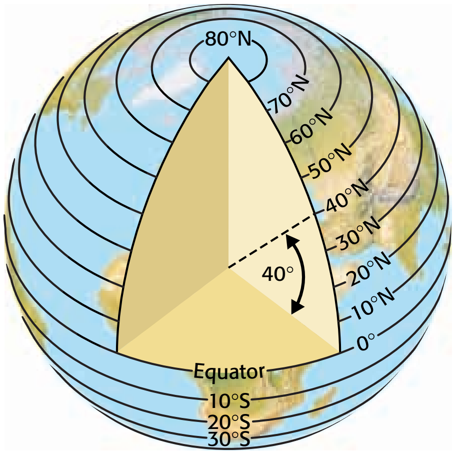


Figure 6 *Degrees latitude are a measure of the angle made by the equator and the location on the Earth's surface, as measured from the center of the Earth.*

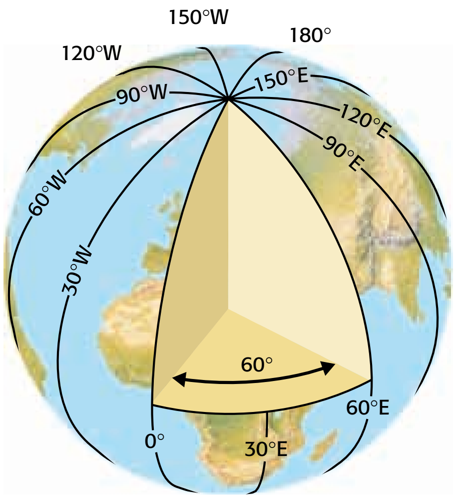


Figure 7 *Degrees longitude are a measure of the angle made by the prime meridian and the location on the Earth's surface, as measured from the center of the Earth.*

Longitude

Lines of longitude, or *meridians*, are imaginary lines that pass through both poles. **Longitude** is the distance east and west from the prime meridian. Like latitude, longitude is expressed in degrees, as shown in **Figure 7.** The **prime meridian** is the line that represents 0° longitude. Unlike lines of latitude, lines of longitude are not parallel. Lines of longitude touch at the poles and are farthest apart at the equator.

Unlike the equator, the prime meridian does not completely circle the globe. The prime meridian runs from the North Pole through Greenwich, England, to the South Pole. The 180° meridian lies on the opposite side of the Earth from the prime meridian. Together, the prime meridian and the 180° meridian divide the Earth into two equal halves—the Eastern and Western Hemispheres. East lines of longitude are found east of the prime meridian, between 0° and 180° longitude. West lines of longitude are found west of the prime meridian, between 0° and 180° longitude.

longitude the distance east and west from the prime meridian; expressed in degrees

prime meridian the meridian, or line of longitude, that is designated as 0° longitude

Using Latitude and Longitude

Points on the Earth's surface can be located by using latitude and longitude. Lines of latitude and lines of longitude cross and form a grid system on globes and maps. This grid system can be used to find locations north or south of the equator and east or west of the prime meridian.

Figure 8 shows you how latitude and longitude can be used to find the location of your state capital. First, locate the star representing your state capital on the appropriate map. Then, use the lines of latitude and longitude closest to your state capital to estimate its approximate latitude and longitude.

Reading Check **Which set of imaginary lines are referred to as meridians: lines of latitude or lines of longitude?**

CONNECTION TO Social Studies

Global Addresses You can find the location of any place on Earth by finding the coordinates of the place, or latitude and longitude, on a globe or a map. Using a globe or an atlas, find the coordinates of the following cities:

New York, New York	Madrid, Spain
Sao Paulo, Brazil	Paris, France
Sydney, Australia	Cairo, Egypt

Then, find the latitude and longitude coordinates of your own city. Can you find another city that shares the same latitude as your city? Can you find another city that shares the same longitude?

ACTIVITY

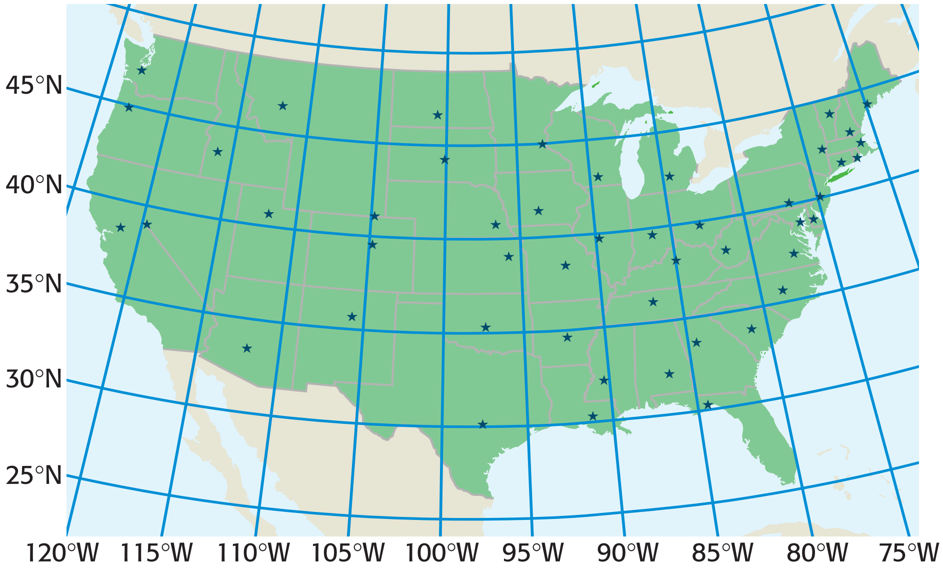


Figure 8 *The grid pattern formed by lines of latitude and longitude allows you to pinpoint any location on the Earth's surface.*

SECTION Review

Summary

- Magnetic compasses are used to find direction on Earth's surface. A compass needle points to the magnetic north pole.
- True north is the direction to the geographic North Pole, which never changes. The magnetic north pole may change over time. Magnetic declination is the difference between true north and magnetic north.
- Latitude and longitude help you find locations on a map or a globe. Lines of latitude run east and west. Lines of longitude run north and south through the poles. These lines cross and form a grid system on globes and maps.

Using Key Terms

1. Use each of the following terms in a separate sentence: *latitude, longitude, equator,* and *prime meridian.*
2. In your own words, write a definition for the term *true north.*

Understanding Key Ideas

3. The geographic poles are
   a. used as reference points when describing direction and location on Earth.
   b. formed because of the Earth's magnetic field.
   c. at either end of the Earth's axis.
   d. Both (a) and (c)
4. How are lines of latitude and lines of longitude alike? How are they different?
5. How can you use a magnetic compass to find directions on Earth?
6. What is the difference between true north and magnetic north?
7. How do lines of latitude and longitude help you find locations on the Earth's surface?

Math Skills

8. The distance between 40°N latitude and 41°N latitude is 69 mi. What is this distance in km? (Hint: 1 km = 0.621 mi)

Critical Thinking

9. **Applying Concepts** While exploring the attic, you find a treasure map. The map shows that the treasure is buried at 97°N and 188°E. Explain why this location is incorrect.
10. **Making Inferences** When using a compass to explore an area, why do you need to know an area's magnetic declination?

SECTION 2

Mapping the Earth's Surface

What do a teddy bear, a toy airplane, and a plastic doll have in common besides being toys? They are all models that represent real things.

READING WARM-UP

Objectives

- Explain why maps of the Earth show distortion.
- Describe four types of map projections.
- Identify five pieces of information that should be shown on a map.

Terms to Learn

cylindrical projection
conic projection
azimuthal projection

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Scientists also use models to represent real things, but their models are not toys. Globes and maps are examples of models that scientists use to study the Earth's surface.

Because a globe is a sphere, a globe is the most accurate model of the Earth. A globe accurately shows the sizes and shapes of the continents and oceans in relation to one another. But a globe is not always the best model to use when studying the Earth's surface. A globe is too small to show many details, such as roads and rivers. It is much easier to show details on maps. But how do you show the Earth's curved surface on a flat surface? Keep reading to find out.

A Flat Sphere?

A map is a flat representation of the Earth's curved surface. However, when you move information from a curved surface to a flat surface, you lose some accuracy. Changes called *distortions* happen in the shapes and sizes of landmasses and oceans on maps. Direction and distance can also be distorted. Consider the example of the orange peel shown in **Figure 1.**

Reading Check **What are distortions on maps?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *If you remove and flatten the peel from an orange, the peel will stretch and tear. Notice how shapes as well as distances between points on the peel are distorted.*

Map Projections

Mapmakers use map projections to move the image of Earth's curved surface onto a flat surface. No map projection of Earth can show the surface of a sphere in the correct proportions. All flat maps have distortion. However, a map showing a smaller area, such as a city, has less distortion than a map showing a larger area, such as the world.

To understand how map projections are made, think of Earth as a translucent globe that has a light inside. If you hold a piece of paper against the globe, shadows appear on the paper. These shadows show marks on the globe, such as continents, oceans, and lines of latitude and longitude. The way the paper is held against the globe determines the kind of map projection that is made. The most common map projections are based on three shapes—cylinders, cones, and planes.

Cylindrical Projection

A map projection that is made when the contents of the globe are moved onto a cylinder of paper is called a **cylindrical projection** (suh LIN dri kuhl proh JEK shuhn). The most common cylindrical projection is called a *Mercator projection* (muhr KAYT uhr proh JEK shuhn). The Mercator projection shows the globe's latitude and longitude lines as straight lines. Equal amounts of space are used between longitude lines. Latitude lines are spaced farther apart north and south of the equator. Because of the spacing, areas near the poles look wider and longer on the map than they look on the globe. In **Figure 2,** Greenland appears almost as large as Africa!

cylindrical projection a map projection that is made by moving the surface features of the globe onto a cylinder

Figure 2 **Cylindrical Projection**

This cylindrical projection is a Mercator projection. It is accurate near the equator but distorts areas near the North and South Poles.

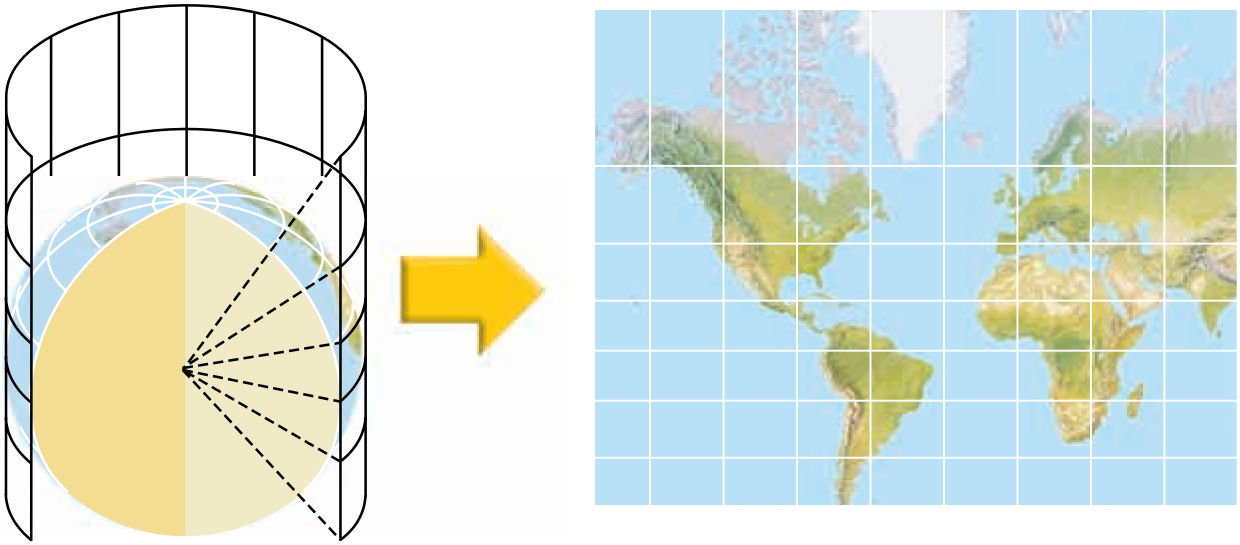
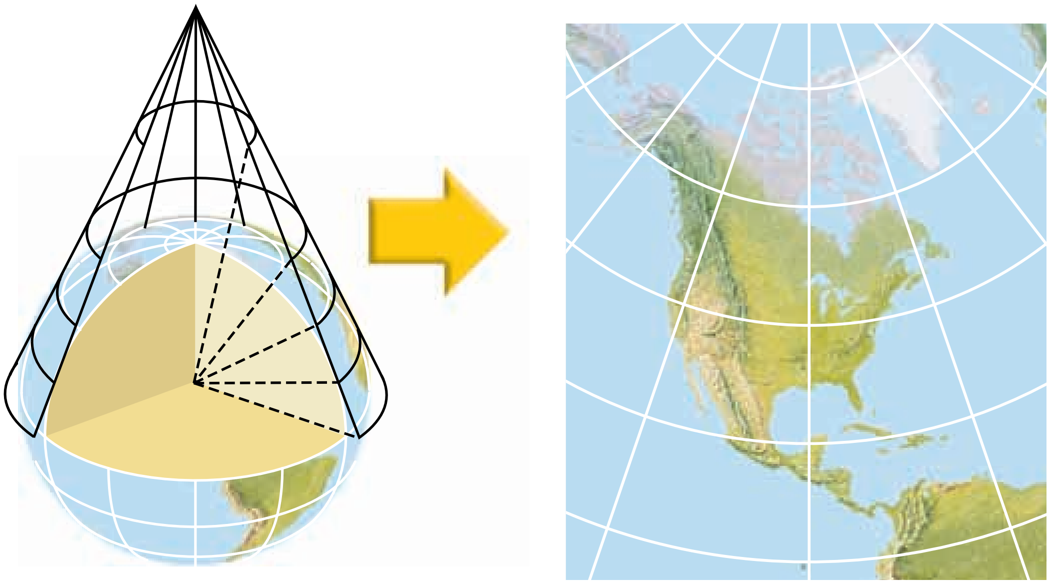


Figure 3 Conic Projection

A series of conic projections can be used to map a large area. Because each cone touches the globe at a different latitude, conic projections reduce distortion.



Conic Projection

conic projection a map projection that is made by moving the surface features of the globe onto a cone

A map projection that is made by moving the contents of the globe onto a cone is a **conic projection,** shown in **Figure 3.** This cone is then unrolled to form a flat plane.

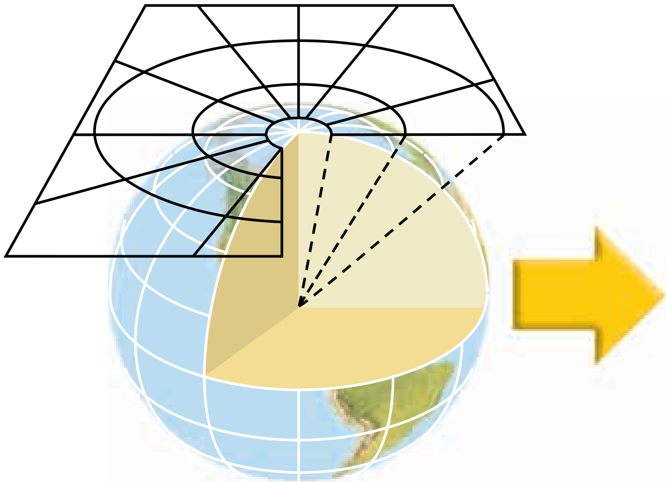
The cone touches the globe at each line of longitude but at only one line of latitude. There is no distortion along the line of latitude where the globe touches the cone. Areas near this line of latitude are distorted less than other areas are. Because the cone touches many lines of longitude and only one line of latitude, conic projections are best for mapping large masses of land that have more area east to west. For example, a conic projection is often used to map the United States.

CONNECTION TO Social Studies

WRITING SKILL **Mapmaking and Ship Navigation** Gerardus Mercator is the cartographer (or mapmaker) who developed the Mercator projection. During his career as a mathematician and cartographer, Mercator worked hard to produce maps of many parts of Europe, including Great Britain. He also produced a terrestrial globe and a celestial globe. Use the library or the Internet to research Mercator. How did his mapmaking skills help ship navigators in the 1500s? Write a paragraph describing what you learn.

Figure 4 **Azimuthal Projection**

On this azimuthal projection, distortion increases as you move farther from the North Pole.



Azimuthal Projection

An **azimuthal projection** (AZ uh MYOOTH uhl proh JEK shuhn) is a map projection that is made by moving the contents of the globe onto a flat plane. Look at **Figure 4.** On an azimuthal projection, the plane touches the globe at only one point. There is little distortion at this point of contact. The point of contact for an azimuthal projection is usually one of the poles. However, distortion of direction, distance, and shape increases as you move away from the point of contact. Azimuthal projections are most often used to map areas of the globe that are near the North and South Poles.

azimuthal projection a map projection that is made by moving the surface features of the globe onto a plane

Reading Check **How are azimuthal and conic projections alike? How are they different?**

Equal-Area Projection

A map projection that shows the area between the latitude and longitude lines the same size as that area on a globe is called an *equal-area projection*. Equal-area projections can be made by using cylindrical, conic, or azimuthal projections. Equal-area projections are often used to map large land areas, such as continents. The shapes of the continents and oceans are distorted on equal-area projections. But because the scale used on equal-area projections is constant throughout the map, this type of projection is good for determining distance on a map. **Figure 5** is an example of an equal-area projection.

Figure 5 *Equal-area projections are useful for determining distance on a map.*

Information Shown on Maps

Regardless of the kind of map you are reading, the map should contain the information shown in **Figure 6.** This information includes a title, a compass rose, a scale, a legend, and a date. Unfortunately, not all maps have all this information. The more of this information a map has, the more reliable the map is.

Reading Check **What information should every map have?**

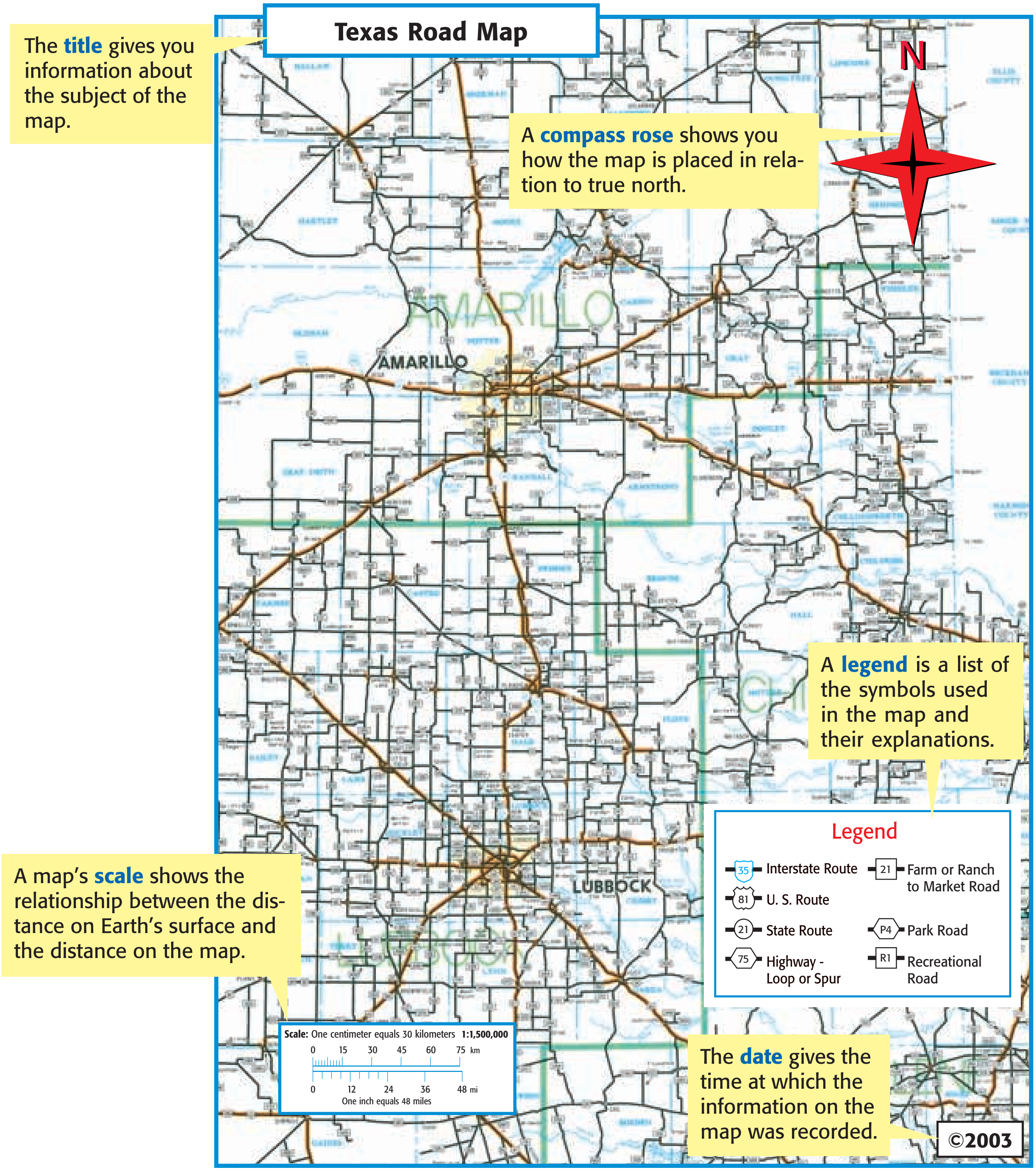


Figure 6 *This Texas road map includes all of the information that a map should contain.*

Mapping North Carolina

Maps of North Carolina date back at least to the 1770s. Many of these early maps showed the locations of towns, settlements, courthouses, forts, roads, and swamps. An early map of North Carolina is shown in **Figure 7.** Beginning in the mid-1880s, maps were made of the North Carolina coastline. These maps showed water depths and harbors. During the late 1800s, many maps showing railroads and county lines were produced. Today, the North Carolina Department of Transportation publishes a state highway map, and the North Carolina Geological Survey publishes geologic and mineral resource maps.

Figure 7 *This map of North Carolina was published in Philadelphia in 1822.*

SECTION Review

Summary

- When a curved surface is converted into a flat surface, distortion occurs.
- Three main types of projections are used to show Earth's surface on a flat map: cylindrical, conic, and azimuthal projections.
- Equal-area maps are used to show the area of a piece of land in relation to the area of other landmasses and oceans.
- Maps should contain a title, a scale, a legend, a compass rose, and a date.

Using Key Terms

1. Use each of the following terms in a single sentence: *cylindrical projection, azimuthal projection,* and *conic projection.*

Understanding Key Ideas

2. Which of the following map projections is most often used to map the United States?
   - **a.** cylindrical projection
   - **b.** conic projection
   - **c.** azimuthal projection
   - **d.** equal-area projection
3. Explain why maps of the Earth show distortion.
4. Describe four types of map projections.
5. Why is equal-area projection useful for determining distance on a map?
6. List five pieces of information found on maps. Explain how each piece of information is important in reading a map.

Math Skills

7. On a map scale, if 1 cm = 30 km, how many centimeters are equal to 315 km?

Critical Thinking

8. **Analyzing Ideas** Imagine that you are a mapmaker. You have been asked to map a landmass that has more area from east to west than from north to south. What type of map projection would you use to map the area? Explain.
9. **Making Inferences** Imagine that you are looking at a map of North America. Would this map have a large scale or a small scale? Would a map of your city have a large scale or a small scale? Explain.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Mapmaking
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SECTION 3

Modern Mapmaking

For centuries mapmakers relied on the observations of explorers to make maps. Today, mapmakers have far more technologically advanced tools for mapmaking.

READING WARM-UP

Objectives

- Identify four uses for the global positioning system.
- Define the term electromagnetic spectrum.
- Explain how reflectance curves are useful to scientists.
- Explain the difference between active and passive remote-sensing systems.
- Identify three types of predictions that can be made using remote-sensing images.

Terms to Learn

remote sensing
global positioning system (GPS)
electromagnetic spectrum

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Many of today's maps are made by a process called *remote sensing*. **Remote sensing** is a way to collect information about objects without physically being in contact with these objects. Most of the maps are made from photographs taken by mapping cameras that are mounted on low-flying aircraft. However, mapmakers are beginning to rely on more-sophisticated instruments that are carried on both aircraft and Earth-orbiting satellites.

Global Positioning System

The **global positioning system** (GPS) can help you find your location on Earth. GPS is a network of 24 orbiting satellites that continuously send radio signals to receivers on Earth. These ground receivers collect and convert the radio signals into estimated position information, such as the approximate latitude, longitude, and elevation of a given location on the Earth's surface.

GPS has a number of applications. Mapmakers use GPS to verify the location of boundary lines between countries and states. Airplane pilots and sailors use GPS for navigation. State agencies and businesses use GPS for mapping and environmental planning. Many new cars have GPS units that show location information to the driver. Some GPS units, such as the unit shown in **Figure 1,** are small enough to wear on your wrist.

remote sensing the process of gathering and analyzing information about an object without physically being in touch with the object

global positioning system a network of satellites that orbit the Earth to measure positions on the Earth's surface (abbreviation, GPS)

Figure 1 *This portable GPS unit provides its wearer with his or her approximate position on Earth's surface.*

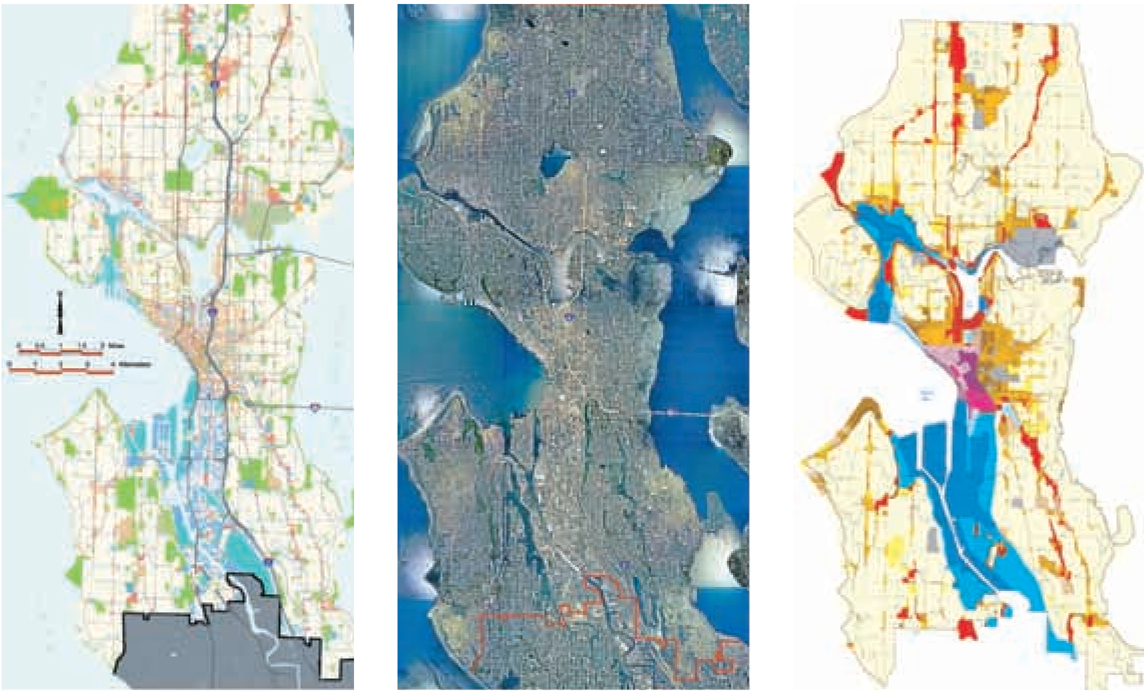


Figure 2 *The images above show the location of sewer lines, roads, and parks in Seattle, Washington. Each image represents a layer of information.*

Geographic Information Systems

Mapmakers now use geographic information systems to acquire, store, analyze, and display geographic information. A *geographic information system*, or GIS, is a computerized system that allows a user to select different types of information about an area from a single database. Each piece of information is displayed on a layer, such as a layer that shows the roads in an area. Users turn on and off layers to access the information they need. **Figure 2** shows three different GIS images of Seattle.

Reading Check **Explain how information is stored using GIS.** (*See the Appendix for answers to Reading Checks.*)

Remote Sensing

You know that remote sensing is the process of gathering and analyzing information about an object without being in physical contact with that object. And you know that the most common method of remote sensing is to photograph the Earth's surface from an aircraft by using a mapping camera. However, more-sophisticated technology for remote sensing is commonly carried on aircraft and satellites. These instruments include radar and sensors that measure electromagnetic radiation that is reflected or emitted from different objects on the Earth's surface—or even on the surfaces of other planets! Data that are collected are processed in computers and are used to make a remote-sensing image of the object that has been sensed remotely. But how do these data travel to the remote sensor? The data travel through *electromagnetic waves*.

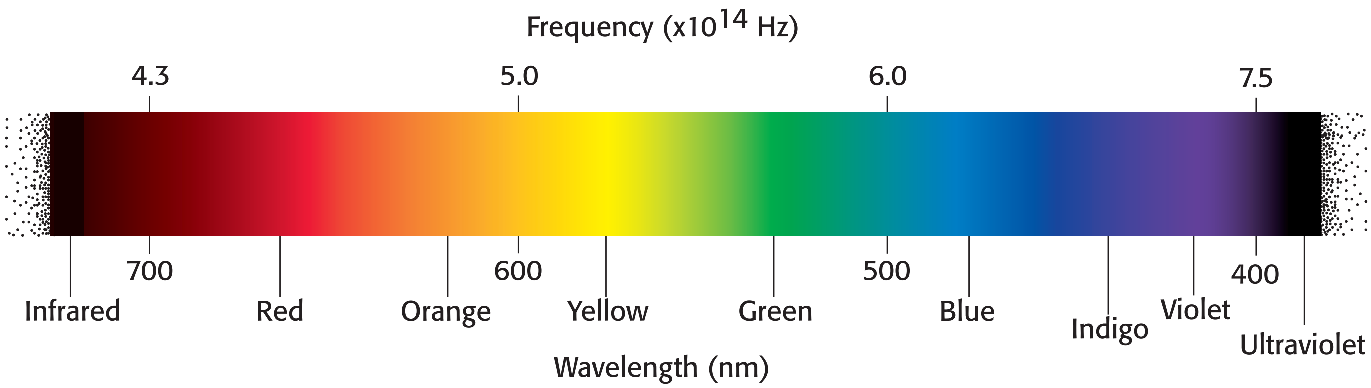


Figure 3 *Most remote sensors detect the infrared and visible light regions of the electromagnetic spectrum. As seen in the figure above, infrared waves have longer wavelengths and lower frequencies than visible light does.*

The Electromagnetic Spectrum

An electromagnetic (EM) wave is a wave that can travel through empty space or matter and that consists of changing electric and magnetic fields. Light is an electromagnetic wave. The entire range of EM waves is called the **electromagnetic spectrum.** Electromagnetic radiation that is reflected or emitted by objects on the Earth's surface is most often measured in wavelengths in the infrared and visible regions of the electromagnetic spectrum, shown in **Figure 3**. Infrared waves have longer wavelengths and lower frequencies than visible light. Almost all objects, including you, give off infrared waves. Visible light waves make up a narrow region of the electromagnetic spectrum. They have longer wavelengths and lower frequencies than ultraviolet light does. The colors humans see are made up of combinations of reflected wavelengths of visible light.

electromagnetic spectrum all of the frequencies or wavelengths of electromagnetic radiation

Emission and Reflection

Electromagnetic radiation is continuously given off, or emitted, by all objects. The temperature of the object determines the amount and type of electromagnetic radiation emitted. Hot objects emit electromagnetic radiation with shorter wavelengths than cooler objects do. Because objects continuously emit electromagnetic radiation, remote sensing that uses emitted electromagnetic radiation can be done day and night.

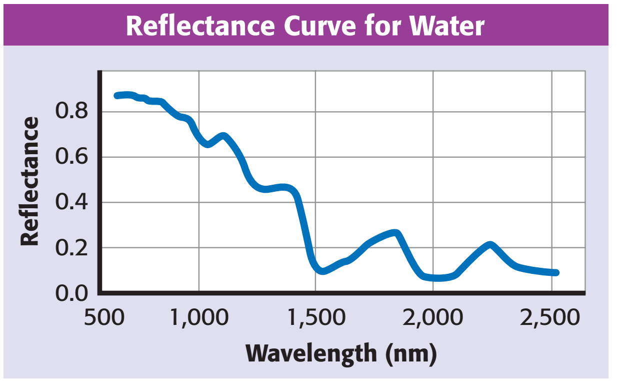
Reflection happens when electromagnetic radiation bounces off an object. Electromagnetic radiation that is emitted by the sun is reflected from the Earth's atmosphere and from objects on the Earth's surface. Because reflection depends on radiation from the sun, remote sensing that measures reflected electromagnetic radiation must be done during daylight hours.

Reading Check **Briefly define *emission* and *reflection*.**

Reflectance Curves

Scientists must know the wavelengths at which an object reflects electromagnetic radiation so that they can use the reflected radiation as a remote-sensing tool. To select the wavelengths that will be most useful in producing a remote-sensing image, scientists make graphs that show wavelengths that an object reflects most in the electromagnetic spectrum. These graphs are known as *reflectance curves*. **Figure 4** shows a reflectance curve for water. From the graph, a scientist can tell that water strongly reflects electromagnetic radiation in the blue and green regions of visible light. So, let's say scientists want to map bodies of freshwater on the Earth's surface. The scientists would want their sensors to detect reflected electromagnetic radiation in blue and green wavelengths.

Figure 4 *Scientists use reflectance curves to determine the wavelengths of electromagnetic radiation that can best be used to remote sense an object.*



Passive Remote Sensing

A *passive remote-sensing system,* illustrated in **Figure 5,** measures the amount of electromagnetic radiation that is emitted or reflected by objects on the Earth's surface. In a passive remote-sensing system, sensors record the amount of electromagnetic radiation that is emitted or reflected by objects at different wavelengths. Sensors are carried by satellites or aircraft. The data that are collected about an object by a satellite-mounted sensor are recorded as a series of numbers. This series of numbers is sent from a satellite to a ground station. At the ground station, these data are processed in a computer. The computer converts the data into a satellite image of Earth's surface.

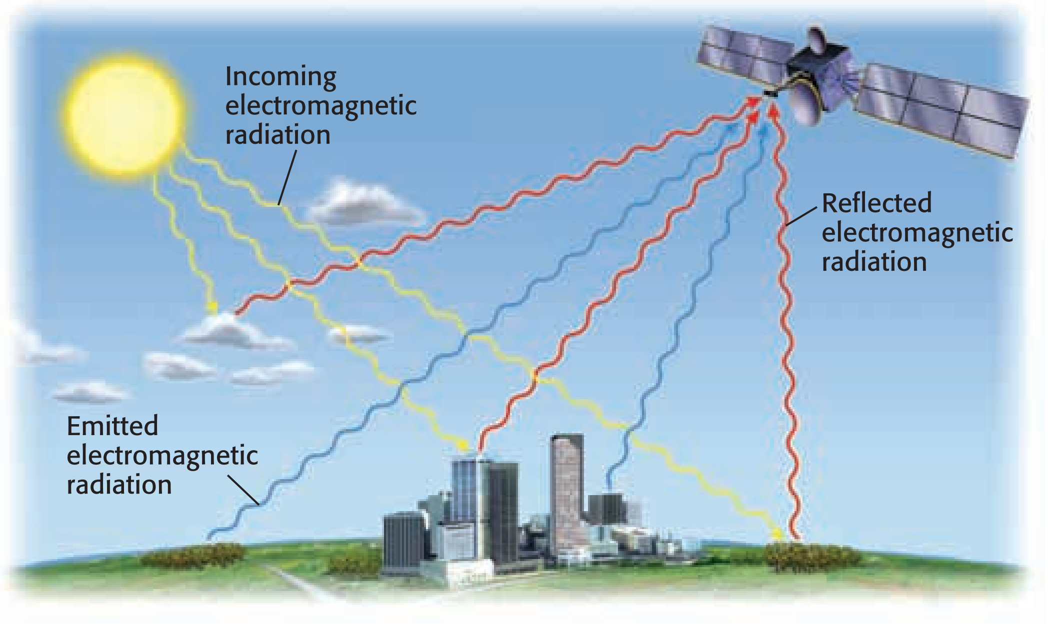


Figure 5 *In a passive remote-sensing system, sensors aboard a satellite or aircraft measure the amount of electromagnetic radiation that is emitted or reflected by objects on the Earth's surface.*

Active Remote Sensing

An *active remote-sensing system* produces its own electromagnetic radiation and measures the strength of the return signal. In an active remote-sensing system, radar that is carried by an aircraft or satellite is used to collect data from which an image of the Earth's surface is produced. Sensors used in a passive remote-sensing system measure reflected electromagnetic radiation in the infrared and visible regions of the electromagnetic spectrum. But radar collects data in the microwave region of wavelengths. Microwaves have longer wavelengths and lower frequencies than infrared waves and visible light waves do. An advantage to using microwaves for remote sensing is that they can penetrate clouds and water. Because of this ability, radar has been used to map areas that are difficult to study, including areas covered by clouds and dense forests.

Reading Check **What are two important differences between active and passive remote-sensing systems?**

Figure 6 *This image, taken using the satellite-mounted Sea-viewing Wide Field-of-view Sensor (SeaWiFS), shows sediment (in light blue) that was stirred up by Hurricane Floyd along the North Carolina coast in September 1999.*

Using Maps to Make Predictions

Data obtained by remote sensing can be used in a number of ways. One important use of remote-sensing images is to show how areas of the Earth's surface are changing. To show surface changes, remote-sensing information is combined with information on maps and with observations made on the ground. The information gathered on the ground is known as *ground truth*. This combination of information allows scientists to monitor changes that take place on Earth's surface. It also allows scientists to make predictions about changes that may take place in the future. For example, future predictions can include the way in which cities will grow, how resources can best be managed, and how land will be used. **Figure 6** is a remote-sensing image that shows how Hurricane Floyd stirred up sediment along the North Carolina coast in 1999. Images such as this can be used to predict how future storms that strike the North Carolina coast may cause shoreline erosion.

Mapping Other Planets

Radar on the *Magellan* spacecraft mapped most of the surface of Venus. The data obtained from the remote sensing of Venus show that lava flows and volcanoes are common features on the surface of the planet.

A map of Mars, shown in **Figure 7,** was made from data collected by the Mars Global Survey. These data show that the southern hemisphere of Mars is about 5 km higher than the northern hemisphere. This difference in elevation indicates that the flow of water on Mars, early in Mars's history, happened mainly in the northern hemisphere.

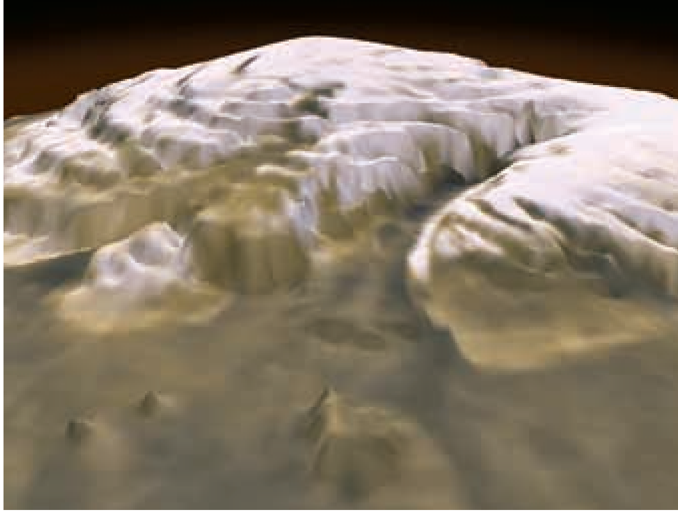


Figure 7 *This is an image of the north pole of Mars. This image will allow scientists to measure the volume of the polar icecap.*

SECTION Review

Summary

- The global positioning system provides position information for a given location on Earth.
- The entire range of electromagnetic waves is called the *electromagnetic spectrum*.
- Remote sensing is the process of gathering and analyzing information about an object without being in physical contact with that object. Remote-sensing systems measure the electromagnetic radiation that is emitted or reflected by objects on the Earth's surface.
- Scientists use remote-sensing images to study changes taking place on Earth's surface.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *remote sensing, global positioning system,* and *electromagnetic spectrum.*

Understanding Key Ideas

2. Which of the following systems provides position information for a given location on Earth?
   a. GIS
   b. GPS
   c. passive remote sensing
   d. active remote sensing
3. Identify four uses for the global positioning system.
4. Define the term *electromagnetic spectrum*.
5. What is the difference between reflected and emitted electromagnetic radiation?
6. What is a reflectance curve?
7. Why is radar useful when investigating areas that are covered in clouds?
8. Describe three ways in which the data obtained from remote-sensing images can be used.

Math Skills

9. If a sensor mounted on a satellite scans an area that is 30 m × 30 m, how many square meters is the sensor scanning?

Critical Thinking

10. **Analyzing Ideas** If you were going to measure the temperature of seawater at the ocean's surface, would you most likely sense reflected or emitted electromagnetic radiation? Explain.
11. **Applying Concepts** Why was the planet Venus most likely imaged using radar rather than using sensors?

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SECTION 4

Topographic Maps

Imagine you are going on a camping trip in the wilderness. To be prepared, you want to take a compass and a map. But what kind of map should you take? Because there won't be any roads in the wilderness, you can forget about a road map. Instead, you will need a topographic map.

READING WARM-UP

Objectives

- Explain how contour lines show elevation and landforms on a map.
- Explain how the relief of an area determines the contour interval used on a map.
- List the rules of contour lines.

Terms to Learn

topographic map
elevation
contour line
contour interval
relief
index contour

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

A **topographic map** (TAHP uh GRAF ik MAP) is a map that shows surface features, or topography (tuh PAHG ruh fee), of the Earth. Topographic maps show both natural features, such as rivers, lakes, and mountains, and features made by humans, such as cities, roads, and bridges. Topographic maps also show elevation. **Elevation** is the height of an object above sea level. The elevation at sea level is 0. In this section, you will learn how to read a topographic map.

topographic map a map that shows the surface features of Earth

elevation the height of an object above sea level

contour line a line that connects points of equal elevation

Elements of Elevation

The United States Geological Survey (USGS), a federal government agency, has made topographic maps for most of the United States. These maps show elevation in feet (ft) rather than in meters, the SI unit usually used by scientists.

Contour Lines

On a topographic map, *contour lines* are used to show elevation. **Contour lines** are lines that connect points of equal elevation. For example, one contour line would connect points on a map that have an elevation of 100 ft. Another line would connect points on a map that have an elevation of 200 ft. **Figure 1** illustrates how contour lines appear on a map.

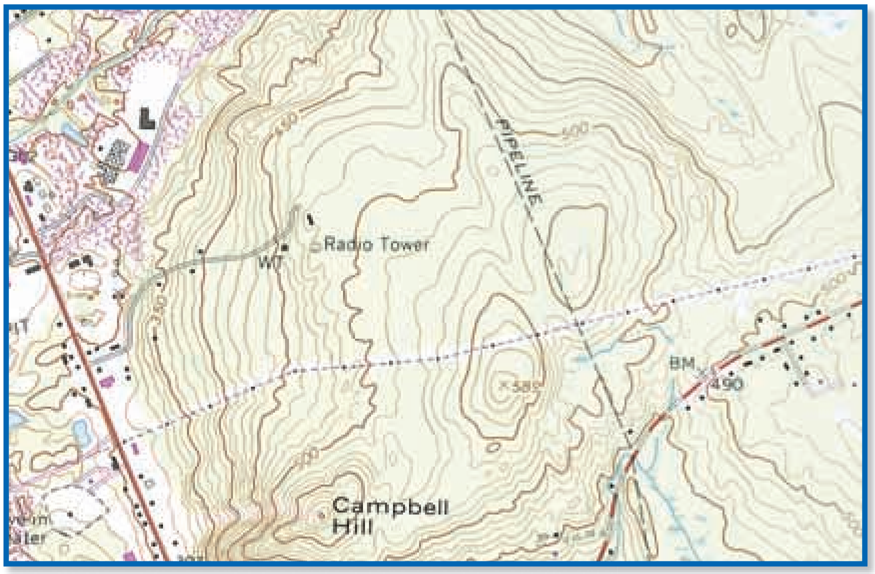


Figure 1 *Because contour lines connect points of equal elevation, the shape of the contour lines reflects the shape of the land.*

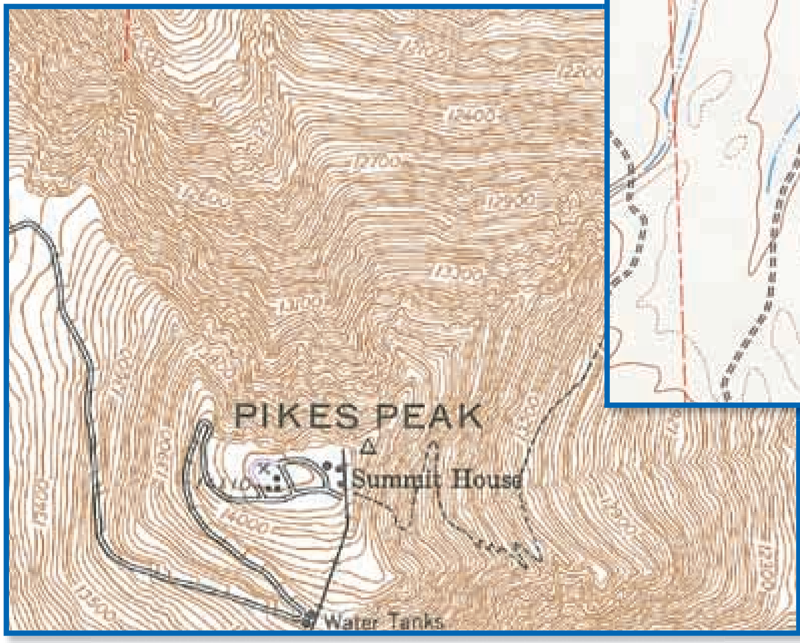


Figure 2 *The portion of the topographic map on the left shows Pikes Peak in Colorado. The map above shows a valley in Big Bend Ranch State Park in Texas.*

Contour Interval

The difference in elevation between one contour line and the next is called the **contour interval.** For example, a map with a contour interval of 20 ft would have contour lines every 20 ft of elevation change, such as 0 ft, 20 ft, 40 ft, and 60 ft. A mapmaker chooses a contour interval based on the area's relief. **Relief** is the difference in elevation between the highest and lowest points of the area being mapped. Because the relief of an area with mountains is large, the relief might be shown on a map using a large contour interval, such as 100 ft. However, a flat area has small relief and might be shown on a map by using a small contour interval, such as 10 ft.

The spacing of contour lines also indicates slope, as shown in **Figure 2.** Contour lines that are close together show a steep slope. Contour lines that are spaced far apart show a gentle slope.

Index Contour

On USGS topographic maps, an index contour is used to make reading the map easier. An **index contour** is a darker, heavier contour line that is usually every fifth line and that is labeled by elevation. Find an index contour on both of the topographic maps shown in **Figure 2.**

Reading Check **What is an index contour?** (*See the Appendix for answers to Reading Checks.*)

contour interval the difference in elevation between one contour line and the next

relief the variations in elevation of a land surface

index contour on a map, a darker, heavier contour line that is usually every fifth line and that indicates a change in elevation

CONNECTION TO Oceanography

Mapping the Ocean Floor
Oceanographers use topographic maps to map the topography of the ocean floor. Use the Internet or the library to find a topographic map of the ocean floor. How are maps of the ocean floor similar to maps of the continents? How are they different?

Reading a Topographic Map

Topographic maps, like other maps, use symbols to represent parts of the Earth's surface. **Figure 3** shows a USGS topographic map. The legend shows some of the symbols that represent features in topographic maps.

Colors are also used to represent features of Earth's surface. In general, buildings, roads, bridges, and railroads are black. Contour lines are brown. Major highways are red. Bodies of water, such as rivers, lakes, and oceans are blue. Cities and towns are pink, and wooded areas are green.

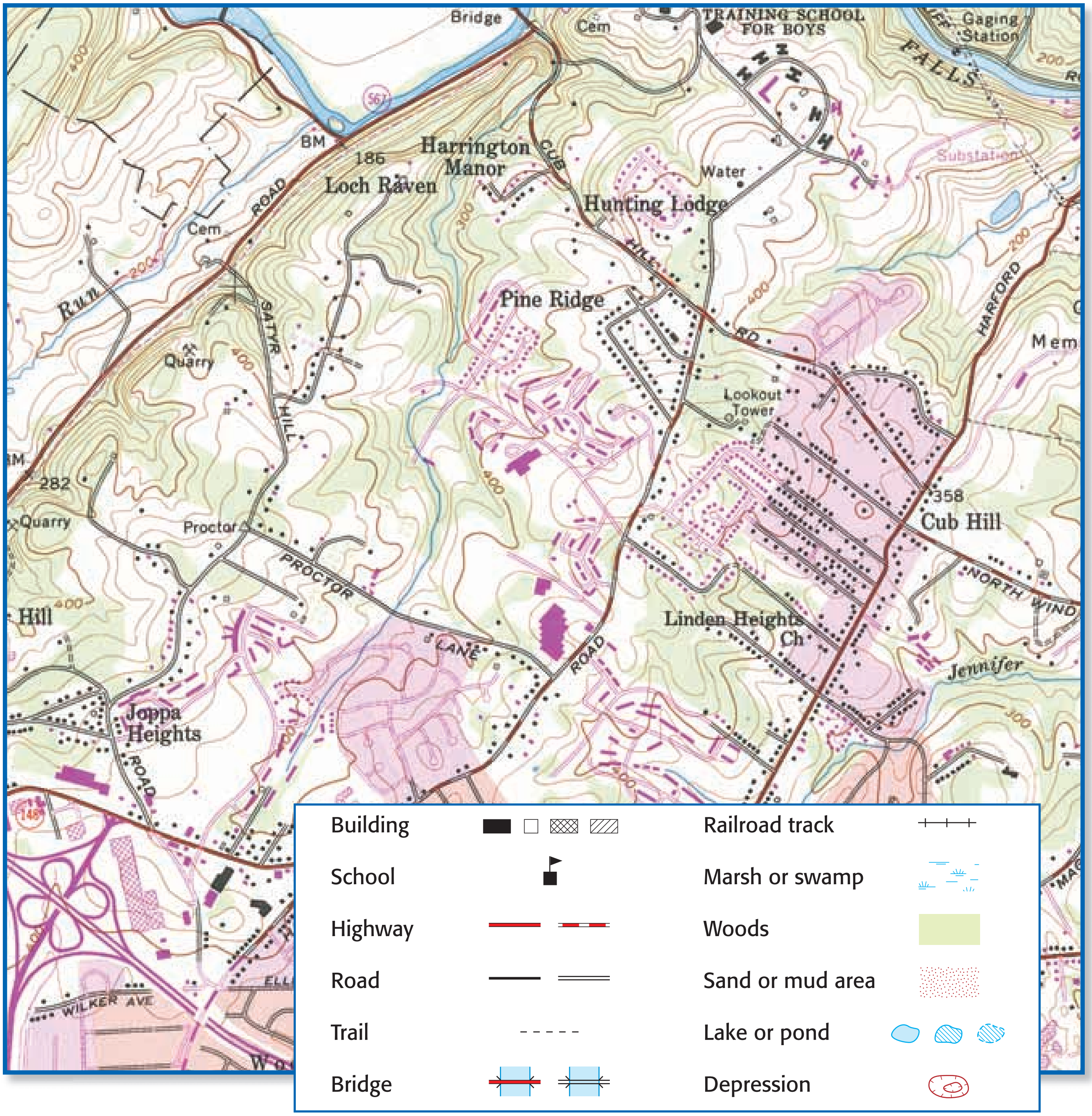


Figure 3 *All USGS topographic maps use the same symbols to show natural and human-made features.*

The Golden Rules of Contour Lines

Contour lines are the key to explaining the size and shape of landforms on a topographic map. Reading a topographic map takes training and practice. The following rules will help you understand how to read topographic maps:

- Contour lines never cross. All points along a contour line represent one elevation.
- The spacing of contour lines depends on slope characteristics. Contour lines that are close together show a steep slope. Contour lines that are far apart show a gentle slope.
- Contour lines that cross a valley or stream are V shaped. The V points toward the area of highest elevation. If a stream or river flows through the valley, the V points upstream.
- The tops of hills, mountains, and depressions are shown by closed circles. Depressions are marked with short, straight lines inside the circle that point downslope to the depression.

CONNECTION TO Environmental Science

Endangered Species State agencies, such as the Texas Parks and Wildlife Department, use topographic maps to mark where endangered plant and animal species are. By marking the location of the endangered plants and animals, these agencies can record and protect these places. Use the Internet or another source to find out if there is an agency in your state that tracks endangered species by using topographic maps.

SECTION Review

Summary

- Contour lines are used to show elevation and landforms by connecting points of equal elevation.
- The contour interval is determined by the relief of an area.
- Contour lines never cross. Contour lines that cross a valley or a stream are V shaped and point upstream. The tops of hills, mountains, and depressions are shown by closed circles.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *topographic map, contour interval,* and *relief*.

Understanding Key Ideas

2. An index contour
   a. is a heavier contour line that shows a change in elevation.
   b. points in the direction of higher elevation.
   c. indicates a depression.
   d. indicates a hill.
3. How do topographic maps represent the Earth's surface?
4. How does the relief of an area determine the contour interval used on a map?
5. What are the rules of contour lines?

Math Skills

6. The contour line at the base of a hill reads 90 ft. There are five contour lines between the base of the hill and the top of the hill. If the contour interval is 30 ft, what is the elevation of the highest contour line?

Critical Thinking

7. **Making Inferences** Why isn't the highest point on a hill represented by a contour line?

Using Scientific Methods

Skills Practice Lab

Round or Flat?

Eratosthenes thought of a way to measure the circumference of Earth. He came up with the idea when he read that a well in southern Egypt was entirely lit by the sun at noon once each year. He realized that to shine on the entire surface of the well water, the sun must be directly over the well. At the same time, in a city just north of the well, a tall monument cast a shadow. Thus, Eratosthenes reasoned that the sun could not be directly over both the monument and the well at noon on the same day. In this experiment, you will see how Eratosthenes' way of measuring works.

OBJECTIVES

Construct a tool to measure the circumference of the Earth.

Calculate the circumference of the Earth.

MATERIALS

- basketball
- books or notebooks (2)
- calculator (optional)
- clay, modeling
- flashlight or small lamp
- meterstick
- pencils, unsharpened (2)
- protractor
- ruler, metric
- string, 10 cm long
- tape, masking
- tape measure

SAFETY

Ask a Question

1. How could I use Eratosthenes' method of investigation to measure the size of the Earth?

Form a Hypothesis

2. Formulate a hypothesis that answers the question above. Record your hypothesis.

Test the Hypothesis

3. Set the basketball on a table. Place a book or notebook on either side of the basketball to hold the ball in place. The ball represents Earth.

4. Use modeling clay to attach a pencil to the "equator" of the ball so that the pencil points away from the ball.
5. Attach the second pencil to the ball at a point that is 5 cm above the first pencil. This second pencil should also point away from the ball.
6. Use a meterstick to measure 1 m away from the ball. Mark the 1 m position with masking tape. Label the position "Sun." Hold the flashlight so that its front edge is above the masking tape.
7. When your teacher turns out the lights, turn on your flashlight and point it so that the pencil on the equator does not cast a shadow. Ask a partner to hold the flashlight in this position. The second pencil should cast a shadow on the ball.
8. Tape one end of the string to the top of the second pencil. Hold the other end of the string against the ball at the far edge of the shadow. Make sure that the string is tight. But be careful not to pull the pencil over.
9. Use a protractor to measure the angle between the string and the pencil. Record this angle.
10. Use the following formula to calculate the experimental circumference of the ball.

$$\textit{Circumference} = \frac{360^\circ \times 5 \text{ cm}}{\text{angle between pencil and string}}$$

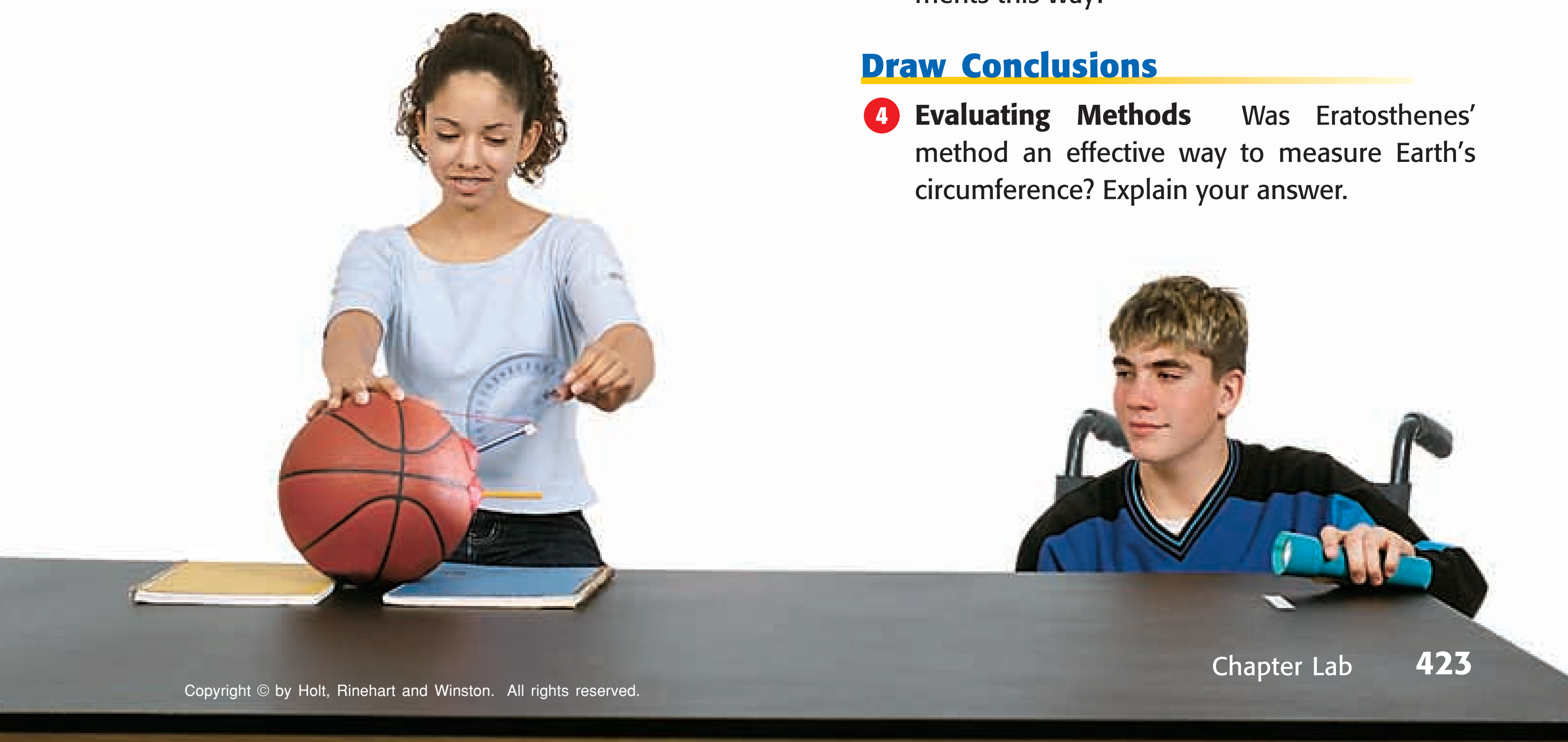
11. Record the experimental circumference you calculated in step 10. Wrap the tape measure around the ball's equator to measure the actual circumference of the ball. Record this circumference.

Analyze the Results

1. **Examining Data** Compare the experimental circumference with the actual circumference.
2. **Analyzing Data** What could have caused your experimental circumference to differ from the actual circumference?
3. **Analyzing Data** What are some of the advantages and disadvantages of taking measurements this way?

Draw Conclusions

4. **Evaluating Methods** Was Eratosthenes' method an effective way to measure Earth's circumference? Explain your answer.



Chapter Review

USING KEY TERMS

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

1. *true north* and *magnetic north*
2. *latitude* and *longitude*
3. *equator* and *prime meridian*
4. *cylindrical projection* and *azimuthal projection*
5. *contour interval* and *index contour*
6. *global positioning system* and *geographic information system*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. A point whose latitude is 0° is located on the
   - a. North Pole.
   - b. equator.
   - c. South Pole.
   - d. prime meridian.
8. The distance in degrees east or west of the prime meridian is
   - a. latitude.
   - b. declination.
   - c. longitude.
   - d. projection.
9. A system of 24 orbiting satellites is used in
   - a. GIS.
   - b. GPS.
   - c. passive remote sensing.
   - d. active remote sensing.
10. The most common map projections are based on three geometric shapes. Which of the following geometric shapes is NOT one of the three geometric shapes?
    - a. cylinder
    - b. square
    - c. cone
    - d. plane
11. A cylindrical projection is distorted near the
    - a. equator.
    - b. poles.
    - c. prime meridian.
    - d. date line.
12. What is the relationship between the distance on a map and the actual distance on Earth called?
    - a. legend
    - b. elevation
    - c. relief
    - d. scale
13. ___ is the height of an object above sea level.
    - a. Contour interval
    - b. Elevation
    - c. Declination
    - d. Index contour

Short Answer

14. List four methods that modern mapmakers use to make accurate maps.
15. Why is a map legend important?

16 Why does Greenland appear so large in relation to other landmasses on a map made using a cylindrical projection?

17 What is the function of contour lines on a topographic map?

18 How are reflectance curves useful to scientists?

19 Explain the difference between active and passive remote-sensing systems.

CRITICAL THINKING

20 **Concept Mapping** Use the following terms to create a concept map: *maps, legend, map projection, map parts, scale, cylinder, title, cone, plane, date,* and *compass rose.*

21 **Making Inferences** One of the important parts of a map is its date. Why is the date important?

22 **Analyzing Ideas** Why is it important for maps to have scales?

23 **Applying Concepts** Imagine that you are looking at a topographic map of the Grand Canyon. Would the contour lines be spaced close together or far apart? Explain your answer.

24 **Analyzing Processes** How would a GIS system help a team of engineers plan a new highway system for a city?

25 **Making Inferences** If you were stranded in a national park, what kind of map of the park would you want to have with you? Explain your answer.

INTERPRETING GRAPHICS

Use the topographic map below to answer the questions that follow.

26 What is the elevation change between two adjacent lines on this map?

27 What type of relief does this area have?

28 What surface features are shown on this map?

29 What is the elevation at the top of Ore Hill?

Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Scientists use models to represent things. Globes and maps are examples of models that scientists use to study Earth's surface.

Because a globe is a sphere, as Earth is, a globe is the most accurate model of Earth. A globe accurately shows the sizes and shapes of the continents and oceans in relation to one another. But a globe is not always the best model to use when studying Earth's surface. For example, a globe is too small to show a lot of detail, such as roads and rivers. It is much easier to show details on maps. Maps can show the whole Earth or parts of it.

1. According to the passage, how are a globe and a map alike?

A Both show a lot of detail.
B Both are used to study the size of Earth's oceans.
C Both are models used to the study Earth's surface.
D Both show one part of Earth.

2. How are a globe and Earth alike?

F Both are spheres.
G Both represent real things.
H Both are flat surfaces.
I Both are models.

3. According to the passage, examining a globe would help you answer which of the following questions?

A How many highways are in Michigan?
B Where are the streams in my state?
C Which continents border the Indian Ocean?
D What is the exact length of the Nile River?

Passage 2 The names of many geographic locations in the United States are rich in description and national history. Names such as Adirondack and Chesapeake come from Native American languages. Some names, such as New London, Baton Rouge, and San Francisco, reflect European naming traditions. Other names, such as Stone Mountain and Long Island, provide a description of the area. The mapping efforts in the United States that took place after the Civil War often led to multiple names for one location. But mapmakers and scientists needed consistent names of locations for their studies. In 1890, the U.S. Board on Geographic Names was formed. This board determines and maintains location names.

1. In the passage, what does *rich* mean?

A wealthy
B abundant
C incomplete
D thick

2. Which of the following statements is true?

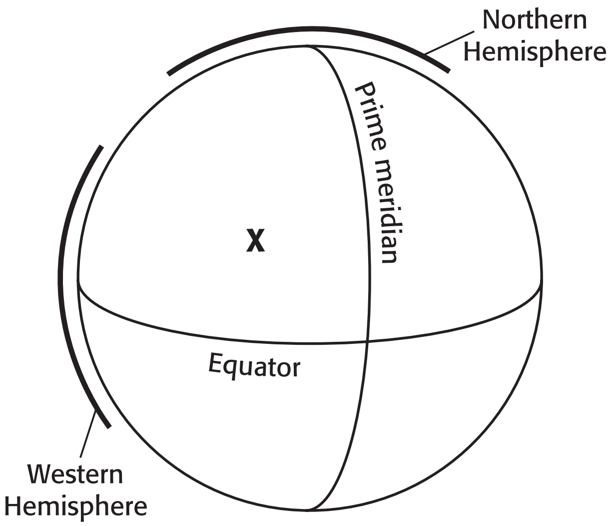
F Mapmakers enjoyed using multiple names for the same location.
G The U.S. Board on Geographic Names determines the name for an area.
H Names such as Baton Rouge and San Francisco describe the physical area.
I All geographic names came from Native American languages.

3. What can you infer from the passage?

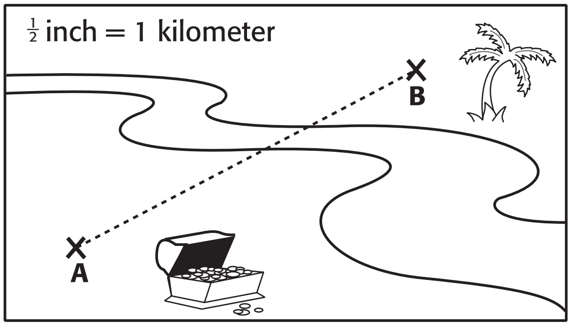
A Mapmakers name locations after themselves.
B Scientists used descriptions of the physical area as names for locations.
C The U.S. Board on Geographic Names now determines the names for locations.
D Today, many locations in the United States have several names.

INTERPRETING GRAPHICS

Use each figure below to answer the question that follows each figure.



1. An X shows the location of a field investigation study site. Which of the following pairs of terms accurately describes the location of the X on the map?
   A Northern Hemisphere; Western Hemisphere
   B Northern Hemisphere; Eastern Hemisphere
   C Southern Hemisphere; Eastern Hemisphere
   D Southern Hemisphere; Western Hemisphere



2. The map above shows the distance from point A to point B. According to this map, what is the actual distance from point A to point B?
   F 1 km
   G 2 km
   H 4 km
   I 6 km

MATH

Read each question below, and choose the best answer.

1. Greenland's area is approximately 2 million square kilometers. The area of Africa is approximately 15 times the area of Greenland. What is the approximate area of Africa?
   A 30 million square kilometers
   B 17 million square kilometers
   C 13 million square kilometers
   D 7.5 million square kilometers

2. A satellite is 264 km above Earth's surface. What is this measurement expressed in meters?
   F 264,000 m
   G 26,400 m
   H 2,640 m
   I 0.264 m

3. On a topographic map, every fifth contour line is a darker line, or *index contour*. How many index contours are there in a series of 50 contour lines?
   A 8
   B 9
   C 10
   D 11

4. Juan and Maria hike up a mountain. Maria is at an elevation of 4.3 km. Juan is at an elevation of 2.7 km. What is the difference between their elevations?
   F 1.6 km
   G 2.6 km
   H 6.0 km
   I 7.0 km

5. The North Pole is 90°N latitude. If you drew a line from the North Pole to the center of Earth and a line from a point on the equator to the center of Earth, what kind of angle would the two lines form at Earth's center?
   A acute
   B obtuse
   C equilateral
   D right

Science in Action

Scientific Discoveries

The Lost City of Ubar

According to legend, the city of Ubar was a prosperous ancient city. Ubar was most famous for its frankincense, a tree sap that had many uses. As Ubar was in its decline, however, something strange happened. The city disappeared! It was a great myth that Ubar was swallowed up by the desert. It wasn't until present-day scientists used information from a Shuttle Imaging Radar system aboard the space shuttle that this lost city was found! Using radar, scientists were able to "see" beneath the huge dunes of the desert, where they finally found the lost city of Ubar.

Roads appear as purple lines on this computer-generated remote-sensing image.

Science, Technology, and Society

Geocaching

Wouldn't it be exciting to go on a hunt for buried treasure? Thousands of people around the world participate in geocaching, which is an adventure game for GPS users. In this adventure game, individuals and groups of people put caches, or hidden treasures, in places all over the world. Once the cache is hidden, the coordinates of the cache's location are posted on the Internet. Then, geocaching teams compete to find the cache. Geocaching should only be attempted with parental supervision.

Language Arts ACTIVITY

Why was the word *geocaching* chosen for this adventure game? Use the Internet or another source to find the origin and meaning of the word *geocaching*.

Social Studies ACTIVITY

WRITING SKILL Ubar was once a very wealthy, magnificent city. Its riches were built on the frankincense trade. Research the history of frankincense, and write a paragraph describing how frankincense was used in ancient times and how it is used today.

People in Science

Matthew Henson

Arctic Explorer Matthew Henson was born in Maryland in 1866. His parents were freeborn sharecroppers. When Henson was a young boy, his parents died. He then went to look for work as a cabin boy on a ship. Several years later, Henson had traveled around the world and had become educated in the areas of geography, history, and mathematics. In 1898, Henson met U.S. Naval Lieutenant Robert E. Peary. Peary was the leader of Arctic expeditions between 1886 and 1909.

Peary asked Henson to accompany him as a navigator on several trips, including trips to Central America and Greenland. One of Peary's passions was to be the first person to reach the North Pole. It was Henson's vast knowledge of mathematics and carpentry that made Peary's trek to the North Pole possible. In 1909, Henson was the first person to reach the North Pole. Part of Henson's job as navigator was to drive ahead of the party and blaze the first trail. As a result, he often arrived ahead of everyone else. On April 6, 1909, Henson reached the approximate North Pole 45 minutes ahead of Peary. Upon his arrival, he exclaimed, "I think I'm the first man to sit on top of the world!"

Math Activity

On the last leg of their journey, Henson and Peary traveled 664.5 km in 16 days! On average, how far did Henson and Peary travel each day?

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Current Science

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15

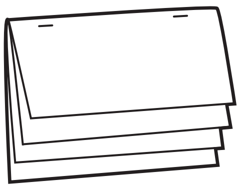
The Rock and Fossil Record

About the PHOTO

This extremely well preserved crocodile fossil has been out of water for 49 million years. Its skeleton was collected in an abandoned mine pit in Messel, Germany.

PRE-READING ACTIVITY

FOLDNOTES **Layered Book** Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Earth's history," "Relative dating," "Absolute dating," "Fossils," and "Geologic time." As you read the chapter, write information you learn about each category under the appropriate tab.



START-UP ACTIVITY

Making Fossils

How do scientists learn from fossils? In this activity, you will study “fossils” and identify the object that made each.

Procedure

1. You and three or four of your classmates will be given **several pieces** of **modeling clay** and a **paper sack** containing a few **small objects.**
2. Press each object firmly into a piece of clay. Try to leave a “fossil” imprint showing as much detail as possible.
3. After you have made an imprint of each object, exchange your model fossils with another group.
4. On a **sheet of paper,** describe the fossils you have received. List as many details as possible. What patterns and textures do you observe?
5. Work as a group to identify each fossil, and check your results. Were you right?

Analysis

1. What kinds of details were important in identifying your fossils? What kinds of details were not preserved in the imprints? For example, can you tell the materials from which the objects are made or their color?
2. Explain how scientists follow similar methods when studying fossils.

SECTION 1

Earth's Story and Those Who First Listened

How do mountains form? How is new rock created? How old is the Earth? Have you ever asked these questions? Nearly 250 years ago, a Scottish farmer and scientist named James Hutton did.

Searching for answers to his questions, Hutton spent more than 30 years studying rock formations in Scotland and England. His observations led to the foundation of modern geology.

READING WARM-UP

Objectives

- Compare uniformitarianism and catastrophism.
- Describe how the science of geology has changed over the past 200 years.
- Explain the role of paleontology in the study of Earth's history.

Terms to Learn

uniformitarianism
catastrophism
paleontology

READING STRATEGY

Reading Organizer As you read this section, make a table comparing uniformitarianism and catastrophism.

The Principle of Uniformitarianism

In 1788, James Hutton collected his notes and wrote *Theory of the Earth*. In *Theory of the Earth,* he stated that the key to understanding Earth's history was all around us. In other words, processes that we observe today—such as erosion and deposition—remain uniform, or do not change, over time. This assumption is now called uniformitarianism. **Uniformitarianism** is the idea that the same geologic processes shaping the Earth today have been at work throughout Earth's history. **Figure 1** shows how Hutton developed the idea of uniformitarianism.

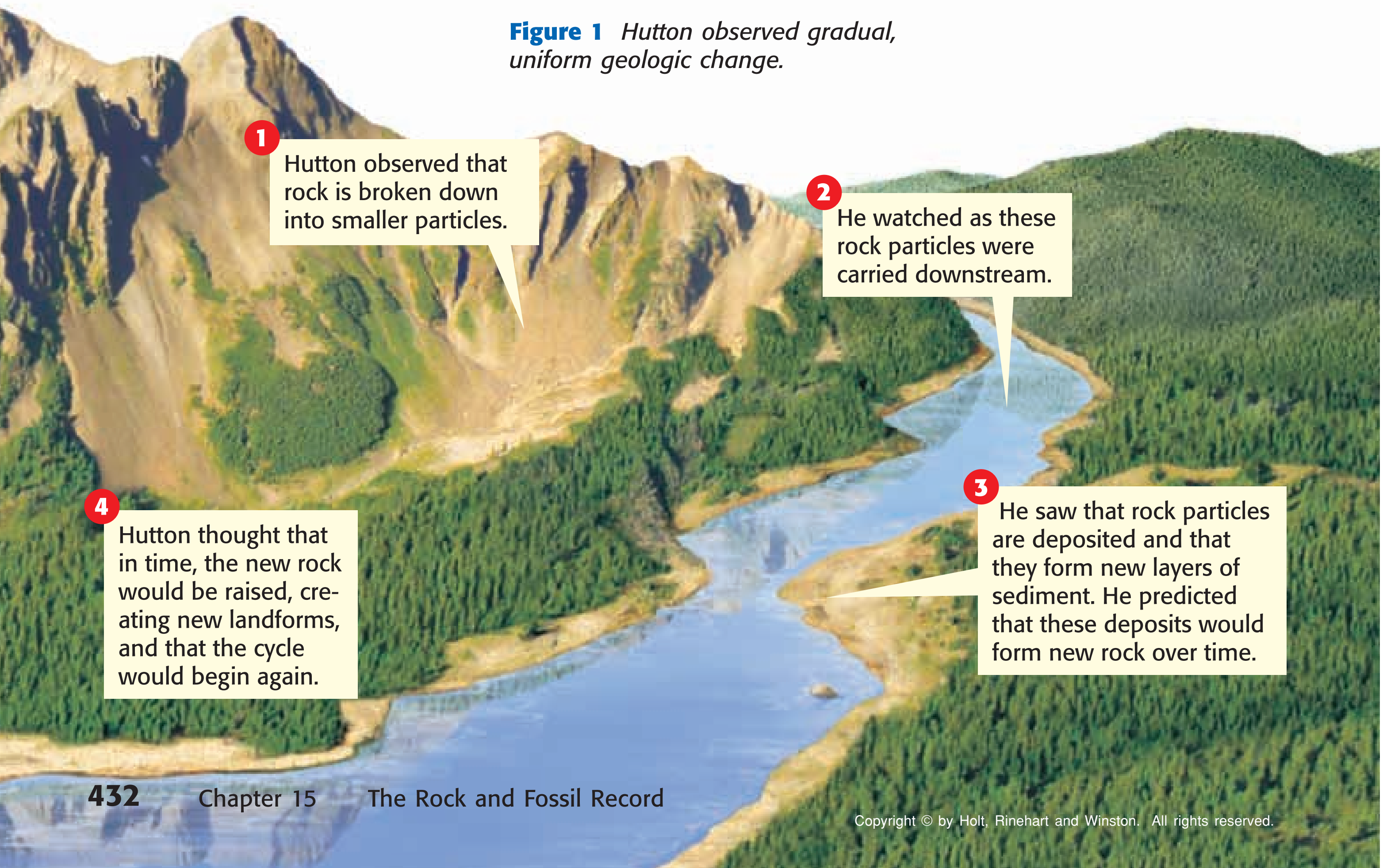


Figure 1 *Hutton observed gradual, uniform geologic change.*

Figure 2 *This photograph shows Siccar Point on the coast of Scotland. Siccar Point is one of the places where Hutton observed results of geologic processes that would lead him to form his principle of uniformitarianism.*

Uniformitarianism Versus Catastrophism

Hutton's theories sparked a scientific debate by suggesting that Earth was much older than previously thought. In Hutton's time, most people thought that Earth was only a few thousand years old. A few thousand years was not nearly enough time for the gradual geologic processes that Hutton described to have shaped our planet. The rocks that he observed at Siccar Point, shown in **Figure 2,** were deposited and folded, indicating a long geological history. To explain Earth's history, most scientists supported catastrophism. **Catastrophism** is the principle that states that all geologic change occurs suddenly. Supporters of catastrophism thought that Earth's features, such as its mountains, canyons, and seas, formed during rare, sudden events called *catastrophes*. These unpredictable events caused rapid geologic change over large areas—sometimes even globally.

uniformitarianism a principle that states that geologic processes that occurred in the past can be explained by current geologic processes

catastrophism a principle that states that geologic change occurs suddenly

Reading Check **According to catastrophists, what was the rate of geologic change?** (*See the Appendix for answers to Reading Checks.*)

A Victory for Uniformitarianism

Despite Hutton's work, catastrophism remained geology's guiding principle for decades. Only after the work of British geologist Charles Lyell did people seriously consider uniformitarianism as geology's guiding principle.

From 1830 to 1833, Lyell published three volumes, collectively titled *Principles of Geology,* in which he reintroduced uniformitarianism. Armed with Hutton's notes and new evidence of his own, Lyell successfully challenged the principle of catastrophism. Lyell saw no reason to doubt that major geologic change happened at the same rate in the past as it happens in the present—gradually.

CONNECTION TO Biology

WRITING SKILL **Darwin and Lyell** The theory of evolution was developed soon after Lyell introduced his ideas, which was no coincidence. Lyell and Charles Darwin were good friends, and their talks greatly influenced Darwin's theories. Similar to uniformitarianism, Darwin's theory of evolution proposes that changes in species occur gradually over long periods of time. Write a short essay comparing uniformitarianism and evolution.

Modern Geology—A Happy Medium

During the late 20th century, scientists such as Stephen J. Gould challenged Lyell's uniformitarianism. They believed that catastrophes do, at times, play an important role in shaping Earth's history.

Today, scientists realize that neither uniformitarianism nor catastrophism accounts for all geologic change throughout Earth's history. Although most geologic change is gradual and uniform, catastrophes that cause geologic change have occurred during Earth's long history. For example, huge craters have been found where asteroids and comets are thought to have struck Earth in the past. Some scientists think one such asteroid strike, approximately 65 million years ago, may have caused the dinosaurs to become extinct. **Figure 3** is an imaginary re-creation of the asteroid strike that is thought to have caused the extinction of the dinosaurs. The impact of this asteroid is thought to have thrown debris into the atmosphere. The debris spread around the entire planet and rained down on Earth for decades. This global debris cloud may have blocked the sun's rays, causing major changes in the global climate that doomed the dinosaurs.

Reading Check **How can a catastrophe affect life on Earth?**

Figure 3 *Today, scientists think that sudden events are responsible for some changes during Earth's past. An asteroid hitting Earth, for example, may have led to the extinction of the dinosaurs about 65 million years ago.*

Paleontology—The Study of Past Life

The history of the Earth would be incomplete without a knowledge of the organisms that have inhabited our planet and the conditions under which they lived. The science involved with the study of past life is called **paleontology.** Scientists who study this life are called *paleontologists*. The data paleontologists use are fossils. Fossils are the remains of organisms preserved by geologic processes. Some paleontologists specialize in the study of particular organisms. Invertebrate paleontologists study animals without backbones, whereas vertebrate paleontologists, such as the scientist in **Figure 4,** study animals with backbones. Paleobotanists study fossils of plants. Other paleontologists reconstruct past ecosystems, study the traces left behind by animals, and piece together the conditions under which fossils were formed. As you see, the study of past life is as varied and complex as Earth's history itself.

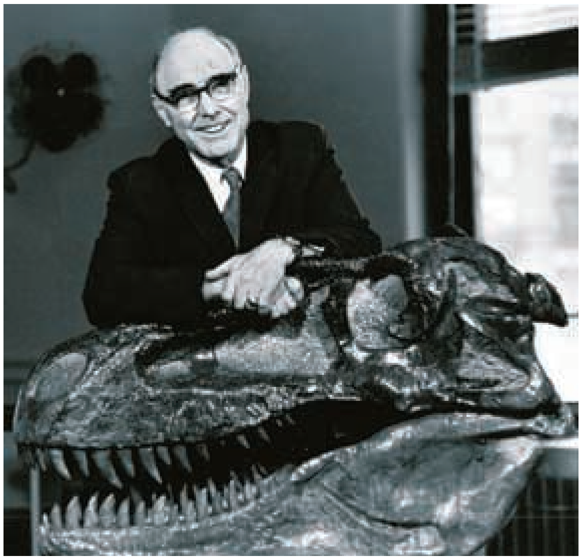


Figure 4 *Edwin Colbert was a 20th-century vertebrate paleontologist who made important contributions to the study of dinosaurs.*

paleontology the scientific study of fossils

SECTION Review

Summary

- Uniformitarianism assumes that geologic change is gradual. Catastrophism is based on the idea that geologic change is sudden.
- Modern geology is based on the idea that gradual geologic change is interrupted by catastrophes.
- Using fossils to study past life is called *paleontology*.

Using Key Terms

1. Use each of the following terms in a separate sentence: *uniformitarianism, catastrophism,* and *paleontology.*

Understanding Key Ideas

2. Which of the following words describes change according to the principle of uniformitarianism?
   a. sudden
   b. rare
   c. global
   d. gradual
3. What is the difference between uniformitarianism and catastrophism?
4. Describe how the science of geology has changed.
5. Give one example of catastrophic global change.
6. Describe the work of three types of paleontologists.

Math Skills

7. An impact crater left by an asteroid strike has a radius of 85 km. What is the area of the crater? (Hint: The area of a circle is πr^2.)

Critical Thinking

8. **Analyzing Ideas** Why is uniformitarianism considered to be the foundation of modern geology?
9. **Applying Concepts** Give an example of a type of recent catastrophe.

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Topic: Earth's Story
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SECTION 2

Relative Dating: Which Came First?

READING WARM-UP

Objectives

- Explain how relative dating is used in geology.
- Explain the principle of superposition.
- Describe how the geologic column is used in relative dating.
- Identify two events and two features that disrupt rock layers.
- Explain how physical features are used to determine relative ages.

Terms to Learn

relative dating
superposition
geologic column
unconformity

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Imagine that you are a detective investigating a crime scene. What is the first thing you would do?

You might begin by dusting the scene for fingerprints or by searching for witnesses. As a detective, you must figure out the sequence of events that took place before you reached the crime scene.

Geologists have a similar goal when investigating the Earth. They try to determine the order in which events have happened during Earth's history. But instead of relying on fingerprints and witnesses, geologists rely on rocks and fossils to help them in their investigation. Determining whether an object or event is older or younger than other objects or events is called **relative dating.**

The Principle of Superposition

Suppose that you have an older brother who takes a lot of photographs of your family and piles them in a box. Over the years, he keeps adding new photographs to the top of the stack. Think about the family history recorded in those photos. Where are the oldest photographs—the ones taken when you were a baby? Where are the most recent photographs—those taken last week?

Layers of sedimentary rock, such as the ones shown in **Figure 1,** are like stacked photographs. As you move from top to bottom, the layers are older. The principle that states that younger rocks lie above older rocks in undisturbed sequences is called **superposition.**

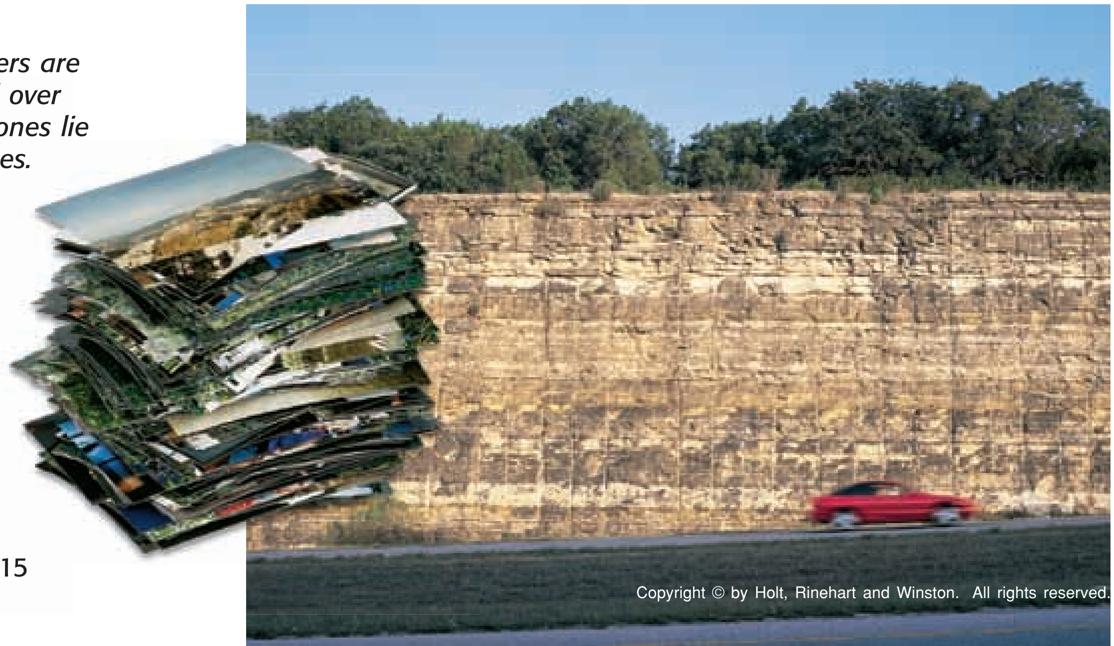


Figure 1 *Rock layers are like photos stacked over time—the younger ones lie above the older ones.*

Disturbing Forces

Not all rock sequences are arranged with the oldest layers on the bottom and the youngest layers on top. Some rock sequences are disturbed by forces within the Earth. These forces can push other rocks into a sequence, tilt or fold rock layers, and break sequences into movable parts. Sometimes, geologists even find rock sequences that are upside down! The disruptions of rock sequences pose a challenge to geologists trying to determine the relative ages of rocks. Fortunately, geologists can get help from a very valuable tool—the geologic column.

relative dating any method of determining whether an event or object is older or younger than other events or objects

superposition a principle that states that younger rocks lie above older rocks if the layers have not been disturbed

geologic column an arrangement of rock layers in which the oldest rocks are at the bottom

The Geologic Column

To make their job easier, geologists combine data from all the known undisturbed rock sequences around the world. From this information, geologists create the geologic column, as illustrated in **Figure 2.** The **geologic column** is an ideal sequence of rock layers that contains all the known fossils and rock formations on Earth, arranged from oldest to youngest.

Geologists rely on the geologic column to interpret rock sequences. Geologists also use the geologic column to identify the layers in puzzling rock sequences.

Reading Check **List two ways in which geologists use the geologic column.** (*See the Appendix for answers to Reading Checks.*)

Figure 2 **Constructing the Geologic Column**

Here, you can see three rock sequences (A, B, and C) from three different locations. Some rock layers appear in more than one sequence. Geologists construct the geologic column by piecing together different rock sequences from all over the world.

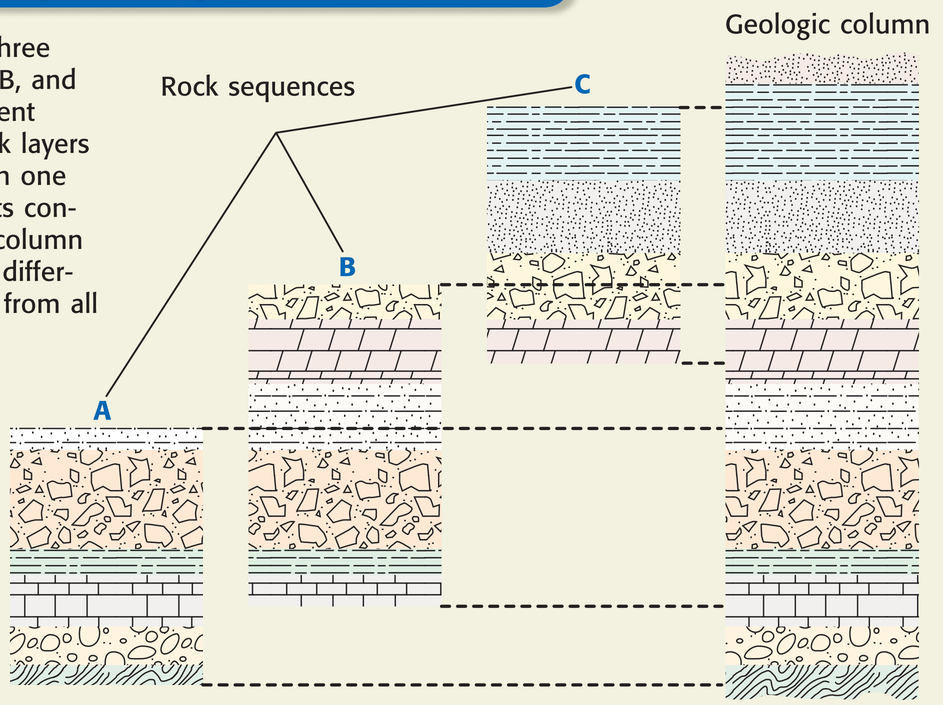
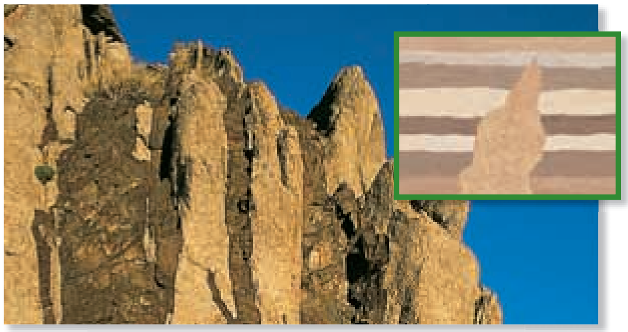


Figure 3 **How Rock Layers Become Disturbed**

Fault A *fault* is a break in the Earth's crust along which blocks of the crust slide relative to one another.



Intrusion An *intrusion* is molten rock from the Earth's interior that squeezes into existing rock and cools.

Folding *Folding* occurs when rock layers bend and buckle from Earth's internal forces.

Tilting *Tilting* occurs when internal forces in the Earth slant rock layers.

Disturbed Rock Layers

Geologists often find features that cut across existing layers of rock. Geologists use the relationships between rock layers and the features that cut across them to assign relative ages to the features and the layers. They know that the features are younger than the rock layers because the rock layers had to be present before the features could cut across them. Faults and intrusions are examples of features that cut across rock layers. A fault and an intrusion are illustrated in **Figure 3.**

Events That Disturb Rock Layers

Geologists assume that the way sediment is deposited to form rock layers—in horizontal layers—has not changed over time. According to this principle, if rock layers are not horizontal, something must have disturbed them after they formed. This principle allows geologists to determine the relative ages of rock layers and the events that disturbed them.

Folding and tilting are two types of events that disturb rock layers. These events are always younger than the rock layers they affect. The results of folding and tilting are shown in **Figure 3.**

Gaps in the Record—Unconformities

Faults, intrusions, and the effects of folding and tilting can make dating rock layers a challenge. Sometimes, layers of rock are missing altogether, creating a gap in the geologic record. To think of this another way, let's say that you stack your newspapers every day after reading them. Now, let's suppose you want to look at a paper you read 10 days ago. You know that the paper should be 10 papers deep in the stack. But when you look, the paper is not there. What happened? Perhaps you forgot to put the paper in the stack. Now, imagine a missing rock layer instead of a missing newspaper.

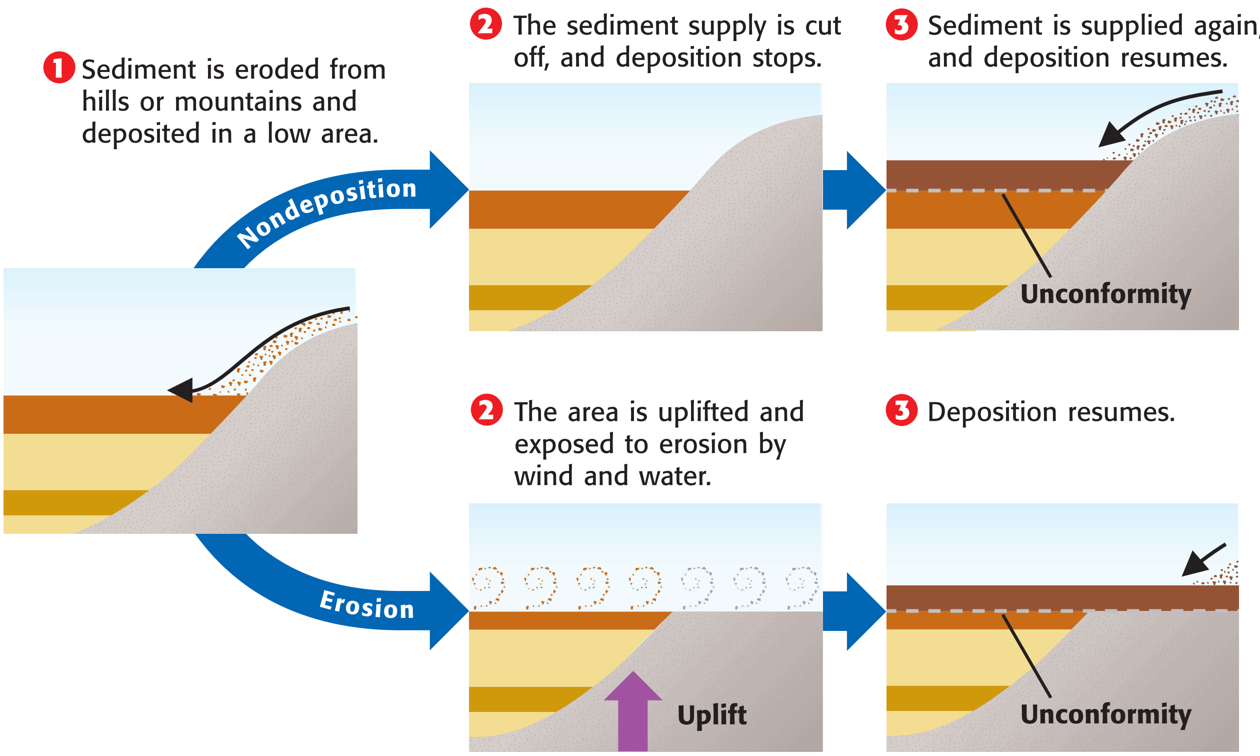
Missing Evidence

Missing rock layers create breaks in rock-layer sequences called unconformities. An **unconformity** is a surface that represents a missing part of the geologic column. Unconformities also represent missing time—time that was not recorded in layers of rock. When geologists find an unconformity, they must question whether the "missing layer" was never present or whether it was somehow removed. **Figure 4** shows how *nondeposition,* or the stoppage of deposition when a supply of sediment is cut off, and *erosion* create unconformities.

unconformity a break in the geologic record created when rock layers are eroded or when sediment is not deposited for a long period of time

Reading Check Define the term unconformity.

Figure 4 How Unconformities Are Created



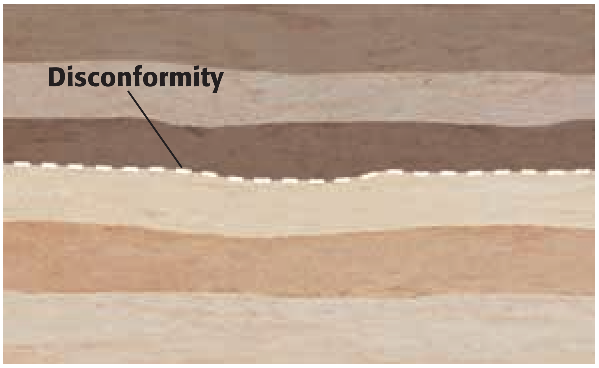


Figure 5 *A disconformity exists where part of a sequence of parallel rock layers is missing.*

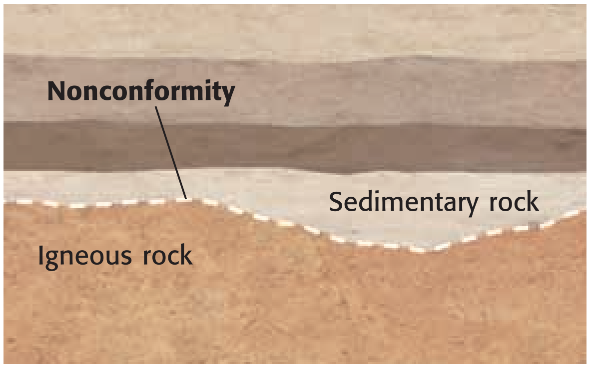


Figure 6 *A nonconformity exists where sedimentary rock layers lie on top of an eroded surface of nonlayered igneous or metamorphic rock.*

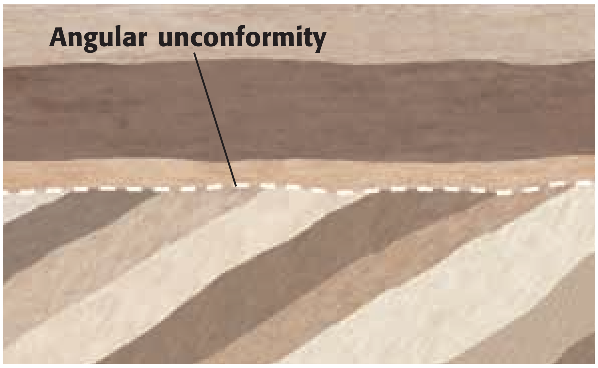


Figure 7 *An angular unconformity exists between horizontal rock layers and rock layers that are tilted or folded.*

Types of Unconformities

Most unconformities form by both erosion and nondeposition. But other factors can complicate matters. To simplify the study of unconformities, geologists place them into three major categories: disconformities, nonconformities, and angular unconformities. The three diagrams at left illustrate these three categories.

Disconformities

The most common type of unconformity is a disconformity, which is illustrated in **Figure 5.** *Disconformities* are found where part of a sequence of parallel rock layers is missing. A disconformity can form in the following way. A sequence of rock layers is uplifted. Younger layers at the top of the sequence are removed by erosion, and the eroded material is deposited elsewhere. At some future time, deposition resumes, and sediment buries the old erosion surface. The disconformity that results shows where erosion has taken place and rock layers are missing. A disconformity represents thousands to many millions of years of missing time.

Nonconformities

A nonconformity is illustrated in **Figure 6.** *Nonconformities* are found where horizontal sedimentary rock layers lie on top of an eroded surface of older intrusive igneous or metamorphic rock. Intrusive igneous and metamorphic rocks form deep within the Earth. When these rocks are raised to Earth's surface, they are eroded. Deposition causes the erosion surface to be buried. Nonconformities represent millions of years of missing time.

Angular Unconformities

An angular unconformity is shown in **Figure 7.** *Angular unconformities* are found between horizontal layers of sedimentary rock and layers of rock that have been tilted or folded. The tilted or folded layers were eroded before horizontal layers formed above them. Angular unconformities represent millions of years of missing time.

Reading Check **Describe each of the three major categories of unconformities.**

Rock-Layer Puzzles

Geologists often find rock-layer sequences that have been affected by more than one of the events and features mentioned in this section. For example, as shown in **Figure 8,** intrusions may squeeze into rock layers that contain an unconformity. Determining the order of events that led to such a sequence is like piecing together a jigsaw puzzle. Geologists must use their knowledge of the events that disturb or remove rock-layer sequences to help piece together the history of Earth as told by the rock record.

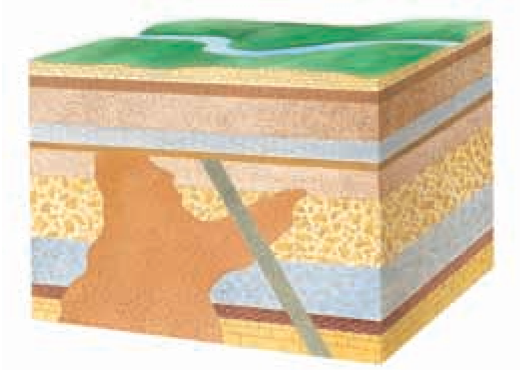


Figure 8 *Rock-layer sequences are often disturbed by more than one rock-disturbing feature.*

SECTION Review

Summary

- Geologists use relative dating to determine the order in which events happen.
- The principle of superposition states that in undisturbed rock sequences, younger layers lie above older layers.
- Folding and tilting are two events that disturb rock layers. Faults and intrusions are two features that disturb rock layers.
- The known rock and fossil record is indicated by the geologic column.
- Geologists examine the relationships between rock layers and the structures that cut across them in order to determine relative ages.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *relative dating, superposition,* and *geologic column.*

Understanding Key Ideas

2. Molten rock that squeezes into existing rock and cools is called a(n)
   a. fold.
   b. fault.
   c. intrusion.
   d. unconformity.
3. List two events and two features that can disturb rock-layer sequences.
4. Explain how physical features are used to determine relative ages.

Critical Thinking

5. **Analyzing Concepts** Is there a place on Earth that has all the layers of the geologic column? Explain.
6. **Analyzing Ideas** Disconformities are hard to recognize because all of the layers are horizontal. How does a geologist know when he or she is looking at a disconformity?

Interpreting Graphics

Use the illustration below to answer the question that follows.

7. If the top rock layer were eroded and deposition later resumed, what type of unconformity would mark the boundary between older rock layers and the newly deposited rock layers?

SECTION 3

Absolute Dating: A Measure of Time

Have you ever heard the expression "turning back the clock"? With the discovery of the natural decay of uranium in 1896, French physicist Henri Becquerel provided a means of doing just that. Scientists could use radioactive elements as clocks to measure geologic time.

The process of establishing the age of an object by determining the number of years it has existed is called **absolute dating.** In this section, you will learn about radiometric dating, which is the most common method of absolute dating.

READING WARM-UP

Objectives

- Describe how radioactive decay occurs.
- Explain how radioactive decay relates to radiometric dating.
- Identify four types of radiometric dating.
- Determine the best type of radiometric dating to use to date an object.

Terms to Learn

absolute dating
isotope
radioactive decay
radiometric dating
half-life

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

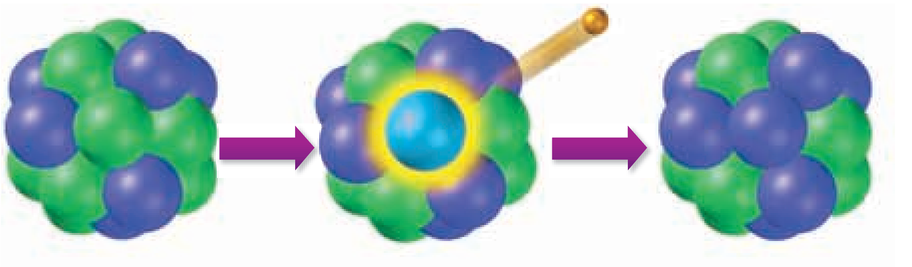
Radioactive Decay

To determine the absolute ages of fossils and rocks, scientists analyze isotopes of radioactive elements. Atoms of the same element that have the same number of protons but have different numbers of neutrons are called **isotopes.** Most isotopes are stable, meaning that they stay in their original form. But some isotopes are unstable. Scientists call unstable isotopes *radioactive*. Radioactive isotopes tend to break down into stable isotopes of the same or other elements in a process called **radioactive decay.** **Figure 1** shows an example of how radioactive decay occurs. Because radioactive decay occurs at a steady rate, scientists can use the relative amounts of stable and unstable isotopes present in an object to determine the object's age.

absolute dating any method of measuring the age of an event or object in years

isotope an atom that has the same number of protons (or the same atomic number) as other atoms of the same element do but that has a different number of neutrons (and thus a different atomic mass)

Figure 1 Radioactive Decay



Unstable Isotope
6 protons,
8 neutrons

Radioactive Decay
When some unstable isotopes decay, a neutron is converted into a proton. In the process, an electron is released.

Stable Isotope
7 protons,
7 neutrons

Dating Rocks—How Does It Work?

In the process of radioactive decay, an unstable radioactive isotope of one element breaks down into a stable isotope. The stable isotope may be of the same element or, more commonly, a different element. The unstable radioactive isotope is called the *parent isotope*. The stable isotope produced by the radioactive decay of the parent isotope is called the *daughter isotope*. The radioactive decay of a parent isotope into a stable daughter isotope can occur in a single step or a series of steps. In either case, the rate of decay is constant. Therefore, to date rock, scientists compare the amount of parent material with the amount of daughter material. The more daughter material there is, the older the rock is.

Radiometric Dating

If you know the rate of decay for a radioactive element in a rock, you can figure out the absolute age of the rock. Determining the absolute age of a sample, based on the ratio of parent material to daughter material, is called **radiometric dating.** For example, let's say that a rock sample contains an isotope with a half-life of 10,000 years. A **half-life** is the time that it takes one-half of a radioactive sample to decay. So, for this rock sample, in 10,000 years, half the parent material will have decayed and become daughter material. You analyze the sample and find equal amounts of parent material and daughter material. This means that half the original radioactive isotope has decayed and that the sample must be about 10,000 years old.

What if one-fourth of your sample is parent material and three-fourths is daughter material? You would know that it took 10,000 years for half the original sample to decay and another 10,000 years for half of what remained to decay. The age of your sample would be $2 \times 10{,}000$, or 20,000, years. **Figure 2** shows how this steady decay happens.

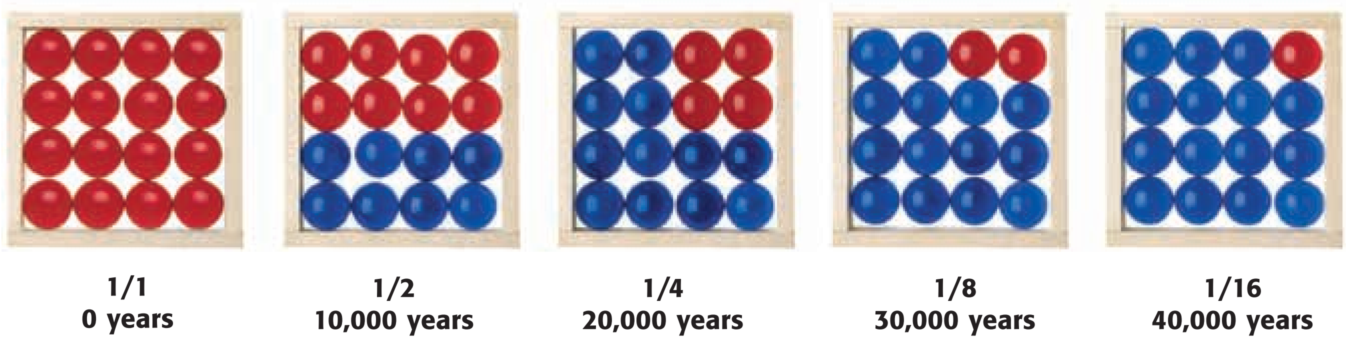
Reading Check **What is a half-life?** (*See the Appendix for answers to Reading Checks.*)

radioactive decay the process in which a radioactive isotope tends to break down into a stable isotope of the same element or another element

radiometric dating a method of determining the age of an object by estimating the relative percentages of a radioactive (parent) isotope and a stable (daughter) isotope

half-life the time needed for half of a sample of a radioactive substance to undergo radioactive decay

Figure 2 *After every half-life, the amount of parent material decreases by one-half.*



Types of Radiometric Dating

Figure 3 *This burial mound at Effigy Mounds resembles a snake.*

Imagine traveling back through the centuries to a time before Columbus arrived in America. You are standing along the bluffs of what will one day be called the Mississippi River. You see dozens of people building large mounds. Who are these people, and what are they building?

The people you saw in your time travel were Native Americans, and the structures they were building were burial mounds. The area you imagined is now an archaeological site called Effigy Mounds National Monument. **Figure 3** shows one of these mounds.

According to archaeologists, people lived at Effigy Mounds from 2,500 years ago to 600 years ago. How do archaeologists know these dates? They have dated bones and other objects in the mounds by using radiometric dating. Scientists use different radiometric-dating techniques based on the estimated age of an object. As you read on, think about how the half-life of an isotope relates to the age of the object being dated. Which technique would you use to date the burial mounds?

Potassium-Argon Method

One isotope that is used for radiometric dating is potassium-40. Potassium-40 has a half-life of 1.3 billion years, and it decays to argon and calcium. Geologists measure argon as the daughter material. This method is used mainly to date rocks older than 100,000 years.

Uranium-Lead Method

Uranium-238 is a radioactive isotope that decays in a series of steps to lead-206. The half-life of uranium-238 is 4.5 billion years. The older the rock is, the more daughter material (lead-206) there will be in the rock. Uranium-lead dating can be used for rocks more than 10 million years old. Younger rocks do not contain enough daughter material to be accurately measured by this method.

Rubidium-Strontium Method

Through radioactive decay, the unstable parent isotope rubidium-87 forms the stable daughter isotope strontium-87. The half-life of rubidium-87 is 49 billion years. This method is used to date rocks older than 10 million years.

Reading Check **What is the daughter isotope of rubidium-87?**

Carbon-14 Method

The element carbon is normally found in three forms, the stable isotopes carbon-12 and carbon-13 and the radioactive isotope carbon-14. These carbon isotopes combine with oxygen to form the gas carbon dioxide, which is taken in by plants during photosynthesis. As long as a plant is alive, new carbon dioxide with a constant carbon-14 to carbon-12 ratio is continually taken in. Animals that eat plants contain the same ratio of carbon isotopes.

Once a plant or an animal dies, however, no new carbon is taken in. The amount of carbon-14 begins to decrease as the plant or animal decays, and the ratio of carbon-14 to carbon-12 decreases. This decrease can be measured in a laboratory, such as the one shown in **Figure 4.** Because the half-life of carbon-14 is only 5,730 years, this dating method is used mainly for dating things that lived within the last 50,000 years.

Figure 4 *Some samples containing carbon must be cleaned and burned before their age can be determined.*

SECTION Review

Summary

- During radioactive decay, an unstable isotope decays at a constant rate and becomes a stable isotope of the same or a different element.
- Radiometric dating, based on the ratio of parent to daughter material, is used to determine the absolute age of a sample.
- Methods of radiometric dating include potassium-argon, uranium-lead, rubidium-strontium, and carbon-14 dating.

Using Key Terms

1. Use each of the following terms in a separate sentence: *absolute dating, isotope,* and *half-life*.

Understanding Key Ideas

2. Rubidium-87 has a half-life of
   a. 5,730 years.
   b. 4.5 billion years.
   c. 49 billion years.
   d. 1.3 billion years.
3. Explain how radioactive decay occurs.
4. How does radioactive decay relate to radiometric dating?
5. List four types of radiometric dating.

Math Skills

6. A radioactive isotope has a half-life of 1.3 billion years. After 3.9 billion years, how much of the parent material will be left?

Critical Thinking

7. **Analyzing Methods** Explain why radioactive decay must be constant in order for radiometric dating to be accurate.
8. **Applying Concepts** Which radiometric-dating method would be most appropriate for dating artifacts found at Effigy Mounds? Explain.

SECTION 4

Looking at Fossils

Descending from the top of a ridge in the badlands of Argentina, your expedition team suddenly stops. You look down and realize that you are walking on eggshells—dinosaur eggshells!

A paleontologist named Luis Chiappe had this experience. He had found an enormous dinosaur nesting ground.

READING WARM-UP

Objectives

- Describe five ways that different types of fossils form.
- List three types of fossils that are not part of organisms.
- Explain how fossils can be used to determine the history of changes in environments and organisms.
- Explain how index fossils can be used to date rock layers.

Terms to Learn

fossil
trace fossil
mold
cast
index fossil

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from this section in your outline.

Fossilized Organisms

The remains or physical evidence of an organism preserved by geologic processes is called a **fossil.** Fossils are most often preserved in sedimentary rock. But as you will see, other materials can also preserve evidence of past life.

fossil the remains or physical evidence of an organism preserved by geological processes

Fossils in Rocks

When an organism dies, it either immediately begins to decay or is consumed by other organisms. Sometimes, however, organisms are quickly buried by sediment when they die. The sediment slows down decay. Hard parts of organisms, such as shells and bones, are more resistant to decay than soft tissues are. So, when sediments become rock, the hard parts of animals are much more commonly preserved than are soft tissues.

Fossils in Amber

Imagine that an insect is caught in soft, sticky tree sap. Suppose that the insect gets covered by more sap, which quickly hardens and preserves the insect inside. Hardened tree sap is called *amber.* Some of our best insect fossils are found in amber, as shown in **Figure 1.** Frogs and lizards have also been found in amber.

Reading Check **Describe how organisms are preserved in amber.** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *These insects are preserved in amber.*

Figure 2 *Scientist Vladimir Eisner studies the upper molars of a 20,000-year-old woolly mammoth found in Siberia, Russia. The almost perfectly preserved male mammoth was excavated from a block of ice in October 1999.*

Petrifaction

Another way that organisms are preserved is by petrifaction. *Petrifaction* is a process in which minerals replace an organism's tissues. One form of petrifaction is called permineralization. *Permineralization* is a process in which the pore space in an organism's hard tissue—for example, bone or wood—is filled up with mineral. Another form of petrifaction is called *replacement,* a process in which the organism's tissues are completely replaced by minerals. For example, in some specimens of petrified wood, all of the wood has been replaced by minerals.

Fossils in Asphalt

There are places where asphalt wells up at the Earth's surface in thick, sticky pools. The La Brea asphalt deposits in Los Angeles, California, for example, are at least 38,000 years old. These pools of thick, sticky asphalt have trapped and preserved many kinds of organisms for the past 38,000 years. From these fossils, scientists have learned about the past environment in southern California.

Frozen Fossils

In October 1999, scientists removed a 20,000-year-old woolly mammoth frozen in the Siberian tundra. The remains of this mammoth are shown in **Figure 2.** Woolly mammoths, relatives of modern elephants, became extinct approximately 10,000 years ago. Because cold temperatures slow down decay, many types of frozen fossils are preserved from the last ice age. Scientists hope to find out more about the mammoth and the environment in which it lived.

CONNECTION TO Environmental Science

WRITING SKILL **Preservation in Ice** Subfreezing climates contain almost no decomposing bacteria. The well-preserved body of John Torrington, a member of an expedition that explored the Northwest Passage in Canada in the 1840s, was uncovered in 1984. His body appeared much as it did at the time he died, more than 160 years earlier. Research another well-preserved discovery, and write a report for your class.

Figure 3 *These dinosaur tracks are located in Arizona. They leave a trace of a dinosaur that had longer legs than humans do.*

Other Types of Fossils

Besides their hard parts—and in rare cases their soft parts—do organisms leave behind any other clues about their existence? What other evidence of past life do paleontologists look for?

Trace Fossils

Any naturally preserved evidence of animal activity is called a **trace fossil.** Tracks like the ones shown in **Figure 3** are a fascinating example of a trace fossil. These fossils form when animal footprints fill with sediment and are preserved in rock. Tracks reveal a lot about the animal that made them, including how big it was and how fast it was moving. Parallel trackways showing dinosaurs moving in the same direction have led paleontologists to hypothesize that dinosaurs moved in herds.

Burrows are another trace fossil. Burrows are shelters made by animals, such as clams, that bury in sediment. Like tracks, burrows are preserved when they are filled in with sediment and buried quickly. A *coprolite* (KAHP roh LIET), a third type of trace fossil, is preserved animal dung.

trace fossil a fossilized mark that is formed in soft sediment by the movement of an animal

mold a mark or cavity made in a sedimentary surface by a shell or other body

cast a type of fossil that forms when sediments fill in the cavity left by a decomposed organism

Molds and Casts

Molds and casts are two more examples of fossils. A cavity in rock where a plant or animal was buried is called a **mold.** A **cast** is an object created when sediment fills a mold and becomes rock. A cast shows what the outside of the organism looked like. **Figure 4** shows two types of molds from the same organism—and internal mold and an external mold.

Reading Check **How are a cast and a mold different?**

Figure 4 *This photograph shows two molds from an ammonite. The image on the left is the internal mold of the ammonite, which formed when sediment filled the ammonite's shell, which later dissolved away. The image on the right is the external mold of the ammonite, which preserves the external features of the shell.*

Figure 5 *This scientist has found marine fossils on mountaintops in the Yoho National Park in Canada. The fossil of* Marrella, *shown at left, tells the scientist that these rocks were pushed up from below sea level millions of years ago.*

Using Fossils to Interpret the Past

Think about your favorite outdoor place. Now, imagine that you are a paleontologist at the same site 65 million years from now. What types of fossils would you dig up? Based on the fossils you found, how would you reconstruct this place?

The Information in the Fossil Record

The fossil record offers only a rough sketch of the history of life on Earth. Some parts of this history are more complete than others. For example, scientists know more about organisms that had hard body parts than about organisms that had soft body parts. Scientists also know more about organisms that lived in environments that favored fossilization. The fossil record is incomplete because most organisms never became fossils. And of course, many fossils have yet to be discovered.

History of Environmental Changes

Would you expect to find marine fossils on the mountaintop shown in **Figure 5**? The presence of marine fossils means that the rocks of these mountaintops in Canada formed in a totally different environment—at the bottom of an ocean.

The fossil record reveals a history of environmental change. For example, marine fossils help scientists reconstruct ancient coastlines and the deepening and shallowing of ancient seas. Using the fossils of plants and land animals, scientists can reconstruct past climates. They can tell whether the climate in an area was cooler or wetter than it is at present.

Quick Lab

Make a Fossil

1. Find a **common object,** such as a shell, a button, or a pencil, to use to make a mold. Keep the object hidden from your classmates.
2. To create a mold, press the items down into **modeling clay** in a **shallow pan or tray.**
3. Trade your tray with a classmate's tray, and try to identify the item that made the mold.
4. Describe how a cast could be formed from your mold.

SCHOOL to HOME

Fossil Hunt

Go on a fossil hunt with your family. Find out what kinds of rocks in your local area might contain fossils. Take pictures or draw sketches of your trip and any fossils that you find.

ACTIVITY

History of Changing Organisms

By studying the relationships between fossils, scientists can interpret how life has changed over time. For example, older rock layers contain organisms that often differ from the organisms found in younger rock layers.

Only a small fraction of the organisms that have existed in Earth's history have been fossilized. Because the fossil record is incomplete, it does not provide paleontologists with a continuous record of change. Instead, they look for similarities between fossils, or between fossilized organisms and their closest living relatives, and try to fill in the blanks in the fossil record.

✓ *Reading Check* **How do paleontologists fill in missing information about changes in organisms in the fossil record?**

Using Fossils to Date Rocks

Scientists have found that particular types of fossils appear only in certain layers of rock. By dating the rock layers above and below these fossils, scientists can determine the time span in which the organisms that formed the fossils lived. If a type of organism existed for only a short period of time, its fossils would show up in a limited range of rock layers. These types of fossils are called index fossils. **Index fossils** are fossils of organisms that lived during a relatively short, well-defined geologic time span.

index fossil a fossil that is found in the rock layers of only one geologic age and that is used to establish the age of the rock layers

Ammonites

To be considered an index fossil, a fossil must be found in rock layers throughout the world. One example of an index fossil is the fossil of a genus of ammonites (AM uh NIETS) called *Tropites*, shown in **Figure 6.** *Tropites* was a marine mollusk similar to a modern squid. It lived in a coiled shell. *Tropites* lived between 230 million and 208 million years ago and is an index fossil for that period of time.

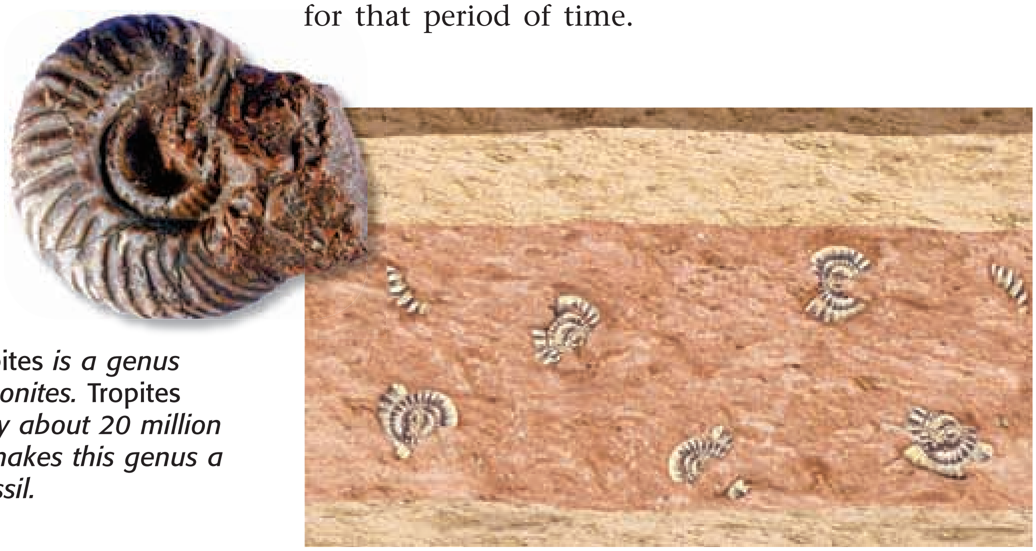


Figure 6 Tropites *is a genus of coiled ammonites.* Tropites *existed for only about 20 million years, which makes this genus a good index fossil.*

Trilobites

Fossils of a genus of trilobites (TRIE loh BIETS) called *Phacops* are another example of an index fossil. Trilobites are extinct. Their closest living relative is the horseshoe crab. Through the dating of rock, paleontologists have determined that *Phacops* lived approximately 400 million years ago. So, when scientists find *Phacops* in rock layers anywhere on Earth, they assume that these rock layers are also approximately 400 million years old. An example of a *Phacops* fossil is shown in **Figure 7.**

Reading Check **Explain how fossils of *Phacops* can be used to establish the age of rock layers.**

Figure 7 *Paleontologists assume that any rock layer containing a fossil of the trilobite* Phacops *is about 400 million years old.*

SECTION Review

Summary

- Fossils are the remains or physical evidence of an organism preserved by geologic processes.
- Fossils can be preserved in rock, amber, asphalt, and ice and by petrifaction.
- Trace fossils are any naturally preserved evidence of animal activity. Tracks, burrows, and coprolites are examples of trace fossils.
- Scientists study fossils to determine how environments and organisms have changed over time.
- An index fossil is a fossil of an organism that lived during a relatively short, well-defined time span. Index fossils can be used to establish the age of rock layers.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

cast	index fossils
mold	trace fossils

1. A ___ is a cavity in rock where a plant or animal was buried.
2. ___ can be used to establish the age of rock layers.

Understanding Key Ideas

3. Fossils are most often preserved in
   a. ice.
   b. amber.
   c. asphalt.
   d. rock.
4. Describe three types of trace fossils.
5. Explain how an index fossil can be used to date rock.
6. Explain why the fossil record contains an incomplete record of the history of life on Earth.
7. Explain how fossils can be used to determine the history of changes in environments and organisms.

Math Skills

8. If a scientist finds the remains of a plant between a rock layer that contains 400 million–year-old *Phacops* fossils and a rock layer that contains 230 million–year-old *Tropites* fossils, how old could the plant fossil be?

Critical Thinking

9. **Making Inferences** If you find rock layers containing fish fossils in a desert, what can you infer about the history of the desert?
10. **Identifying Bias** Because information in the fossil record is incomplete, scientists are left with certain biases concerning fossil preservation. Explain two of these biases.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Looking at Fossils
SciLinks code: HSM0886

Time Marches On

How old is the Earth? Well, if the Earth celebrated its birthday every million years, there would be 4,600 candles on its birthday cake! Humans have been around only long enough to light the last candle on the cake.

READING WARM-UP

Objectives

- Explain how geologic time is recorded in rock layers.
- Identify important dates on the geologic time scale.
- Explain how changes in climate resulted in the extinction of some species.
- Explain why ice cores are important to the study of Earth's climate history.

Terms to Learn

geologic time scale
eon
era
period
epoch
extinction

READING STRATEGY

Brainstorming The key idea of this section is the geologic time scale. Brainstorm words and phrases related to the geologic time scale.

Try to think of the Earth's history in "fast-forward." If you could watch the Earth change from this perspective, you would see mountains rise up like wrinkles in fabric and quickly wear away. You would see life-forms appear and then go extinct. In this section, you will learn that geologists must "fast-forward" the Earth's history when they write or talk about it. You will also learn about some incredible events in the history of life on Earth.

Geologic Time

Shown in **Figure 1** is the rock wall at the Dinosaur Quarry Visitor Center in Dinosaur National Monument, Utah. Contained within this wall are approximately 1,500 fossil bones that have been excavated by paleontologists. These are the remains of dinosaurs that inhabited the area about 150 million years ago. Granted, 150 million years seems to be an incredibly long period of time. However, in terms of the Earth's history, 150 million years is little more than 3% of the time our planet has existed. It is a little less than 4% of the time represented by the Earth's oldest known rocks.

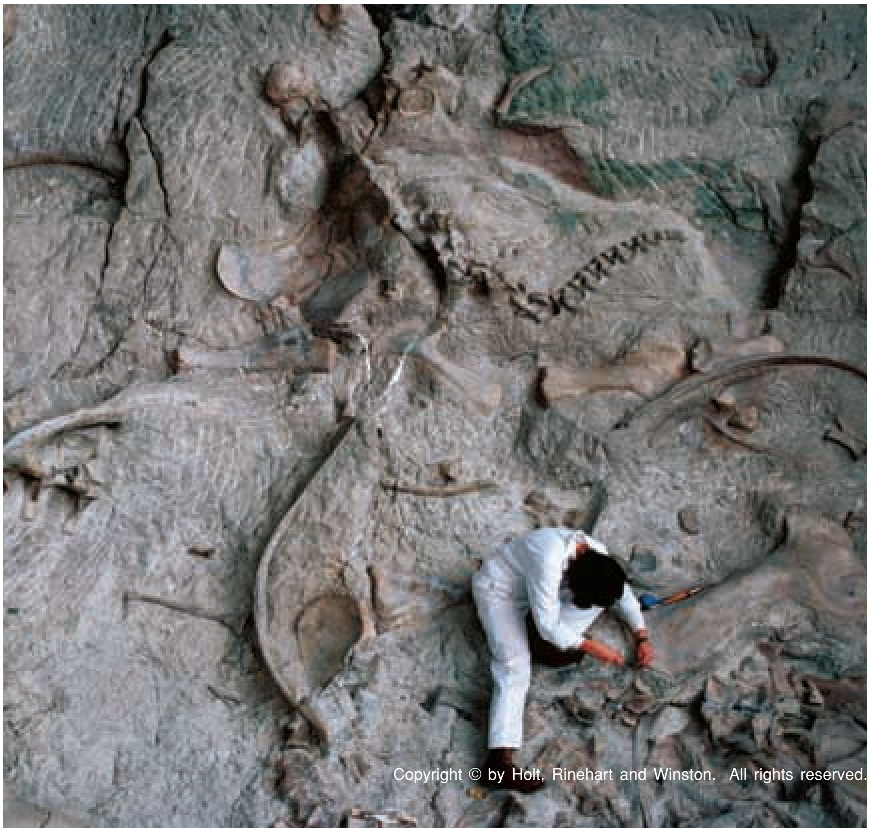

Figure 1 *Bones of dinosaurs that lived about 150 million years ago are exposed in the quarry wall at Dinosaur National Monument in Utah.*

Figure 2 *Well-preserved plant and animal fossils are common in the Green River formation. Clockwise from the upper right are a fossil leaf, a dragonfly, a fish, and a turtle.*

The Rock Record and Geologic Time

One of the best places in North America to see the Earth's history recorded in rock layers is in Grand Canyon National Park. The Colorado River has cut the canyon nearly 2 km deep in some places. Over the course of 6 million years, the river has eroded countless layers of rock. These layers represent almost half, or nearly 2 billion years, of Earth's history.

Reading Check **How much geologic time is represented by the rock layers in the Grand Canyon?** (*See the Appendix for answers to Reading Checks.*)

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5FOSW.**

The Fossil Record and Geologic Time

Figure 2 shows sedimentary rocks that belong to the Green River formation. These rocks, which are found in parts of Wyoming, Utah, and Colorado, are thousands of meters thick. These rocks were once part of a system of ancient lakes that existed for a period of millions of years. Fossils of plants and animals are common in these rocks and are very well preserved. Burial in the fine-grained lake-bed sediments preserved even the most delicate structures.

Phanerozoic Eon

(543 million years ago to the present)
The rock and fossil record mainly represents the Phanerozoic eon, which is the eon in which we live.

Proterozoic Eon

(2.5 billion years ago to 543 million years ago)
The first organisms with well-developed cells appeared during this eon.

Archean Eon

(3.8 billion years ago to 2.5 billion years ago)
The earliest known rocks on Earth formed during this eon.

Hadean Eon

(4.6 billion years ago to 3.8 billion years ago)
The only rocks that scientists have found from this eon are meteorites and rocks from the moon.

Geologic Time Scale

Eon	Era	Period	Epoch	Millions of years ago
PHANEROZOIC EON	Cenozoic	Quaternary	Holocene	0.01
			Pleistocene	1.8
		Tertiary	Pliocene	5.3
			Miocene	23.8
			Oligocene	33.7
			Eocene	54.8
			Paleocene	65
	Mesozoic	Cretaceous		144
		Jurassic		206
		Triassic		248
	Paleozoic	Permian		290
		Pennsylvanian		323
		Mississippian		354
		Devonian		417
		Silurian		443
		Ordovician		490
		Cambrian		543
PROTEROZOIC EON				2,500
ARCHEAN EON				3,800
HADEAN EON				4,600

Figure 3 *The geologic time scale accounts for Earth's entire history. It is divided into four major parts called* eons. *Dates given for intervals on the geologic time scale are estimates.*

The Geologic Time Scale

The geologic column represents the billions of years that have passed since the first rocks formed on Earth. Altogether, geologists study 4.6 billion years of Earth's history! To make their job easier, geologists have created the geologic time scale. The **geologic time scale,** which is shown in **Figure 3,** is a scale that divides Earth's 4.6 billion–year history into distinct intervals of time.

Reading Check **Define the term *geologic time scale*.**

Divisions of Time

Geologists have divided Earth's history into sections of time, as shown on the geologic time scale in **Figure 3.** The largest divisions of geologic time are **eons** (EE AHNZ). There are four eons—the Hadean eon, the Archean eon, the Proterozoic eon, and the Phanerozoic eon. The Phanerozoic eon is divided into three **eras,** which are the second-largest divisions of geologic time. The three eras are further divided into **periods,** which are the third-largest divisions of geologic time. Periods are divided into **epochs** (EP uhks), which are the fourth-largest divisions of geologic time.

The boundaries between geologic time intervals represent shorter intervals in which visible changes took place on Earth. Some changes are marked by the disappearance of index fossil species, while others are recognized only by detailed paleontological studies.

geologic time scale the standard method used to divide the Earth's long natural history into manageable parts

eon the largest division of geologic time

era a unit of geologic time that includes two or more periods

period a unit of geologic time into which eras are divided

epoch a subdivision of a geologic period

extinction the death of every member of a species

The Appearance and Disappearance of Species

At certain times during Earth's history, the number of species has increased or decreased dramatically. An increase in the number of species often comes as a result of either a relatively sudden increase or decrease in competition among species. *Hallucigenia,* shown in **Figure 4,** appeared during the Cambrian period, when the number of marine species greatly increased. On the other hand, the number of species decreases dramatically over a relatively short period of time during a mass extinction event. **Extinction** is the death of every member of a species. Events such as global climate change can cause mass extinctions. The subject of global climate change and mass extinction will be discussed on the following page.

Figure 4 Hallucigenia, *named for its "bizarre and dreamlike quality," was one of numerous marine organisms to make its appearance during the early Cambrian period.*

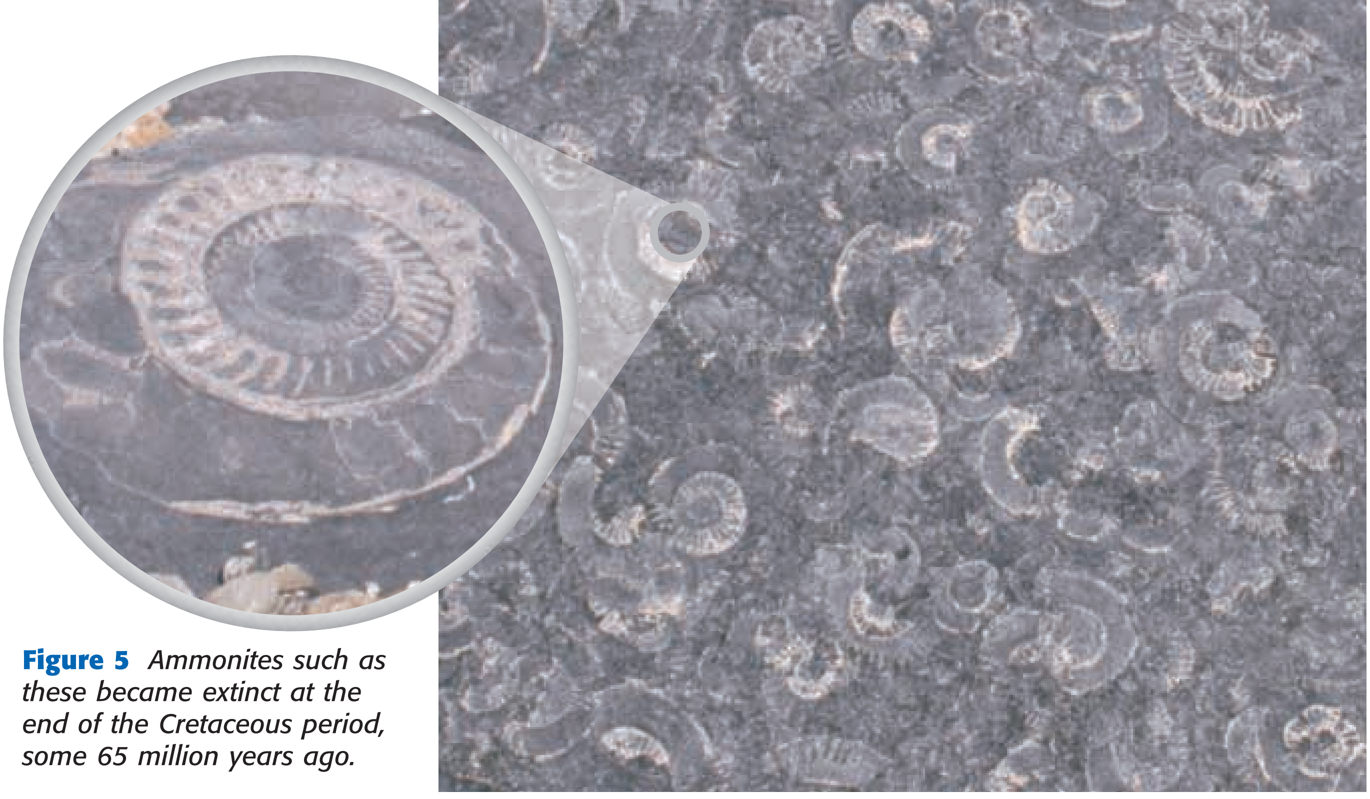

Figure 5 *Ammonites such as these became extinct at the end of the Cretaceous period, some 65 million years ago.*

Climate Change and Extinction

Most paleontologists agree that at least five mass extinction events have happened since organisms first appeared in the fossil record. However, many paleontologists do not agree about the specific cause of each extinction event because the fossil record is often hard to interpret. In each extinction event, some species that lived in an environment disappeared completely. But other species that lived in the same environment survived for many more millions of years.

Scientists hypothesize that changes in the Earth's climate sometimes disrupt environments and result in the mass extinction of organisms. One of the changes that could cause mass extinctions is global cooling. Global cooling can be caused by airborne ash from volcanic eruptions or by debris thrown into the atmosphere by asteroid impacts. Each of these events decreases the amount of electromagnetic radiation that reaches the Earth from the sun. This decrease in electromagnetic radiation results in a decrease in global temperature.

During global cooling, large amounts of the Earth's water are frozen in ice sheets in a process known as *glaciation*. Glaciation also results in a lowering in sea level because such large amounts of Earth's water are frozen. For example, during the last glaciation, which occurred approximately 20,000 years ago, glaciers in North America were up to 500 m thick and sea level was 100 m lower than it is today.

Reading Check **How does glaciation produce changes in sea level?**

CONNECTION TO Language Arts

WRITING SKILL **"She Sells Seashells by the Seashore"** Although you may be familiar with this well-known tongue twister, you are probably not familiar with the person to whom it refers. "She" was Mary Anning, the "seashells" were actually marine fossils, and the "seashore" was the Dorset coast of southern England. Mary Anning was a 19th-century fossil collector. She spent nearly 40 years exploring the seacliffs of the Dorset coast. She collected fossils and sold them to the geologists of the time. Research Anning, and write a short essay summarizing your findings.

Earth's Climate Frozen in Time

A record of the Earth's climate is frozen in glaciers and polar ice sheets. Substances such as dust, soot, volcanic ash, and chemical compounds from the air are buried within the ice. Air itself is contained within air bubbles trapped within the ice. Scientists drill out cylinders of ice, called *ice cores,* shown in **Figure 6,** to obtain the trapped atmospheric gases and particles. Ice cores show scientists the composition of the atmosphere at a particular time in the past.

Figure 6 *Ice cores help scientists reconstruct the Earth's climate history. For example, the Antarctic ice sheet has provided a continuous record of climate change for the past 750,000 years.*

Phanerozoic Means "Visible Life"

Geologists divide the Phanerozoic eon—the eon of visible life—into three eras: the Paleozoic era, the Mesozoic era, and the Cenozoic era. Some of the vast number of organisms that lived and died during each of these three eras will be discussed in the following paragraphs.

The Paleozoic Era—Old Life

The Paleozoic era lasted from about 543 million to 248 million years ago. It is the first era well represented by fossils.

Marine life flourished at the beginning of the Paleozoic era. The oceans became home to a diversity of life. However, there were few land organisms. By the middle of the Paleozoic era, most modern groups of land plants had appeared. By the end of the era, amphibians and reptiles lived on the land, and insects were abundant. **Figure 7** shows what the Earth might have looked like late in the Paleozoic era. The Paleozoic era came to an end with the largest mass extinction in Earth's history. Some scientists believe that changes in seawater circulation were a likely cause of this extinction, which killed nearly 90% of all species.

Figure 7 *Jungles were present during the Paleozoic era, but there were no birds singing in the trees and no monkeys swinging from the branches. Birds and mammals didn't evolve until much later.*

Figure 8 *Imagine walking in the desert and bumping into these fierce creatures! It's a good thing humans didn't evolve in the Mesozoic era, which was dominated by dinosaurs.*

The Mesozoic Era—The Age of Reptiles

The Mesozoic era began about 248 million years ago. The Mesozoic is known as the *Age of Reptiles* because reptiles, such as the dinosaurs shown in **Figure 8,** inhabited the land.

During this time, reptiles dominated. Small mammals appeared about the same time as dinosaurs, and birds appeared late in the Mesozoic era. Many scientists think that birds evolved directly from a type of dinosaur. At the end of the Mesozoic era, about 15% to 20% of all species on Earth, including the dinosaurs, became extinct. Global climate change may have been the cause.

Reading Check **Why is the Mesozoic known as the *Age of Reptiles*?**

The Cenozoic Era—The Age of Mammals

The Cenozoic era, as shown in **Figure 9,** began about 65 million years ago and continues to the present. This era is known as the *Age of Mammals*. During the Mesozoic era, mammals had to compete with dinosaurs and other animals for food and habitat. After the mass extinction at the end of the Mesozoic era, mammals flourished. Unique traits, such as regulating body temperature internally and bearing young that develop inside the mother, may have helped mammals survive the environmental changes that probably caused the extinction of the dinosaurs.

Figure 9 *Thousands of species of mammals evolved during the Cenozoic era. This scene shows species from the early Cenozoic era that are now extinct.*

SECTION Review

Summary

- The geologic time scale divides Earth's 4.6 billion–year history into distinct intervals of time. Divisions of geologic time include eons, eras, periods, and epochs.
- The boundaries between geologic time intervals represent visible changes that have taken place on Earth.
- The rock and fossil record represents mainly the Phanerozoic eon, which is the eon in which we live.
- At certain times in Earth's history, the number of life-forms has increased or decreased dramatically.
- Different changes in the Earth's climate are hypothesized to disrupt environments and result in the mass extinction of organisms.
- Ice cores provide scientists with a history of Earth's climates that extends back in time 750,000 years.

Using Key Terms

1. Use each of the following terms in the same sentence: *era, period,* and *epoch.*

Understanding Key Ideas

2. The unit of geologic time that began 65 million years ago and continues to the present is the

a. Holocene epoch.
b. Cenozoic era.
c. Phanerozoic eon.
d. Quaternary period.

3. What are the major time intervals represented by the geologic time scale?

4. Explain how geologic time is recorded in rock layers.

5. What kinds of climate changes cause mass extinctions?

6. Explain why ice cores are important to the study of Earth's climate history.

Critical Thinking

7. Making Inferences What future event might mark the end of the Cenozoic era?

8. Identifying Relationships How might a decrease in competition between species lead to the sudden appearance of many new species?

Interpreting Graphics

9. Look at the illustration below. On the Earth-history clock shown, 1 h equals 383 million years, and 1 min equals 6.4 million years. In millions of years, how much more time is represented by the Proterozoic eon than by the Phanerozoic eon?

SCILINKS
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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Geologic Time
SciLinks code: HSM0668

Model-Making Lab

How Do You Stack Up?

OBJECTIVES

Make a model of a geologic column.

Interpret the geologic history represented by the geologic column you have made.

MATERIALS

- paper, white
- pencil
- pencils or crayons, assorted colors
- ruler, metric
- scissors
- tape, transparent

SAFETY

According to the principle of superposition, in undisturbed sequences of sedimentary rock, the oldest layers are on the bottom. Geologists use this principle to determine the relative age of the rocks in a small area. In this activity, you will model what geologists do by drawing sections of different rock outcrops. Then, you will create a part of the geologic column, showing the geologic history of the area that contains all of the outcrops.

Procedure

1. Use a metric ruler and a pencil to draw four boxes on a blank piece of paper. Each box should be 3 cm wide and at least 6 cm tall. (You can trace the boxes shown on the next page.)
2. With colored pencils, copy the illustrations of the four outcrops on the next page. Copy one illustration in each of the four boxes. Use colors and patterns similar to those shown.
3. Pay close attention to the contact between layers-straight or wavy. Straight lines represent bedding planes, where deposition was continuous. Wavy lines represent unconformities, where rock layers may be missing. The top of each outcrop is incomplete, so it should be a jagged line. (Assume that the bottom of the lowest layer is a bedding plane.)
4. Use a black crayon or pencil to add the symbols representing fossils to the layers in your drawings. Pay attention to the shapes of the fossils and the layers that they are in.
5. Write the outcrop number on the back of each section.
6. Carefully cut the outcrops out of the paper, and lay the individual outcrops next to each other on your desk or table.
7. Find layers that have the same rocks and contain the same fossils. Move each outcrop up or down to line up similar layers next to each other.
8. If unconformities appear in any of the outcrops, there may be rock layers missing. You may need to examine other sections to find out what fits between the layers above and below the unconformities. Leave room for these layers by cutting the outcrops along the unconformities (wavy lines).

9. Eventually, you should be able to make a geologic column that represents all four of the outcrops. It will show rock types and fossils for all the known layers in the area.

10. Tape the pieces of paper together in a pattern that represents the complete geologic column.

Analyze the Results

1. **Examining Data** How many layers are in the part of the geologic column that you modeled?

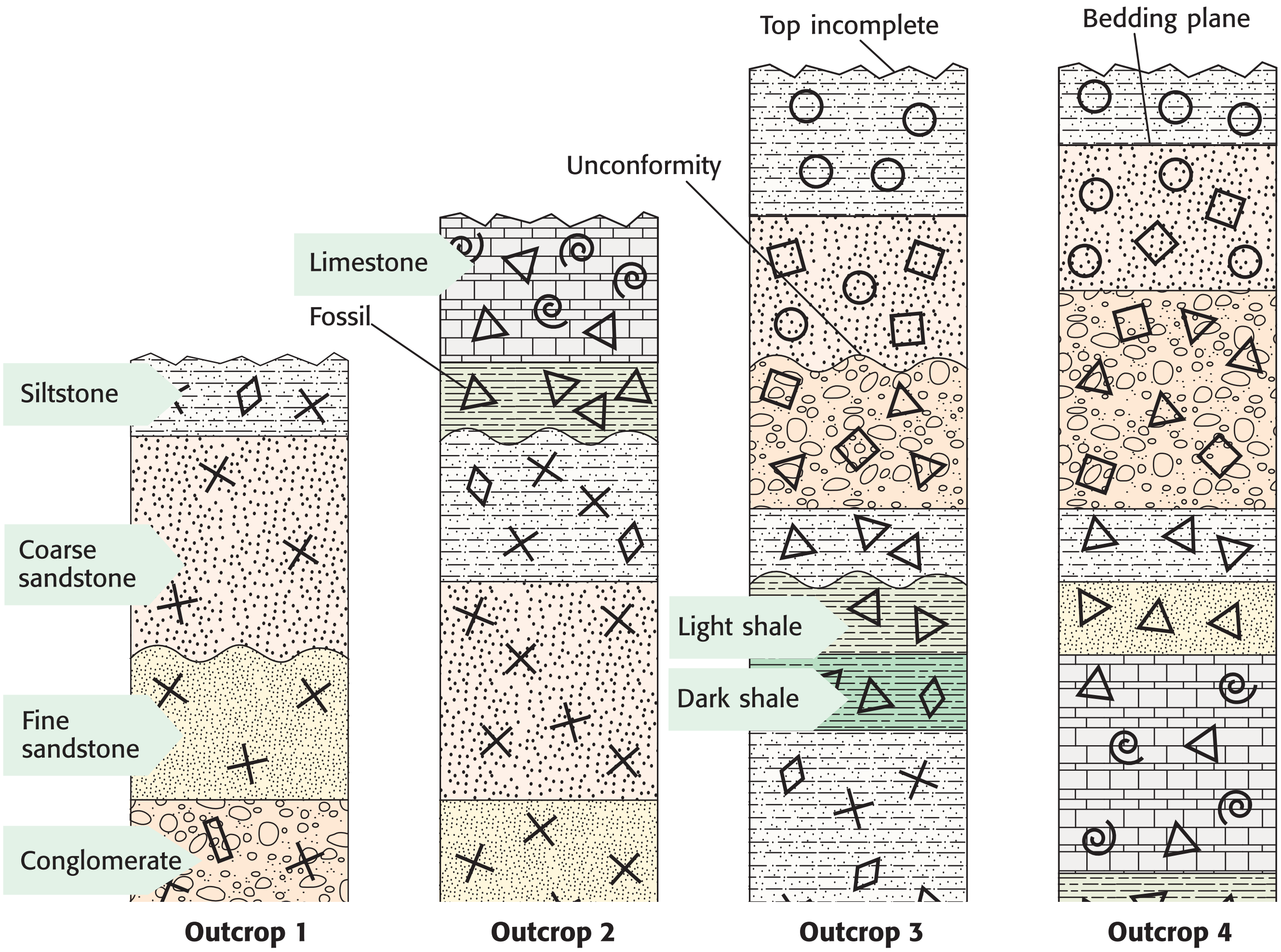
2. **Examining Data** Which is the oldest layer in your column? Which rock layer is the youngest? How do you know? Describe these layers in terms of rock type or the fossils they contain.

3. **Classifying** List the fossils in your column from oldest to youngest. Label the youngest and oldest fossils.

4. **Analyzing Data** Look at the unconformity in outcrop 2. Which rock layers are partially or completely missing? How do you know?

Draw Conclusions

5. **Drawing Conclusions** Which (if any) fossils can be used as index fossils for a single layer? Why are these fossils considered index fossils? What method(s) would be required to determine the absolute age of these fossils?



Chapter Review

USING KEY TERMS

1. In your own words, write a definition for each of the following terms: *superposition, geologic column,* and *geologic time scale.*

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

2. *uniformitarianism* and *catastrophism*

3. *relative dating* and *absolute dating*

4. *trace fossil* and *index fossil*

UNDERSTANDING KEY IDEAS

Multiple Choice

5. Which of the following does not describe catastrophic change?
   - **a.** widespread
   - **b.** sudden
   - **c.** rare
   - **d.** gradual

6. Scientists assign relative ages by using
   - **a.** absolute dating.
   - **b.** the principle of superposition.
   - **c.** radioactive half-lives.
   - **d.** carbon-14 dating.

7. Which of the following is a trace fossil?
   - **a.** an insect preserved in amber
   - **b.** a mammoth frozen in ice
   - **c.** wood replaced by minerals
   - **d.** a dinosaur trackway

8. The largest divisions of geologic time are called
   - **a.** periods.
   - **b.** eras.
   - **c.** eons.
   - **d.** epochs.

9. Rock layers cut by a fault formed
   - **a.** after the fault.
   - **b.** before the fault.
   - **c.** at the same time as the fault.
   - **d.** There is not enough information to determine the answer.

10. Of the following isotopes, which is stable?
    - **a.** uranium-238
    - **b.** potassium-40
    - **c.** carbon-12
    - **d.** carbon-14

11. A surface that represents a missing part of the geologic column is called a(n)
    - **a.** intrusion.
    - **b.** fault.
    - **c.** unconformity.
    - **d.** fold.

12. Which method of radiometric dating is used mainly to date the remains of organisms that lived within the last 50,000 years?
    - **a.** carbon-14 dating
    - **b.** potassium-argon dating
    - **c.** uranium-lead dating
    - **d.** rubidium-strontium dating

Short Answer

13 Describe three processes by which fossils form.

14 Identify the role of uniformitarianism in Earth science.

15 Explain how radioactive decay occurs.

16 Describe two ways in which scientists use fossils to determine environmental change.

17 Explain why ice cores are important to the study of Earth's climate history.

CRITICAL THINKING

18 **Concept Mapping** Use the following terms to create a concept map: *age, half-life, absolute dating, radioactive decay, radiometric dating, relative dating, superposition, geologic column,* and *isotopes*.

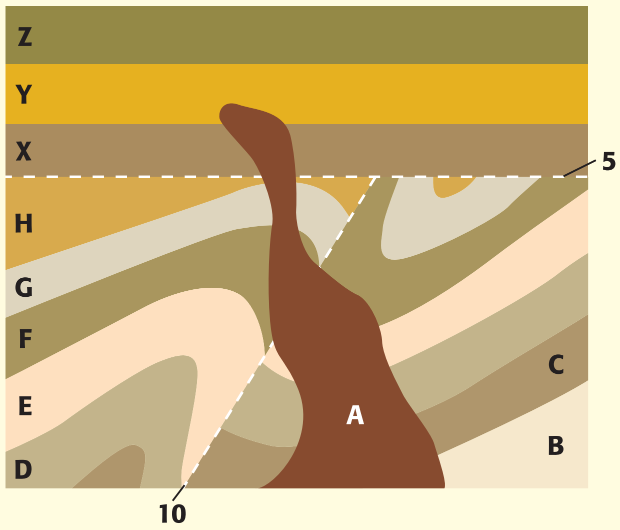
19 **Applying Concepts** Identify how changes in environmental conditions can affect the survival of a species.

20 **Identifying Relationships** Why do paleontologists know more about hard-bodied organisms than about soft-bodied organisms?

21 **Analyzing Processes** Why isn't a 100 million–year-old fossilized tree made of wood?

INTERPRETING GRAPHICS

Use the diagram below to answer the questions that follow.

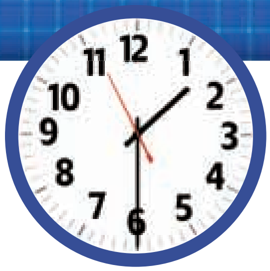


22 Is intrusion **A** younger or older than layer **X**? Explain.

23 What feature is marked by **5**?

24 Is intrusion **A** younger or older than fault **10**? Explain.

25 Other than the intrusion and faulting, what event happened in layers **B**, **C**, **D**, **E**, **F**, **G**, and **H**? Number this event, the intrusion, and the faulting in the order that they happened.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Three hundred million years ago, the region that is now Illinois had a different climate than it does today. Swamps and shallow bays covered much of the area. No fewer than 500 species of plants and animals lived in this environment. Today, the remains of these organisms are found beautifully preserved within nodules. Nodules are round or oblong structures usually composed of cemented sediments that sometimes contain the fossilized hard parts of plants and animals. The Illinois nodules are exceptional because the soft parts of organisms are found together with hard parts. For this reason, these nodules are found in fossil collections around the world.

1. In the passage, what is the meaning of the word *exceptional*?

A beautiful
B extraordinary
C average
D large

2. According to the passage, which of the following statements about nodules is correct?

F Nodules are rarely round or oblong.
G Nodules are usually composed of cemented sediment.
H Nodules are not found in present-day Illinois.
I Nodules always contain fossils.

3. Which of the following is a fact in the passage?

A The Illinois nodules are not well known outside of Illinois.
B Illinois has had the same climate throughout Earth's history.
C Both the hard and soft parts of organisms are preserved in the Illinois nodules.
D Fewer than 500 species of plants and animals have been found in Illinois nodules.

Passage 2 In 1995, paleontologist Paul Sereno and his team were working in an unexplored region of Morocco when they made an astounding find—an enormous dinosaur skull! The skull measured approximately 1.6 m in length, which is about the height of a refrigerator. Given the size of the skull, Sereno concluded that the skeleton of the animal it came from must have been about 14 m long—about as big as a school bus. The dinosaur was even larger than *Tyrannosaurus rex*! The newly discovered 90 million–year-old predator most likely chased other dinosaurs by running on large, powerful hind legs, and its bladelike teeth meant certain death for its prey.

1. In the passage, what does the word *astounding* mean?

A important
B new
C incredible
D one of a kind

2. Which of the following is evidence that the dinosaur described in the passage was a predator?

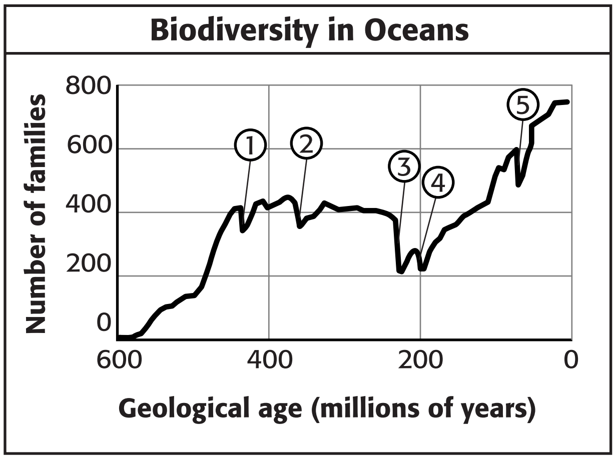
F It had bladelike teeth.
G It had a large skeleton.
H It was found with the bones of a smaller animal nearby.
I It is 90 million years old.

3. What types of information do you think that fossil teeth provide about an organism?

A the color of its skin
B the types of food it ate
C the speed that it ran
D the mating habits it had

INTERPRETING GRAPHICS

Use the graph below to answer the questions that follow.



1. At which point in Earth's history did the greatest mass-extinction event take place?

A at point **1**, the Ordovician-Silurian boundary
B at point **3**, the Permian-Triassic boundary
C at point **4**, the Triassic-Jurassic boundary
D at point **5**, the Cretaceous-Tertiary boundary

2. Immediately following the Cretaceous-Tertiary extinction, represented by point **5**, approximately how many families of marine organisms remained in the Earth's oceans?

F 200 marine families
G 300 marine families
H 500 marine families
I 700 marine families

3. Approximately how many million years ago did the Ordovician-Silurian mass-extinction event, represented by point **1**, take place?

A 200 million years ago
B 250 million years ago
C 350 million years ago
D 420 million years ago

MATH

Read each question below, and choose the best answer.

1. Carbon-14 is a radioactive isotope with a half-life of 5,730 years. How much carbon-14 would remain in a sample that is 11,460 years old?

A 12.5%
B 25%
C 50%
D 100%

2. If a sample contains an isotope with a half-life of 10,000 years, how old would the sample be if 1/8 of the original isotope remained in the sample?

F 20,000 years
G 30,000 years
H 40,000 years
I 50,000 years

3. If a sample contains an isotope with a half-life of 5,000 years, how old would the sample be if 1/4 of the original isotope remained in the sample?

A 10,000 years
B 20,000 years
C 30,000 years
D 40,000 years

4. If Earth history spans 4.6 billion years and the Phanerozoic eon was 543 million years, what percentage of Earth history does the Phanerozoic eon represent?

F about 6%
G about 12%
H about 18%
I about 24%

5. Humans live in the Holocene epoch. If the Holocene epoch has lasted approximately 10,000 years, what percentage of the Quaternary period, which began 1.8 million years ago, is represented by the Holocene?

A about 0.0055%
B about 0.055%
C about 0.55%
D about 5.5%

Science in Action

Scientific Debate

Feathered Dinosaurs

One day in 1996, a Chinese farmer broke open a rock he found in the bed of an ancient dry lake. What he found inside the rock became one of the most exciting paleontological discoveries of the 20th century. Preserved inside were the remains of a dinosaur. The dinosaur had a large head; powerful jaws; sharp, jagged teeth; and, most important of all, a row of featherlike structures along the backbone. Scientists named the dinosaur *Sinosauropteryx*, or "Chinese dragon wing." *Sinosauropteryx* and the remains of other "feathered" dinosaurs recently discovered in China have led some scientists to hypothesize that feathers evolved through theropod (three-toed) dinosaurs. Other paleontologists disagree. They believe the structures along the backbone of these dinosaurs are not feathers but the remains of elongated spines, like those that run down the head and back of an iguana.

Language Arts ACTIVITY

Paleontologists often give dinosaurs names that describe something unusual about the animal's head, body, feet, or size. These names have Greek or Latin roots. Research the names of some dinosaurs, and find out what the names mean. Create a list of dinosaur names and their meanings.

Science, Technology, and Society

DNA and a Mammoth Discovery

In recent years, scientists have unearthed several mammoths that had been frozen in ice in Siberia and other remote northern locations. Bones, fur, food in the stomach, and even dung have all been found in good condition. Some scientists hoped that DNA extracted from the mammoths might lead to the cloning of this animal, which became extinct about 10,000 years ago. But the DNA might not be able to be duplicated by scientists. However, DNA samples may nevertheless help scientists understand why mammoths became extinct. One theory about why mammoths became extinct is that they were killed off by disease. Using DNA taken from fossilized mammoth bone, hair, or dung, scientists can check to see if it contains the DNA of a disease-causing pathogen that led to the extinction of the mammoths.

Math ACTIVITY

The male Siberian mammoth reached a height of about 3 m at the shoulder. Females reached a height of about 2.5 m at the shoulder. What is the ratio of the maximum height of a female Siberian mammoth to the height of a male Siberian mammoth?

People in Science

Lizzie May

Amateur Paleontologist For Lizzie May, summer vacations have meant trips into the Alaskan wilderness with her stepfather, geologist/paleontologist Kevin May. The purpose of these trips has not been for fun. Instead, Kevin and Lizzie have been exploring the Alaskan wilderness for the remains of ancient life—dinosaurs, in particular.

At age 18, Lizzie May has gained the reputation of being Alaska's most famous teenage paleontologist. It is a reputation that is well deserved. To date, Lizzie has collected hundreds of dinosaur bones and located important sites of dinosaur, bird, and mammal tracks. In her honor and as a result of her hard work in the field, scientists named the skeleton of a dinosaur discovered by the Mays "Lizzie." "Lizzie" is a duckbill dinosaur, or hadrosaur, that lived approximately 90 million years ago. "Lizzie" is the oldest dinosaur ever found in Alaska and one of the earliest known duckbill dinosaurs in North America.

The Mays have made other, equally exciting discoveries. On one summer trip, Kevin and Lizzie located six dinosaur and bird track sites that dated back 97 million to 144 million years. On another trip, the Mays found a fossil marine reptile more than 200 million years old—an ichthyosaur—that had to be removed with the help of a military helicopter. You have to wonder what other exciting adventures are in store for Lizzie and Kevin!

Social Studies Activity

WRITING SKILL Lizzie May is not the only young person to have made a mark in dinosaur paleontology. Using the Internet or another source, research people such as Bucky Derflinger, Johnny Maurice, Brad Riney, and Wendy Sloboda, who as young people made contributions to the field of dinosaur study. Write a short essay summarizing your findings.

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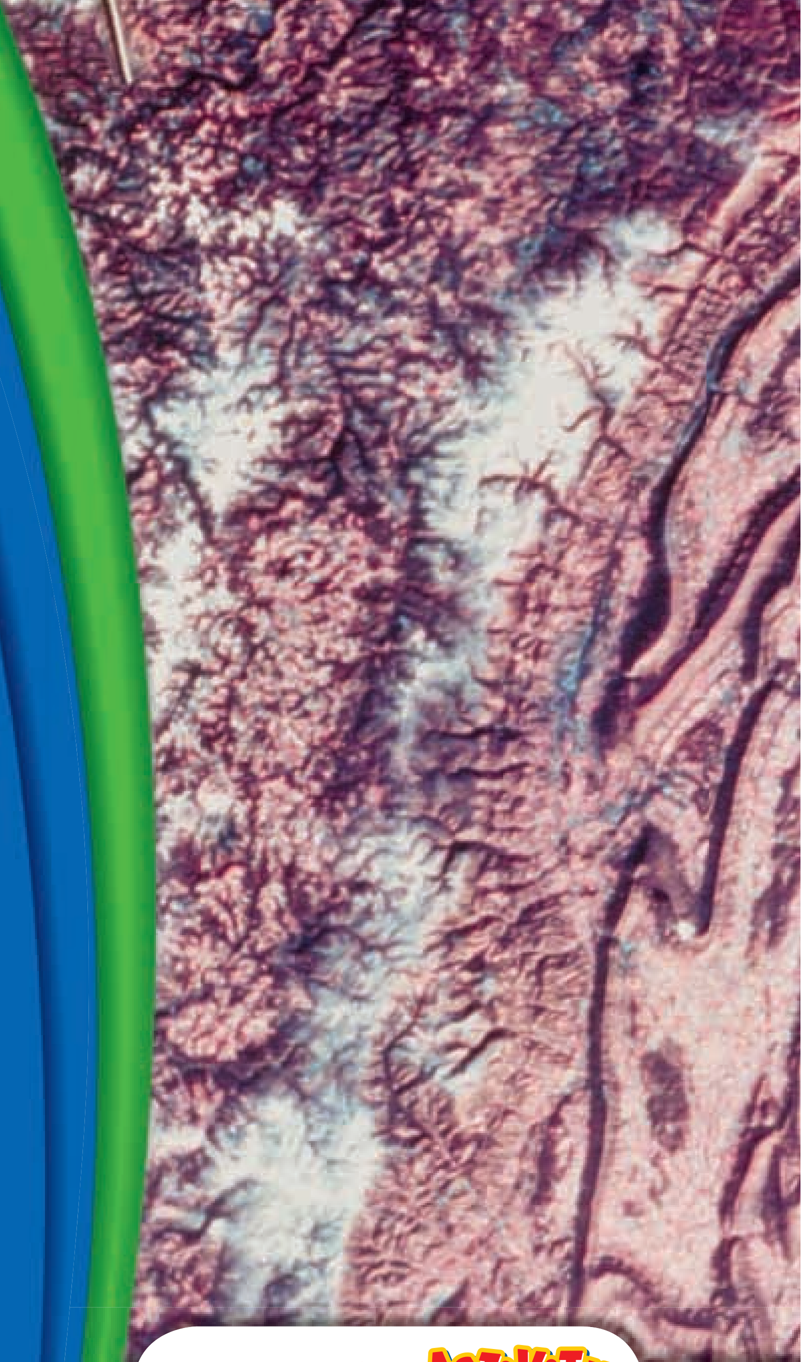
16

The Restless Earth

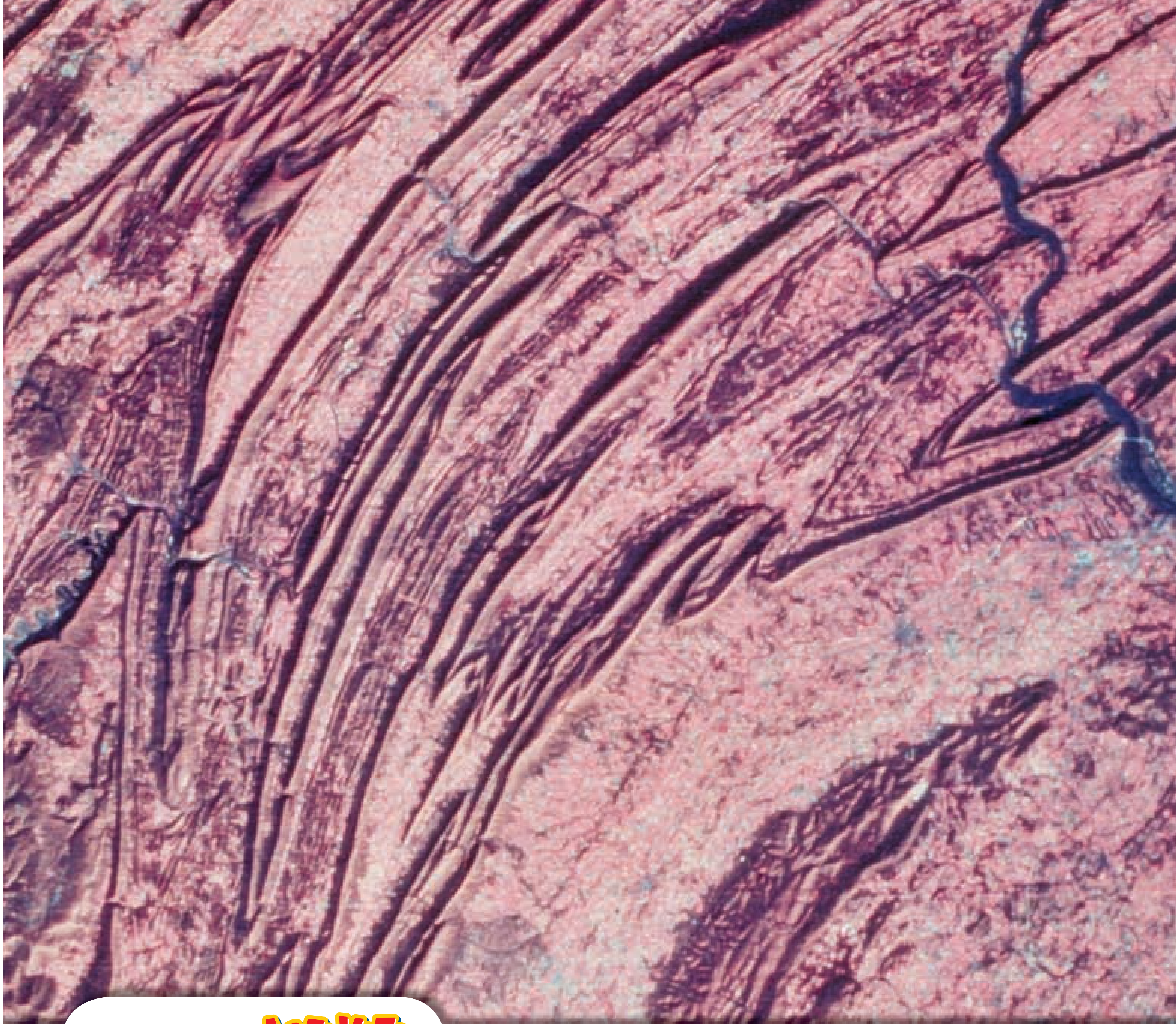


About the PHOTO

This photograph shows a satellite view of the Appalachian Mountains. The Appalachian Mountains formed approximately 300 million years ago by the collision of the African continent and the North American continent.

PRE-READING ACTIVITY

FOLDNOTES **Key-Term Fold** Before you read the chapter, create the FoldNote entitled "Key-Term Fold" described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.



START-UP ACTIVITY

Continental Collisions

As you can see, continents not only move but can also crash into each other. In this activity, you will model the collision of two continents.

Procedure

1. Obtain **two stacks of paper** that are each about 1 cm thick.
2. Place the two stacks of paper on a **flat surface,** such as a desk.
3. Very slowly, push the stacks of paper together so that they collide. Continue to push the stacks until the paper in one of the stacks folds over.

Analysis

1. What happens to the stacks of paper when they collide with each other?
2. Are all of the pieces of paper pushed upward? If not, what happens to the pieces that are not pushed upward?
3. What type of landform will most likely result from this continental collision?

SECTION 1

Restless Continents

Have you ever looked at a map of the world and noticed how the coastlines of continents on opposite sides of the oceans appear to fit together like the pieces of a puzzle? Is it just coincidence that the coastlines fit together well? Is it possible that the continents were actually together sometime in the past?

READING WARM-UP

Objectives

- Describe Wegener's hypothesis of continental drift.
- Explain how sea-floor spreading provides a way for continents to move.
- Describe how new oceanic lithosphere forms at mid-ocean ridges.
- Explain how magnetic reversals provide evidence for sea-floor spreading.

Terms to Learn

continental drift
sea-floor spreading

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Wegener's Continental Drift Hypothesis

One scientist who looked at the pieces of this puzzle was Alfred Wegener (VAY guh nuhr). In the early 1900s, he wrote about his hypothesis of *continental drift*. **Continental drift** is the hypothesis that states that the continents once formed a single landmass, broke up, and drifted to their present locations. This hypothesis seemed to explain a lot of puzzling observations, including the observation of how well continents fit together.

Continental drift also explained why fossils of the same plant and animal species are found on continents that are on different sides of the Atlantic Ocean. Many of these ancient species could not have crossed the Atlantic Ocean. As you can see in **Figure 1,** without continental drift, this pattern of fossils would be hard to explain. In addition to fossils, similar types of rock and evidence of the same ancient climatic conditions were found on several continents.

Reading Check **How did fossils provide evidence for Wegener's hypothesis of continental drift?** (*See the Appendix for answers to Reading Checks.*)

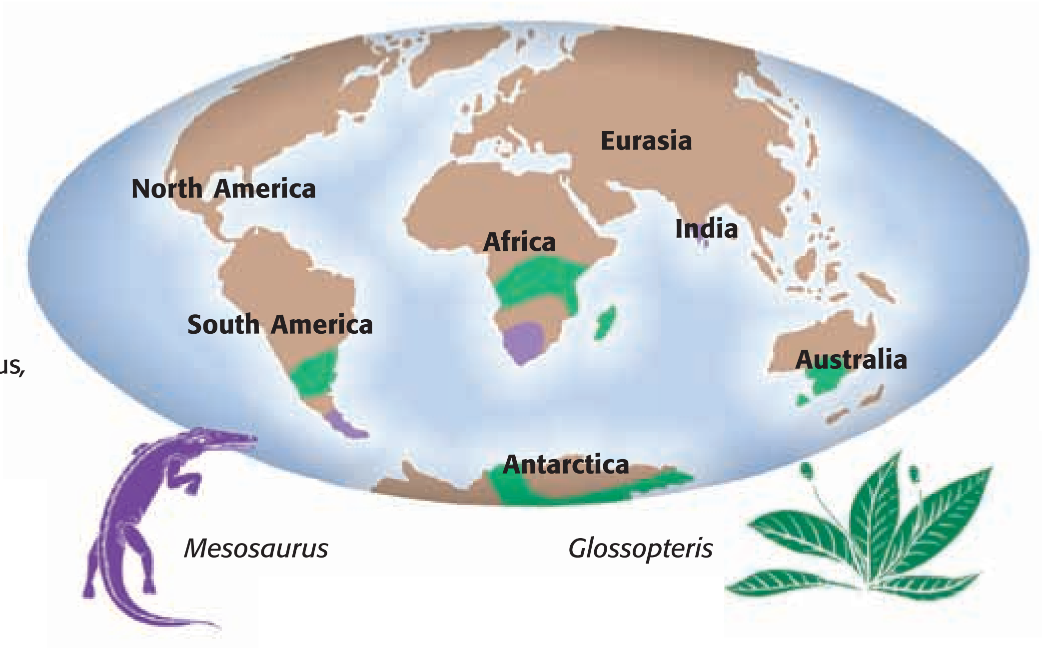
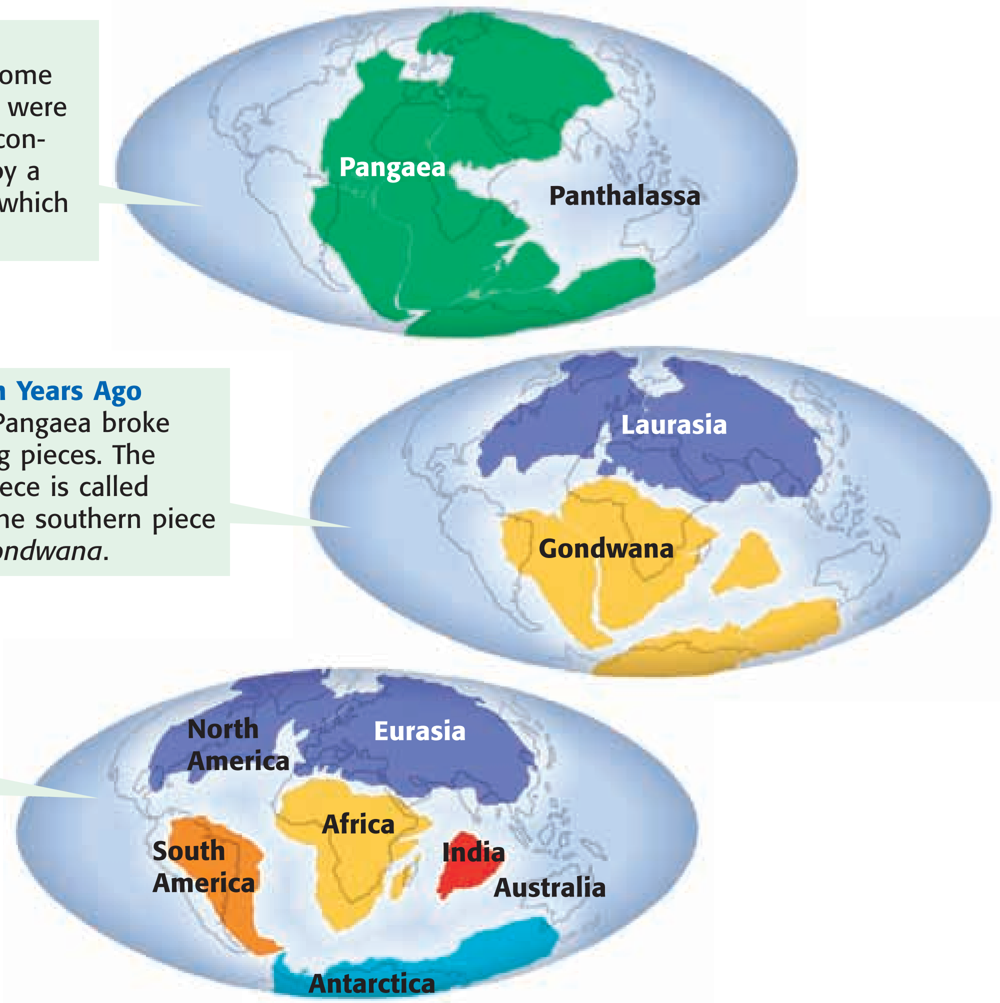


Figure 1 *Fossils of* Mesosaurus, *a small, aquatic reptile, and* Glossopteris, *an ancient plant species, have been found on several continents.*

Figure 2 The Drifting Continents



245 Million Years Ago
Pangaea existed when some of the earliest dinosaurs were roaming the Earth. The continent was surrounded by a sea called *Panthalassa*, which means "all sea."

180 Million Years Ago
Gradually, Pangaea broke into two big pieces. The northern piece is called *Laurasia*. The southern piece is called *Gondwana*.

65 Million Years Ago
By the time the dinosaurs became extinct, Laurasia and Gondwana had split into smaller pieces.

The Breakup of Pangaea

Wegener made many observations before proposing his hypothesis of continental drift. He thought that all of the present continents were once joined in a single, huge continent. Wegener called this continent *Pangaea* (pan JEE uh), which is Greek for "all earth." We now know from the hypothesis of plate tectonics that Pangaea existed about 245 million years ago. We also know that Pangaea further split into two huge continents—Laurasia and Gondwana—about 180 million years ago. As shown in **Figure 2,** these two continents split again and formed the continents we know today.

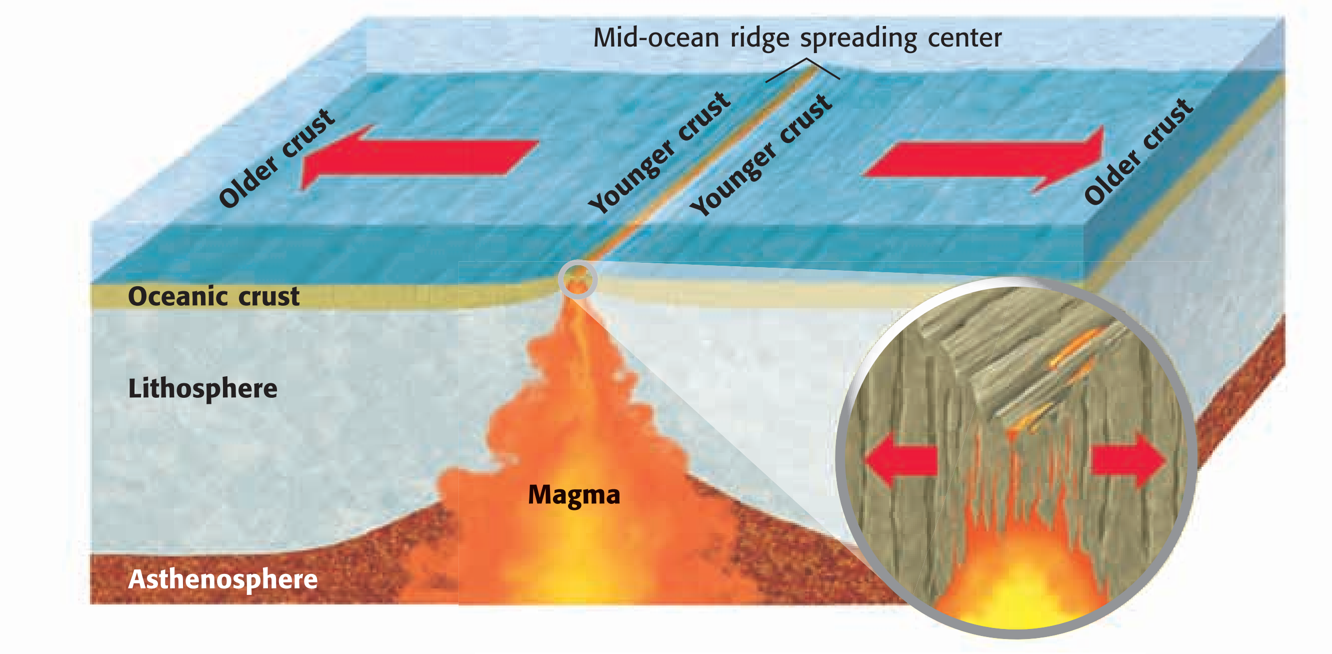
continental drift the hypothesis that states that the continents once formed a single landmass, broke up, and drifted to their present locations

Sea-Floor Spreading

When Wegener put forth his hypothesis of continental drift, many scientists would not accept his hypothesis. From the calculated strength of the rocks, it did not seem possible for the crust to move in this way. During Wegener's life, no one knew the answer. It wasn't until many years later that evidence provided some clues to the forces that moved the continents.

Figure 3 **Sea-Floor Spreading**

Sea-floor spreading creates new oceanic lithosphere at mid-ocean ridges.



sea-floor spreading the process by which new oceanic lithosphere forms as magma rises toward the surface and solidifies

Mid-Ocean Ridges and Sea-Floor Spreading

A chain of submerged mountains runs through the center of the Atlantic Ocean. The chain is part of a worldwide system of mid-ocean ridges. Mid-ocean ridges are underwater mountain chains that run through Earth's ocean basins.

Mid-ocean ridges are places where sea-floor spreading takes place. **Sea-floor spreading** is the process by which new oceanic lithosphere forms as magma rises toward the surface and solidifies. As the tectonic plates move away from each other, the sea floor spreads apart and magma fills in the gap. As this new crust forms, the older crust gets pushed away from the mid-ocean ridge. As **Figure 3** shows, the older crust is farther away from the mid-ocean ridge than the younger crust is.

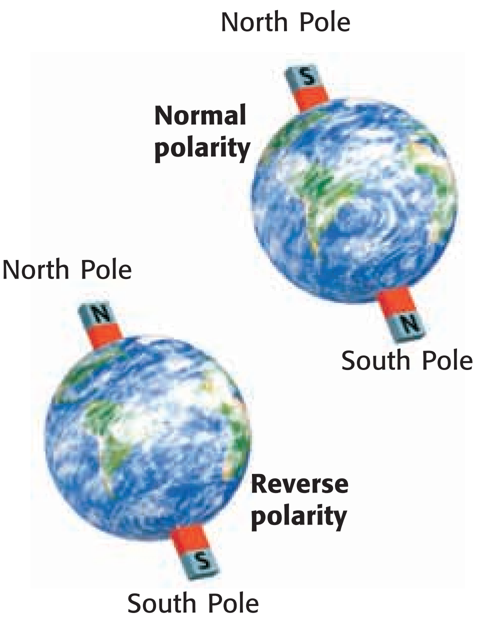


Figure 4 *The polarity of Earth's magnetic field changes over time.*

Evidence for Sea-Floor Spreading: Magnetic Reversals

Some of the most important evidence of sea-floor spreading comes from magnetic reversals recorded in the ocean floor. Throughout Earth's history, the north and south magnetic poles have changed places many times. When the poles change places, the polarity of Earth's magnetic poles changes, as shown in **Figure 4.** When Earth's magnetic poles change places, this change is called a *magnetic reversal*.

Magnetic Reversals and Sea-Floor Spreading

The molten rock at the mid-ocean ridges contains tiny grains of magnetic minerals. These mineral grains contain iron and are like compasses. They align with the magnetic field of the Earth. When the molten rock cools, the record of these tiny compasses remains in the rock. This record is then carried slowly away from the spreading center of the ridge as sea-floor spreading occurs.

As you can see in **Figure 5,** when the Earth's magnetic field reverses, the magnetic mineral grains align in the opposite direction. The new rock records the direction of the Earth's magnetic field. As the sea floor spreads away from a mid-ocean ridge, it carries with it a record of magnetic reversals. This record of magnetic reversals was the final proof that sea-floor spreading does occur.

Reading Check **How is a record of magnetic reversals recorded in molten rock at mid-ocean ridges?**

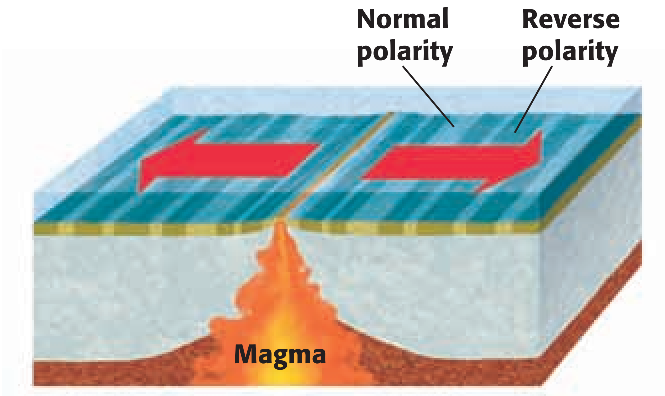


Figure 5 *Magnetic reversals in oceanic crust are shown as bands of light blue and dark blue oceanic crust. Light blue bands indicate normal polarity, and dark blue bands indicate reverse polarity.*

SECTION Review

Summary

- Wegener hypothesized that continents drift apart from one another and have done so in the past.
- The process by which new oceanic lithosphere forms at mid-ocean ridges is called sea-floor spreading.
- As tectonic plates separate, the sea floor spreads apart and magma fills in the gap.
- Magnetic reversals are recorded over time in oceanic crust.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *continental drift* and *sea-floor spreading*.

Understanding Key Ideas

2. At mid-ocean ridges,
   a. the crust is older.
   b. sea-floor spreading occurs.
   c. oceanic lithosphere is destroyed.
   d. tectonic plates are colliding.
3. Explain how oceanic lithosphere forms at mid-ocean ridges.
4. What is magnetic reversal?

Math Skills

5. If a piece of sea floor has moved 50 km in 5 million years, what is the yearly rate of sea-floor motion?

Critical Thinking

6. **Identifying Relationships** Explain how magnetic reversals provide evidence for sea-floor spreading.
7. **Applying Concepts** Why do bands indicating magnetic reversals appear to be of similar width on both sides of a mid-ocean ridge?
8. **Applying Concepts** Why do you think that old rocks are rare on the ocean floor?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Tectonic Plates
SciLinks code: HSM1497

SECTION 2

The Theory of Plate Tectonics

It takes an incredible amount of force to move a tectonic plate! But where does this force come from?

READING WARM-UP

Objectives

- Describe the three types of tectonic plate boundaries.
- Describe the three forces thought to move tectonic plates.
- Explain how scientists measure the rate at which tectonic plates move.

Terms to Learn

plate tectonics
convergent boundary
divergent boundary
transform boundary

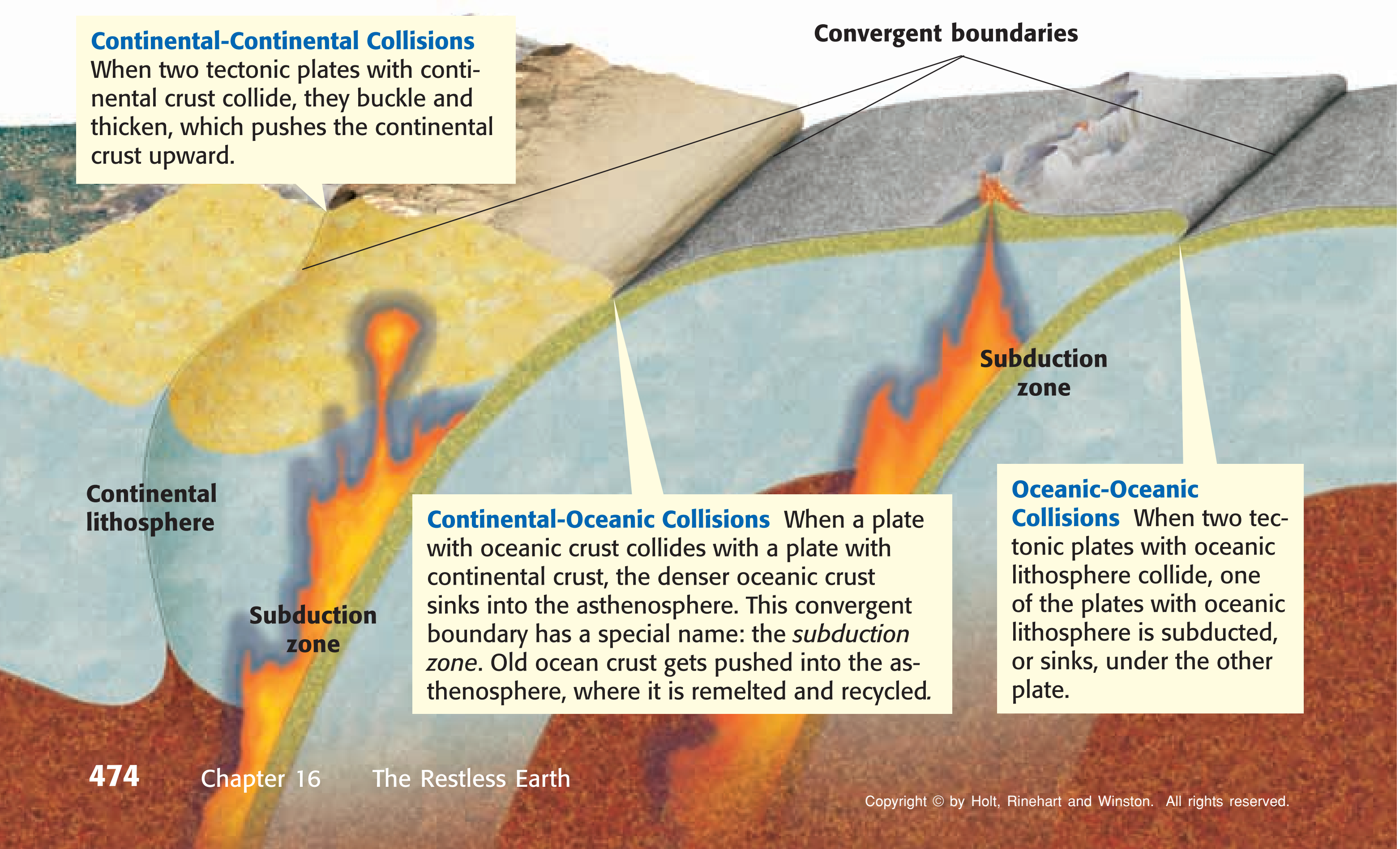
READING STRATEGY

Brainstorming The key idea of this section is plate tectonics. Brainstorm words and phrases related to plate tectonics.

As scientists' understanding of mid-ocean ridges and magnetic reversals grew, scientists formed a theory to explain how tectonic plates move. **Plate tectonics** is the theory that the Earth's lithosphere is divided into tectonic plates that move around on top of the asthenosphere. In this section, you will learn what causes tectonic plates to move. But first you will learn about the different types of tectonic plate boundaries.

Tectonic Plate Boundaries

A boundary is a place where tectonic plates touch. All tectonic plates share boundaries with other tectonic plates. These boundaries are divided into three types: convergent, divergent, and transform. The type of boundary depends on how the tectonic plates move relative to one another. Tectonic plates can collide, separate, or slide past each other. Earthquakes can occur at all three types of plate boundaries. The figure below shows examples of tectonic plate boundaries.



Continental-Continental Collisions When two tectonic plates with continental crust collide, they buckle and thicken, which pushes the continental crust upward.

Continental-Oceanic Collisions When a plate with oceanic crust collides with a plate with continental crust, the denser oceanic crust sinks into the asthenosphere. This convergent boundary has a special name: the *subduction zone*. Old ocean crust gets pushed into the asthenosphere, where it is remelted and recycled.

Oceanic-Oceanic Collisions When two tectonic plates with oceanic lithosphere collide, one of the plates with oceanic lithosphere is subducted, or sinks, under the other plate.

Convergent Boundaries

When two tectonic plates collide, the boundary between them is a **convergent boundary.** What happens at a convergent boundary depends on the kind of crust at the leading edge of each tectonic plate. The three types of convergent boundaries are continental-continental boundaries, continental-oceanic boundaries, and oceanic-oceanic boundaries.

Divergent Boundaries

When two tectonic plates separate, the boundary between them is called a **divergent boundary.** New sea floor forms at divergent boundaries. Mid-ocean ridges are the most common type of divergent boundary.

Transform Boundaries

When two tectonic plates slide past each other horizontally, the boundary between them is a **transform boundary.** The San Andreas Fault in California is a good example of a transform boundary. This fault marks the place where the Pacific and North American plates are sliding past each other.

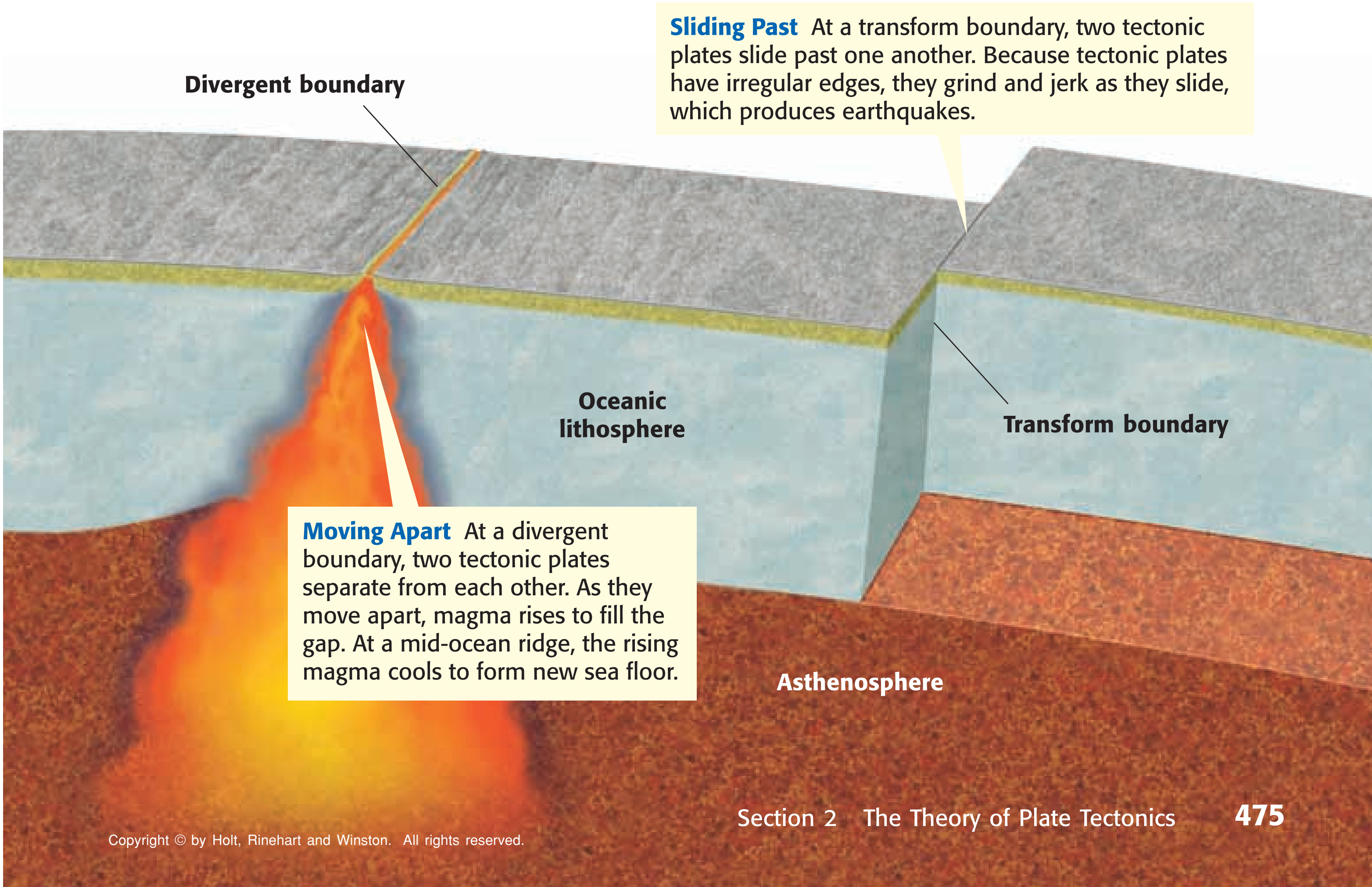
Reading Check **Define the term *transform boundary*.** (*See the Appendix for answers to Reading Checks.*)

plate tectonics the theory that explains how large pieces of the Earth's outermost layer, called *tectonic plates,* move and change shape

convergent boundary the boundary formed by the collision of two lithospheric plates

divergent boundary the boundary between two tectonic plates that are moving away from each other

transform boundary the boundary between tectonic plates that are sliding past each other horizontally

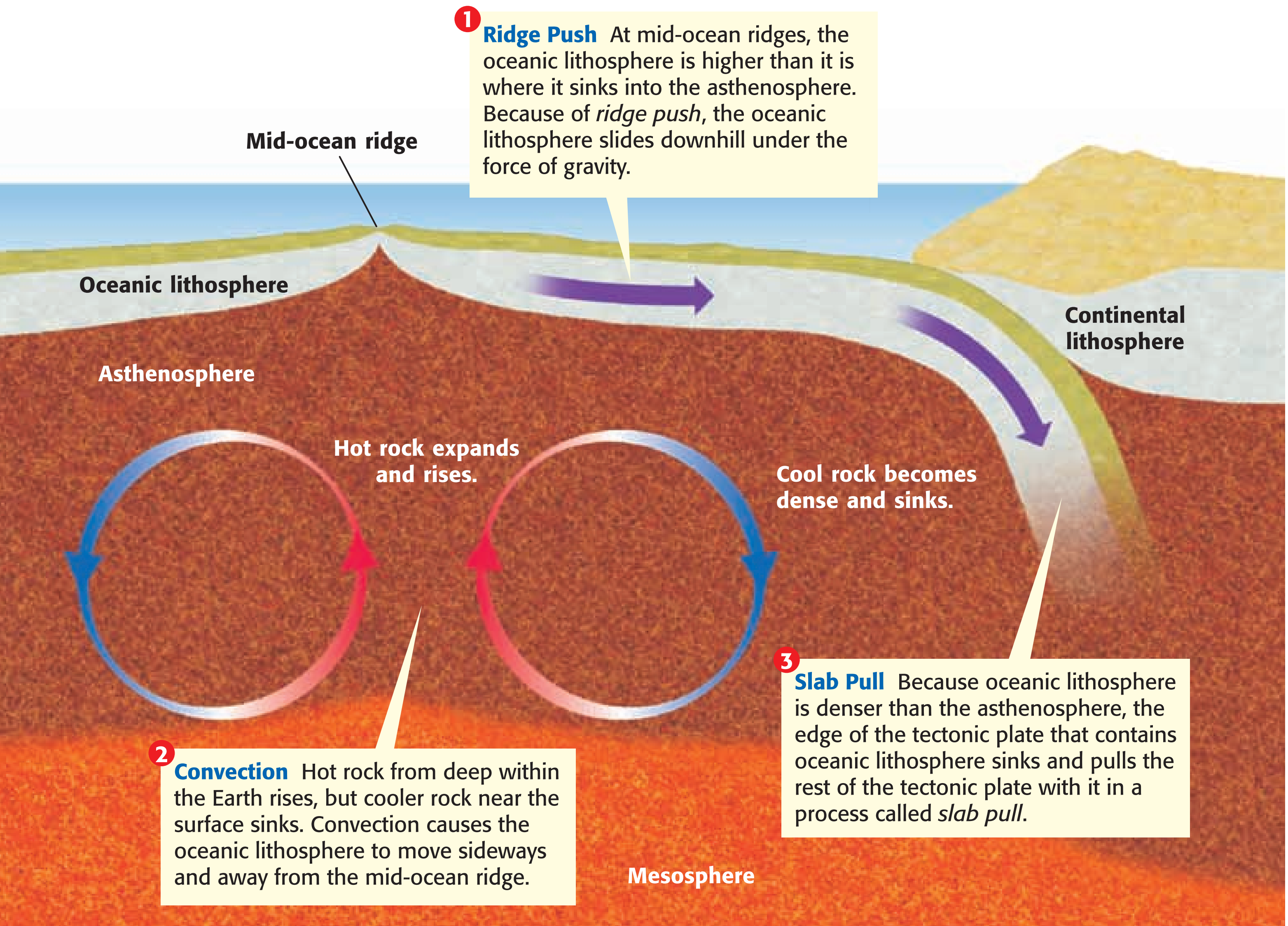


Possible Causes of Tectonic Plate Motion

You have learned that plate tectonics is the theory that the lithosphere is divided into tectonic plates that move around on top of the asthenosphere. What causes the motion of tectonic plates? Remember that the solid rock of the asthenosphere flows very slowly. This movement occurs because of changes in density within the asthenosphere. These density changes are caused by the outward flow of thermal energy from deep within the Earth. When rock is heated, it expands, becomes less dense, and tends to rise to the surface of the Earth. As the rock gets near the surface, the rock cools, becomes more dense, and tends to sink. **Figure 1** shows three possible causes of tectonic plate motion.

Reading Check **What causes changes in density in the asthenosphere?**

Figure 1 **Three Possible Driving Forces of Plate Tectonics**



Tracking Tectonic Plate Motion

How fast do tectonic plates move? The answer to this question depends on many factors, such as the type and shape of the tectonic plate and the way that the tectonic plate interacts with the tectonic plates that surround it. Tectonic plate movements are so slow and gradual that you can't see or feel them—the movement is measured in centimeters per year.

The Global Positioning System

Scientists use a system of satellites called the *global positioning system* (GPS), shown in **Figure 2,** to measure the rate of tectonic plate movement. Radio signals are continuously beamed from satellites to GPS ground stations, which record the exact distance between the satellites and the ground station. Over time, these distances change slightly. By recording the time it takes for the GPS ground stations to move a given distance, scientists can measure the speed at which each tectonic plate moves.

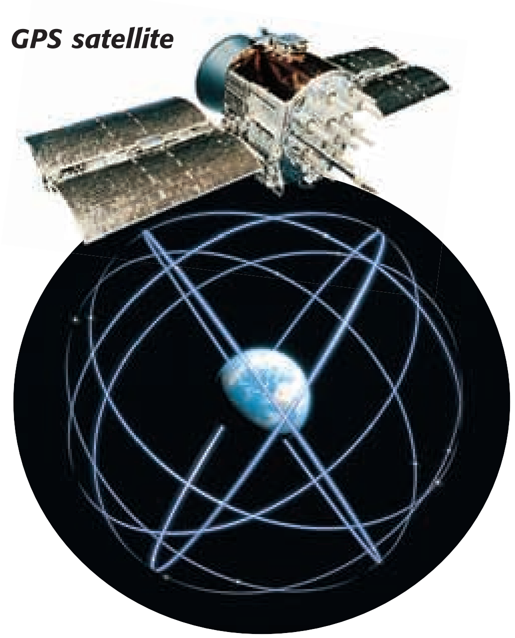


Figure 2 *The image above shows the orbits of the GPS satellites.*

SECTION Review

Summary

- Boundaries between tectonic plates are classified as convergent, divergent, or transform.
- Ridge push, convection, and slab pull are three possible driving forces of plate tectonics.
- Scientists use data from a system of satellites called the global positioning system to measure the rate of motion of tectonic plates.

Using Key Terms

1. In your own words, write a definition for the term *plate tectonics*.

Understanding Key Ideas

2. The speed a tectonic plate moves per year is best measured in
   a. kilometers per year.
   b. centimeters per year.
   c. meters per year.
   d. millimeters per year.
3. Briefly describe three possible driving forces of tectonic plate movement.
4. Explain how scientists use GPS to measure the rate of tectonic plate movement.

Math Skills

5. If an orbiting satellite has a diameter of 60 cm, what is the total surface area of the satellite? (Hint: *surface area* = $4\pi r^2$)

Critical Thinking

6. **Identifying Relationships** When convection takes place in the mantle, why does cool rock material sink and warm rock material rise?
7. **Analyzing Processes** Why does oceanic crust sink beneath continental crust at convergent boundaries?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Plate Tectonics
SciLinks code: HSM1171

SECTION 3

Deforming the Earth's Crust

Have you ever tried to bend something, only to have it break? Take long, uncooked pieces of spaghetti, and bend them very slowly but only a little. Now, bend them again, but this time, bend them much farther and faster. What happened?

READING WARM-UP

Objectives

- Describe two types of stress that deform rocks.
- Describe three major types of folds.
- Explain the differences between the three major types of faults.
- Identify the most common types of mountains.
- Explain the difference between uplift and subsidence.

Terms to Learn

compression	fault
tension	uplift
folding	subsidence

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

How can a material bend at one time and break at another time? The answer is that the stress you put on the material was different each time. *Stress* is the amount of force per unit area on a given material. The same principle applies to the rocks in the Earth's crust. Different things happen to rock when different types of stress are applied.

Deformation

The process by which the shape of a rock changes because of stress is called *deformation*. In the example above, the spaghetti deformed in two different ways—by bending and by breaking. **Figure 1** illustrates this concept. The same thing happens in rock layers. Rock layers bend when stress is placed on them. But when enough stress is placed on rocks, they can reach their elastic limit and break.

Compression and Tension

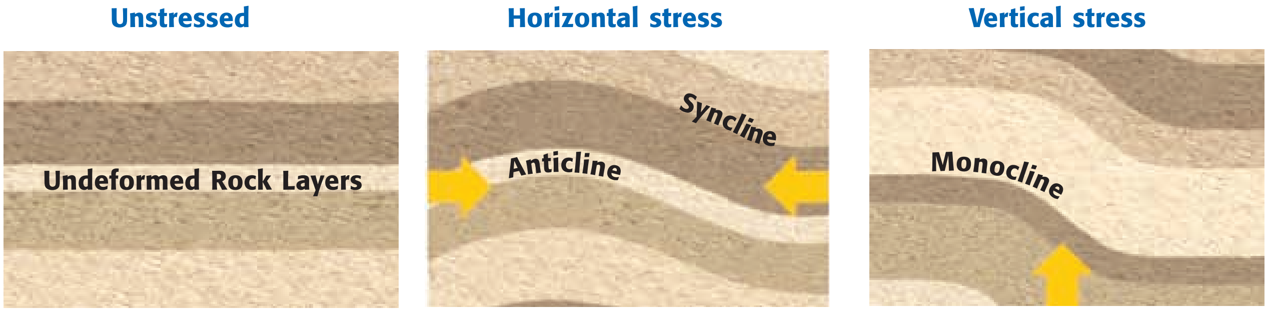
The type of stress that occurs when an object is squeezed, such as when two tectonic plates collide, is called **compression.** When compression occurs at a convergent boundary, large mountain ranges can form.

Another form of stress is *tension*. **Tension** is stress that occurs when forces act to stretch an object. As you might guess, tension occurs at divergent plate boundaries, such as mid-ocean ridges, when two tectonic plates pull away from each other.

Reading Check **How do the forces of plate tectonics cause rock to deform?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *When a small amount of stress is placed on uncooked spaghetti, the spaghetti bends. Additional stress causes the spaghetti to break.*

Figure 2 **Folding: When Rock Layers Bend Because of Stress**



Folding

The bending of rock layers because of stress in the Earth's crust is called **folding.** Scientists assume that all rock layers started as horizontal layers. So, when scientists see a fold, they know that deformation has taken place.

compression stress that occurs when forces act to squeeze an object

tension stress that occurs when forces act to stretch an object

folding the bending of rock layers due to stress

Types of Folds

Depending on how the rock layers deform, different types of folds are made. **Figure 2** shows the two most common types of folds—*anticlines*, or upward-arching folds, and *synclines,* downward, troughlike folds. Another type of fold is a *monocline*. In a monocline, rock layers are folded so that both ends of the fold are horizontal. Imagine taking a stack of paper and laying it on a table. Think of the sheets of paper as different rock layers. Now put a book under one end of the stack. You can see that both ends of the sheets are horizontal, but all of the sheets are bent in the middle.

Folds can be large or small. The largest folds are measured in kilometers. Other folds are also obvious but are much smaller. These small folds can be measured in centimeters. **Figure 3** shows examples of large and small folds.

Figure 3 *The large photo shows mountain-sized folds in the Rocky Mountains. The small photo shows a rock that has folds smaller than a penknife.*

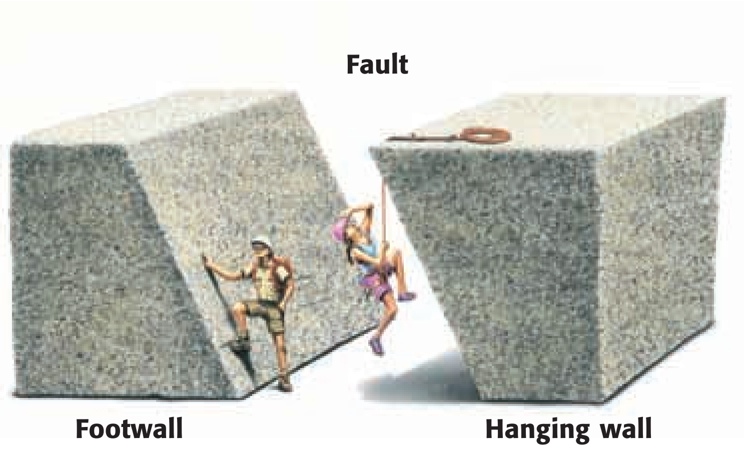


Figure 4 *The position of a fault block determines whether it is a hanging wall or a footwall.*

Faulting

Some rock layers break when stress is applied to them. The surface along which rocks break and slide past each other is called a **fault.** The blocks of crust on each side of the fault are called *fault blocks.*

When a fault is not vertical, understanding the difference between its two sides—the *hanging wall* and the *footwall*—is useful. **Figure 4** shows the difference between a hanging wall and a footwall. Two main types of faults can form. The type of fault that forms depends on how the hanging wall and footwall move in relationship to each other.

fault a break in a body of rock along which one block slides relative to another

Normal Faults

A *normal fault* is shown in **Figure 5.** When a normal fault moves, it causes the hanging wall to move down relative to the footwall. Normal faults usually occur when tectonic forces cause tension that pulls rocks apart.

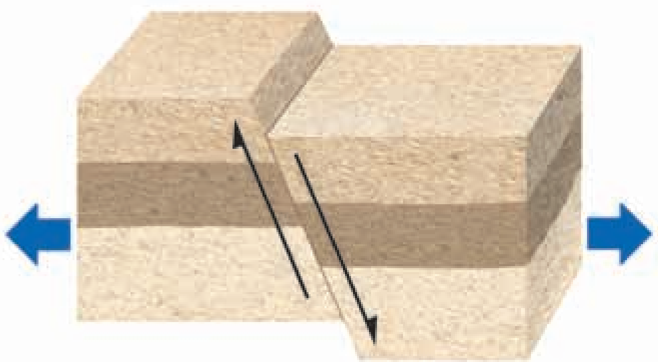
Reverse Faults

A *reverse fault* is shown in **Figure 5.** When a reverse fault moves, it causes the hanging wall to move up relative to the footwall. This movement is the reverse of a normal fault. Reverse faults usually happen when tectonic forces cause compression that pushes rocks together.

Reading Check **How does the hanging wall in a normal fault move in relation to a reverse fault?**

Figure 5 **Normal and Reverse Faults**

Normal Fault When rocks are pulled apart because of tension, normal faults often form.



Reverse Fault When rocks are pushed together by compression, reverse faults often form.

Figure 6 *The photo at left is a normal fault. The photo at right is a reverse fault.*

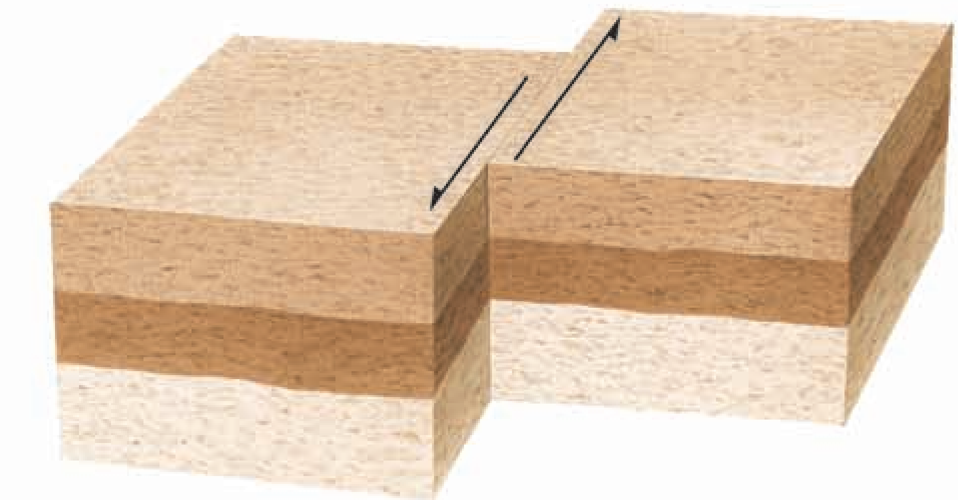
Telling the Difference Between Faults

It's easy to tell the difference between a normal fault and a reverse fault in drawings with arrows. But what types of faults are shown in **Figure 6**? You can certainly see the faults, but which one is a normal fault, and which one is a reverse fault? In the top left photo in **Figure 6,** one side has obviously moved relative to the other side. You can tell this fault is a normal fault by looking at the order of sedimentary rock layers. If you compare the two dark layers near the surface, you can see that the hanging wall has moved down relative to the footwall.

Strike-Slip Faults

A third major type of fault is called a *strike-slip fault*. An illustration of a strike-slip fault is shown in **Figure 7.** *Strike-slip faults* form when opposing forces cause rock to break and move horizontally. If you were standing on one side of a strike-slip fault looking across the fault when it moved, the ground on the other side would appear to move to your left or right. The San Andreas Fault in California is a spectacular example of a strike-slip fault.

Figure 7 *When rocks are moved horizontally by opposing forces, strike-slip faults often form.*



Quick Lab

Modeling Strike-Slip Faults

1. Use **modeling clay** to construct a box that is 6 in. × 6 in. × 4 in. Use different colors of clay to represent different horizontal layers.
2. Using **scissors,** cut the box down the middle. Place **two 4 in. × 6 in. index cards** inside the cut so that the two sides of the box slide freely.
3. Using gentle pressure, slide the two sides horizontally past one another.
4. How does this model illustrate the motion that occurs along a strike-slip fault?

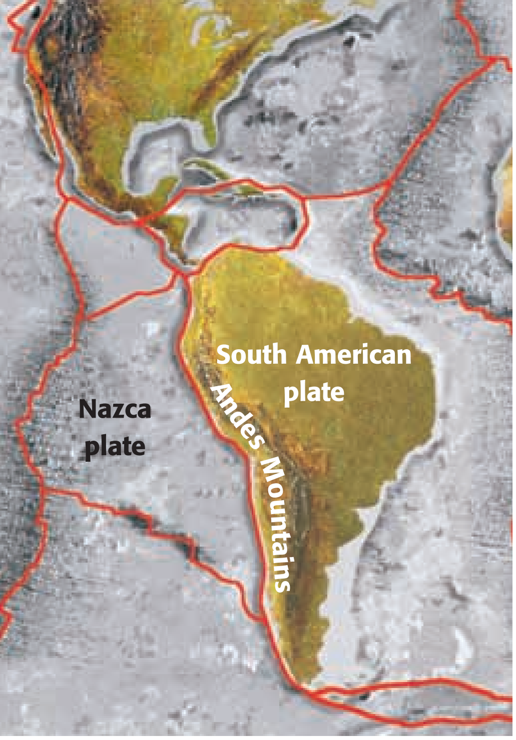


Figure 8 *The Andes Mountains formed on the edge of the South American plate where it converges with the Nazca plate.*

Plate Tectonics and Mountain Building

You have just learned about several ways the Earth's crust changes because of the forces of plate tectonics. When tectonic plates collide, land features that start as folds and faults can eventually become large mountain ranges. Mountains exist because tectonic plates are continually moving around and colliding with one another. As shown in **Figure 8,** the Andes Mountains formed above the subduction zone where two tectonic plates converge.

When tectonic plates undergo compression or tension, they can form mountains in several ways. Take a look at three of the most common types of mountains—folded mountains, fault-block mountains, and volcanic mountains.

Folded Mountains

The highest mountain ranges in the world are made up of folded mountains. These ranges form at convergent boundaries where continents have collided. *Folded mountains* form when rock layers are squeezed together and pushed upward. If you place a pile of paper on a table and push on opposite edges of the pile, you will see how folded mountains form.

An example of a folded mountain range that formed at a convergent boundary is shown in **Figure 9.** About 390 million years ago, the Appalachian Mountains formed when the landmasses that are now North America and Africa collided. Other examples of mountain ranges that consist of very large and complex folds are the Alps in central Europe, the Ural Mountains in Russia, and the Himalayas in Asia.

Reading Check **Explain how folded mountains form.**

Figure 9 *The Appalachian Mountains were once as tall as the Himalaya Mountains but have been worn down by hundreds of millions of years of weathering and erosion.*

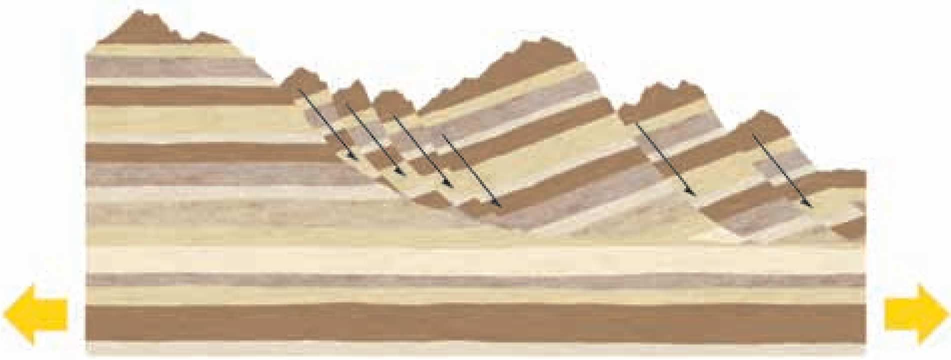


Figure 10 *When the crust is subjected to tension, the rock can break along a series of normal faults, which creates fault-block mountains.*

Fault-Block Mountains

When tectonic forces put enough tension on the Earth's crust, a large number of normal faults can result. *Fault-block mountains* form when this tension causes large blocks of the Earth's crust to drop down relative to other blocks. **Figure 10** shows one way that fault-block mountains form.

When sedimentary rock layers are tilted up by faulting, they can produce mountains that have sharp, jagged peaks. As shown in **Figure 11,** the Tetons in western Wyoming are a spectacular example of fault-block mountains.

Volcanic Mountains

Most of the world's major volcanic mountains are located at convergent boundaries where oceanic crust sinks into the asthenosphere at subduction zones. The rock that is melted in subduction zones forms magma, which rises to the Earth's surface and erupts to form *volcanic mountains*. Volcanic mountains can also form under the sea. Sometimes these mountains can rise above the ocean surface to become islands. The majority of tectonically active volcanic mountains on the Earth have formed around the tectonically active rim of the Pacific Ocean. The rim has become known as the *Ring of Fire*.

CONNECTION TO Social Studies

WRITING SKILL **The Naming of the Appalachian Mountains** How did the Appalachian Mountains get their name? It is believed that the Appalachian Mountains were named by Spanish explorers in North America during the 16th century. It is thought that the name was taken from a Native American tribe called *Appalachee,* who lived in northern Florida. Research other geological features in the United States, including mountains and rivers, whose names are of Native American origin. Write the results of your research in a short essay.

Figure 11 *The Tetons formed as a result of tectonic forces that stretched the Earth's crust and caused it to break in a series of normal faults.*

Uplift and Subsidence

Vertical movements in the crust are divided into two types—uplift and subsidence. The rising of regions of Earth's crust to higher elevations is called **uplift.** Rocks that are uplifted may or may not be highly deformed. The sinking of regions of Earth's crust to lower elevations is known as **subsidence** (suhb SIED'ns). Unlike some uplifted rocks, rocks that subside do not undergo much deformation.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5TECW.**

uplift the rising of regions of the Earth's crust to higher elevations

subsidence the sinking of regions of the Earth's crust to lower elevations

Uplifting of Depressed Rocks

The formation of mountains is one type of uplift. Uplift can also occur when large areas of land rise without deforming. One way areas rise without deforming is a process known as *rebound*. When the crust rebounds, it slowly springs back to its previous elevation. Uplift often happens when a weight is removed from the crust.

Subsidence of Cooler Rocks

Rocks that are hot take up more space than cooler rocks. For example, the lithosphere is relatively hot at mid-ocean ridges. The farther the lithosphere is from the ridge, the cooler and denser the lithosphere becomes. Because the oceanic lithosphere now takes up less volume, the ocean floor subsides.

Tectonic Letdown

Subsidence can also occur when the lithosphere becomes stretched in rift zones. A *rift zone* is a set of deep cracks that forms between two tectonic plates that are pulling away from each other. As tectonic plates pull apart, stress between the plates causes a series of faults to form along the rift zone. As shown in **Figure 12,** the blocks of crust in the center of the rift zone subside.

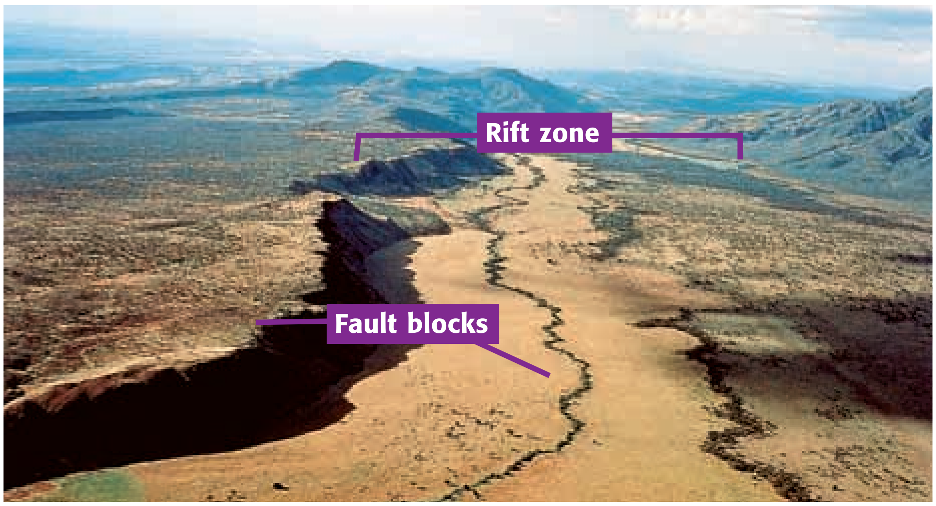


Figure 12 *The East African Rift, from Ethiopia to Kenya, is part of a divergent boundary, but you can see how the crust has subsided relative to the blocks at the edge of the rift zone.*

SECTION Review

Summary

- Compression and tension are two forces of plate tectonics that can cause rock to deform.
- Folding occurs when rock layers bend because of stress.
- Faulting occurs when rock layers break because of stress and then move on either side of the break.
- Mountains are classified as either folded, fault-block, or volcanic depending on how they form.
- Mountain building is caused by the movement of tectonic plates. Folded mountains and volcanic mountains form at convergent boundaries. Fault-block mountains form at divergent boundaries.
- Uplift and subsidence are the two types of vertical movement in the Earth's crust. Uplift occurs when regions of the crust rise to higher elevations. Subsidence occurs when regions of the crust sink to lower elevations.

Using Key Terms

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

1. *compression* and *tension*
2. *uplift* and *subsidence*

Understanding Key Ideas

3. The type of fault in which the hanging wall moves up relative to the footwall is called a
   a. strike-slip fault.
   b. fault-block fault.
   c. normal fault.
   d. reverse fault.
4. Describe three types of folds.
5. Describe three types of faults.
6. Identify the most common types of mountains.
7. What is rebound?
8. What are rift zones, and how do they form?

Critical Thinking

9. **Predicting Consequences** If a fault occurs in an area where rock layers have been folded, which type of fault is it likely to be? Why?
10. **Identifying Relationships** Would you expect to see a folded mountain range at a mid-ocean ridge? Explain your answer.

Interpreting Graphics

Use the diagram below to answer the questions that follow.

11. What type of fault is shown in the diagram?
12. At what kind of tectonic boundary would you most likely find this fault?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Faults; Mountain Building
SciLinks code: HSM0566; HSM0999

Using Scientific Methods

Model-Making Lab

Convection Connection

Some scientists think that convection currents within the Earth's mantle cause tectonic plates to move. Because these convection currents cannot be observed directly, scientists use models to simulate the process. In this activity, you will make your own model to simulate tectonic plate movement.

OBJECTIVES

Model convection currents to simulate plate tectonic movement.

Draw conclusions about the role of convection in plate tectonics.

MATERIALS

- craft sticks (2)
- food coloring
- gloves, heat-resistant
- hot plates, small (2)
- pan, aluminum, rectangular
- pencil
- ruler, metric
- thermometers (3)
- water, cold
- wooden blocks

SAFETY

Ask a Question

1. How can I make a model of convection currents in the Earth's mantle?

Form a Hypothesis

2. Turn the question above into a statement in which you give your best guess about what factors will have the greatest effect on your convection model.

Test the Hypothesis

3. Place two hot plates side by side in the center of your lab table. Be sure that they are away from the edge of the table.
4. Place the pan on top of the hot plates. Slide the wooden blocks under the pan to support the ends. Make sure that the pan is level and secure.
5. Fill the pan with cold water. The water should be at least 4 cm deep. Turn on the hot plates, and put on your gloves.
6. After a minute or two, tiny bubbles will begin to rise in the water above the hot plates. Gently place two craft sticks on the water's surface.
7. Use the pencil to align the sticks parallel to the short ends of the pan. The sticks should be about 3 cm apart and near the center of the pan.
8. As soon as the sticks begin to move, place a drop of food coloring in the center of the pan. Observe what happens to the food coloring.

9. With the help of a partner, hold one thermometer bulb just under the water at the center of the pan. Hold the other two thermometers just under the water near the ends of the pan. Record the temperatures.
10. When you are finished, turn off the hot plates. After the water has cooled, carefully empty the water into a sink.

Analyze the Results

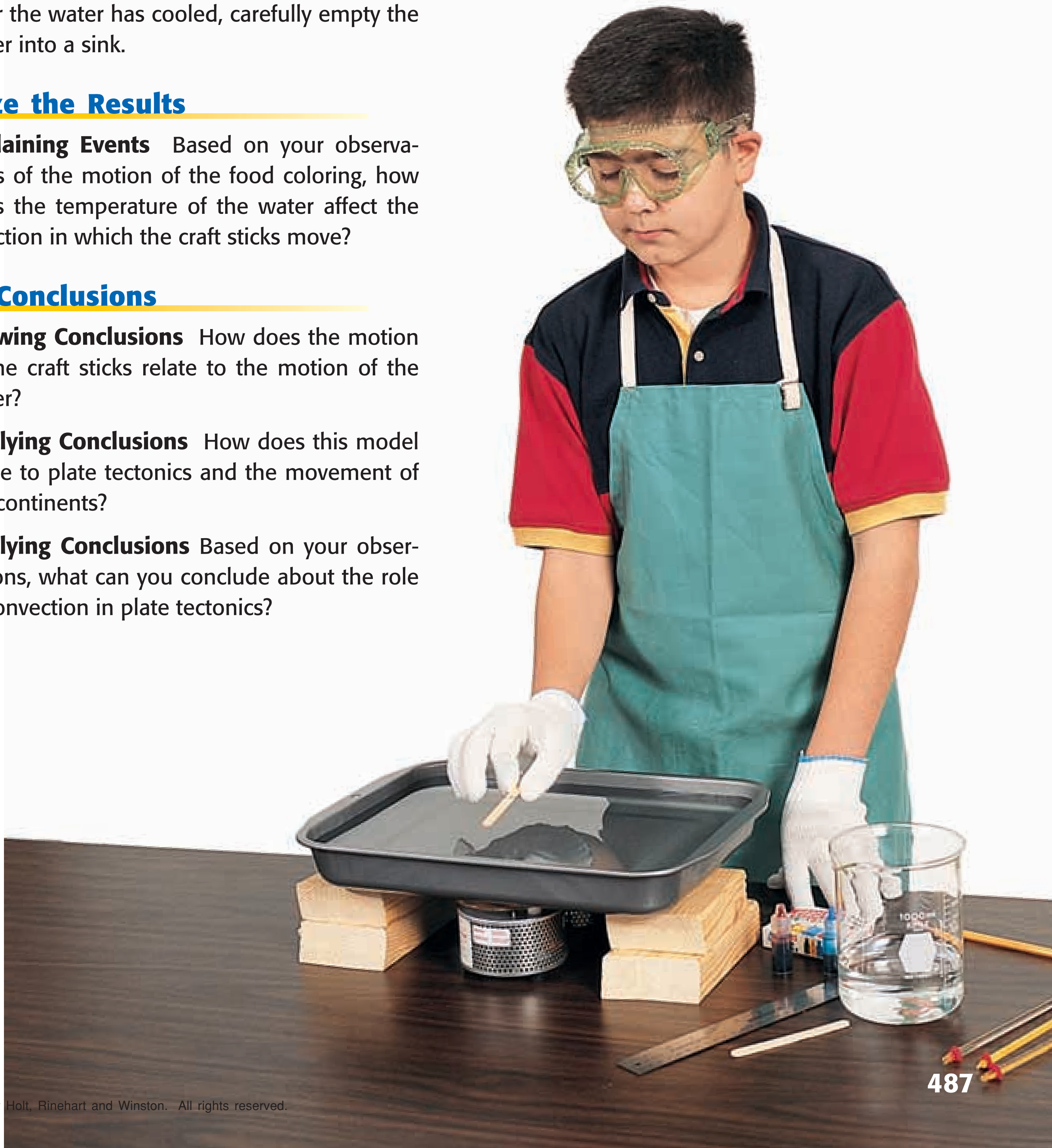
1. **Explaining Events** Based on your observations of the motion of the food coloring, how does the temperature of the water affect the direction in which the craft sticks move?

Draw Conclusions

2. **Drawing Conclusions** How does the motion of the craft sticks relate to the motion of the water?
3. **Applying Conclusions** How does this model relate to plate tectonics and the movement of the continents?
4. **Applying Conclusions** Based on your observations, what can you conclude about the role of convection in plate tectonics?

Applying Your Data

Suggest a substance other than water that might be used to model convection in the mantle. Consider using a substance that flows more slowly than water.



Chapter Review

USING KEY TERMS

1. Use the following terms in the same sentence: *convergent boundary, divergent boundary,* and *strike-slip boundary*.

Complete each of the following sentences by choosing the correct term from the word bank.

folding	uplift
tension	continental drift

2. The hypothesis that continents can drift apart and have done so in the past is known as ___.

3. ___ occurs when rock layers bend because of stress.

4. ___ is stress that occurs when forces act to stretch an object.

5. The rising of regions of the Earth's crust to higher elevations is called ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Which of the following is NOT a possible driving force of plate tectonics?
   - **a.** convection
   - **b.** ridge push
   - **c.** deformation
   - **d.** slab pull

7. The type of tectonic plate boundary that forms from a collision between two tectonic plates is a
   - **a.** divergent plate boundary.
   - **b.** transform plate boundary.
   - **c.** convergent plate boundary.
   - **d.** normal plate boundary.

8. The bending of rock layers due to stress in the Earth's crust is known as
   - **a.** uplift.
   - **b.** folding.
   - **c.** faulting.
   - **d.** subsidence.

9. The type of fault in which the hanging wall moves up relative to the footwall is called a
   - **a.** strike-slip fault.
   - **b.** fault-block fault.
   - **c.** normal fault.
   - **d.** reverse fault.

10. The type of mountain that forms when rock layers are squeezed together and pushed upward is the
    - **a.** folded mountain.
    - **b.** fault-block mountain.
    - **c.** volcanic mountain.
    - **d.** strike-slip mountain.

11. Scientists' knowledge of sea-floor spreading has come primarily from
    - **a.** studying magnetic reversals in oceanic crust.
    - **b.** using a system of satellites called the *global positioning system*.
    - **c.** studying the deformation of rock at sea-floor spreading centers.
    - **d.** studying the pattern of fossils on different continents.

Short Answer

12. Describe the three types of folds.

13. How do magnetic reversals provide evidence of sea-floor spreading?

14 Explain how sea-floor spreading provides a way for continents to move.

15 Describe two types of stress that deform rock.

16 What is the global positioning system (GPS), and how does GPS allow scientists to measure the rate of motion of tectonic plates?

CRITICAL THINKING

17 **Concept Mapping** Use the following terms to create a concept map: *sea-floor spreading, convergent boundary, divergent boundary, subduction zone, transform boundary,* and *tectonic plates*.

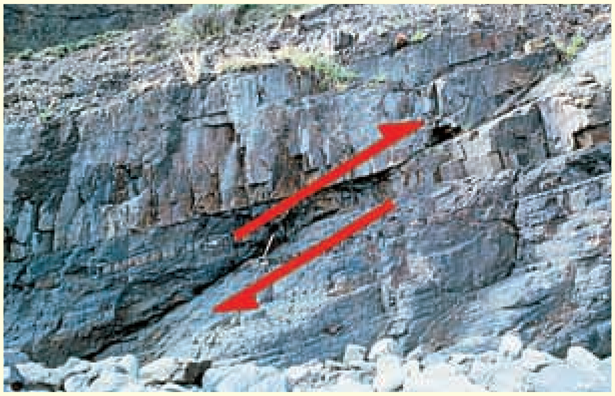
18 **Applying Concepts** Why does oceanic lithosphere sink at subduction zones but not at mid-ocean ridges?

19 **Identifying Relationships** New tectonic material continually forms at divergent boundaries. Tectonic plate material is also continually destroyed in subduction zones at convergent boundaries. Do you think that the total amount of lithosphere formed on the Earth is about equal to the amount destroyed? Why?

20 **Applying Concepts** Folded mountains usually form at the edge of a tectonic plate. How can you explain folded mountain ranges located in the middle of a tectonic plate?

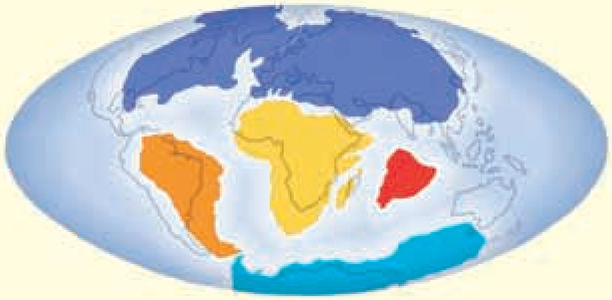
INTERPRETING GRAPHICS

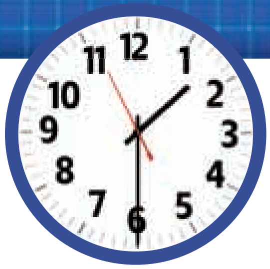
Use the figures below to answer the questions that follow.



21 Which type of fault does the upper figure illustrate? Which kind of stress causes this type of fault to form?

22 Which type of fault does the lower figure illustrate? Which kind of stress causes this type of fault to form?





Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The Deep Sea Drilling Project was a program to retrieve and research rocks below the ocean to test the hypothesis of sea-floor spreading. For 15 years, scientists studying sea-floor spreading conducted research aboard the ship *Glomar Challenger*. Holes were drilled in the sea floor from the ship. Long, cylindrical lengths of rock, called *cores,* were obtained from the drill holes. By examining fossils in the cores, scientists discovered that rock closest to mid-ocean ridges was the youngest. The farther from the ridge the holes were drilled, the older the rock in the cores was. This evidence supported the idea that sea-floor spreading creates new lithosphere at mid-ocean ridges.

1. In the passage, what does *conducted* mean?

A directed
B led
C carried on
D guided

2. Why were cores drilled in the sea floor from the *Glomar Challenger*?

F to determine the depth of the crust
G to find minerals in the sea-floor rock
H to examine fossils in the sea-floor rock
I to find oil and gas in the sea-floor rock

3. Which of the following statements is a fact according to the passage?

A Rock closest to mid-ocean ridges is older than rock at a distance from mid-ocean ridges.
B One purpose of scientific research on the *Glomar Challenger* was to gather evidence for sea-floor spreading.
C Fossils examined by scientists came directly from the sea floor.
D Evidence gathered by scientists did not support sea-floor spreading.

Passage 2 The Himalayas are a range of mountains that is 2,400 km long and that arcs across Pakistan, India, Tibet, Nepal, Sikkim, and Bhutan. The Himalayas are the highest mountains on Earth. Nine mountains, including Mount Everest, the highest mountain on Earth, are more than 8,000 m tall. The formation of the Himalaya Mountains began about 80 million years ago. A tectonic plate carrying the Indian subcontinent collided with the Eurasian plate. The Indian plate was driven beneath the Eurasian plate. This collision caused the uplift of the Eurasian plate and the formation of the Himalayas. This process is continuing today.

1. In the passage, what does the word *arcs* mean?

A forms a circle
B forms a plane
C forms a curve
D forms a straight line

2. According to the passage, which geologic process formed the Himalaya Mountains?

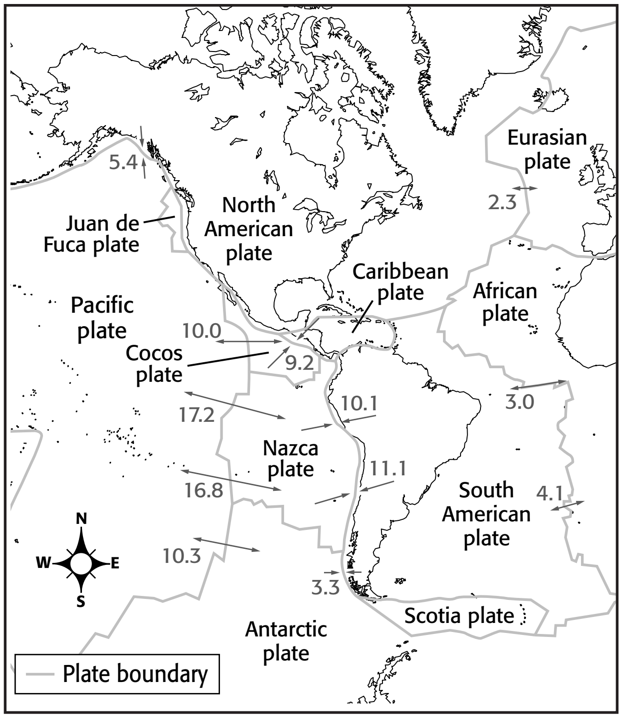
F divergence
G subsidence
H strike-slip faulting
I convergence

3. Which of the following statements is a fact according to the passage?

A The nine tallest mountains on Earth are located in the Himalaya Mountains.
B The Himalaya Mountains are located within six countries.
C The Himalaya Mountains are the longest mountain range on Earth.
D The Himalaya Mountains formed more than 80 million years ago.

INTERPRETING GRAPHICS

The illustration below shows the relative velocities (in centimeters per year) and directions in which tectonic plates are separating and colliding. Arrows that point away from one another indicate plate separation. Arrows that point toward one another indicate plate collision. Use the illustration below to answer the questions that follow.



1. Between which two tectonic plates does spreading appear to be the fastest?

A the Australian plate and the Pacific plate
B the Antarctic plate and the Pacific plate
C the Nazca plate and the Pacific plate
D the Cocos plate and the Pacific plate

2. Where do you think mountain building is taking place?

F between the African plate and the South American plate
G between the Nazca plate and the South American plate
H between the North American plate and the Eurasian plate
I between the African plate and the North American plate

MATH

Read each question below, and choose the best answer.

1. The center of the Earth is located about 6,380 km beneath the surface. If the crust is approximately 50 km thick and the mantle is 2,900 km thick, how thick is the Earth's core?

A 3,480 km
B 3,430 km
C 3,380 km
D 3,340 km

2. If a seismic wave travels through the mantle at an average velocity of 8 km/s, and if the mantle is 2,900 km thick, how many seconds will the wave take to travel through the mantle?

F 318.75 s
G 350.0 s
H 362.5 s
I 368.75 s

3. If the crust in a certain area is subsiding at the rate of 2 cm per year and has an elevation of 1,000 m, what elevation will the crust have in 10,000 years?

A 500 m
B 800 m
C 1,200 m
D 2,000 m

4. Assume that a very small oceanic plate is located between a mid-ocean ridge and a subduction zone. At the ridge, the plate is growing at a rate of 5 km every 1 million years. At the subduction zone, the plate is being destroyed at a rate of 10 km every 1 million years. If the oceanic plate is 100 km across, how long will it take the plate to disappear?

F 100 million years
G 50 million years
H 20 million years
I 5 million years

Science in Action

Science, Technology, and Society

Using Satellites to Track Plate Motion

When you think of laser beams firing, you may think of science fiction movies. However, scientists use laser beams to determine the rate and direction of motion of tectonic plates. From ground stations on Earth, laser beams are fired at several small satellites orbiting 5,900 km above Earth. From the satellites, the laser beams are reflected back to ground stations. Differences in the time it takes signals to be reflected from targets are measured over a period of time. From these differences, scientists can determine the rate and direction of plate motion.

Social Studies ACTIVITY

WRITING SKILL Research a society that lives at an active plate boundary. Find out how the people live with dangers such as volcanoes and earthquakes. Include your findings in a short report.

This scientist is using a laser to test one of the satellites that will be used to track plate motion.

Scientific Discoveries

Megaplumes

Eruptions of boiling water from the sea floor form giant, spiral disks that twist through the oceans. Do you think it's impossible? Oceanographers have discovered these disks at eight locations at mid-ocean ridges over the past 20 years. These disks, which may be tens of kilometers across, are called *megaplumes*. Megaplumes are like blenders. They mix hot water with cold water in the oceans. Megaplumes can rise hundreds of meters from the ocean floor to the upper layers of the ocean. They carry gases and minerals and provide extra energy and food to animals in the upper layers of the ocean.

Language Arts ACTIVITY

WRITING SKILL Did you ever wonder about the origin of the name *Himalaya*? Research the origin of the name *Himalaya,* and write a short report about what you find.

Alfred Wegener

Continental Drift Alfred Wegener's greatest contribution to science was the hypothesis of continental drift. This hypothesis states that continents drift apart from one another and have done so in the past. To support his hypothesis, Wegener used geologic, fossil, and glacial evidence gathered on both sides of the Atlantic Ocean. For example, Wegener recognized similarities between rock layers in North America and Europe and between rock layers in South America and Africa. He believed that these similarities could be explained only if these geologic features were once part of the same continent.

Although continental drift explained many of his observations, Wegener could not find scientific evidence to develop a complete explanation of how continents move. Most scientists were skeptical of Wegener's hypothesis and dismissed it as foolishness. It was not until the 1950s and 1960s that the discoveries of magnetic reversals and sea-floor spreading provided evidence of continental drift.

Math ACTIVITY

The distance between South America and Africa is 7,200 km. As new crust is created at the mid-ocean ridge, South America and Africa are moving away from each other at a rate of about 3.5 cm per year. How many millions of years ago were South America and Africa joined?

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HZ5TECF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS07.

UNIT 6

TIMELINE

Cells

Cells are everywhere. Even though most cells can't be seen with the naked eye, they make up every living thing. Your body alone contains trillions of cells.

In this unit, you will learn the difference between animal cells, plant cells, and bacterial cells. You will study the parts of a cell and will see how the parts of the cell work together. You will also learn how characteristics are passed from one generation to another.

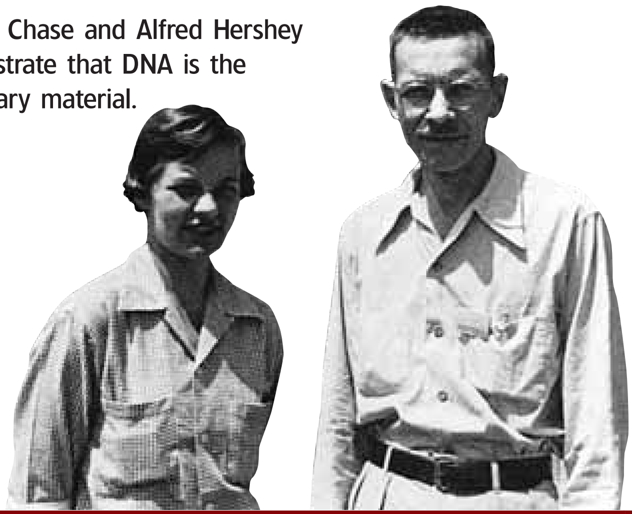
This timeline shows some of the discoveries that have been made since cells were discovered in 1665, but there is still a lot to learn about the fascinating world of cells!

1620
The Pilgrims settle Plymouth Colony.

1665
Robert Hooke discovers cells after observing a thin piece of cork under a microscope.

1861
The American Civil War begins.

1952
Martha Chase and Alfred Hershey demonstrate that DNA is the hereditary material.



1831

Robert Brown discovers the nucleus in a plant cell.

1838

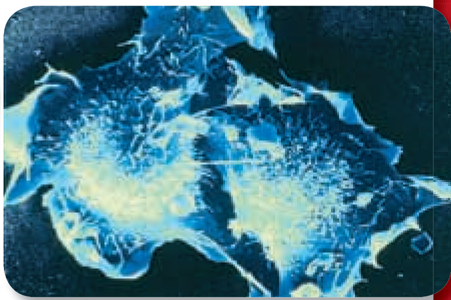
Matthias Schleiden discovers that all plant tissue is made up of cells.

1839

Theodor Schwann shows that all animal tissue is made up of cells.

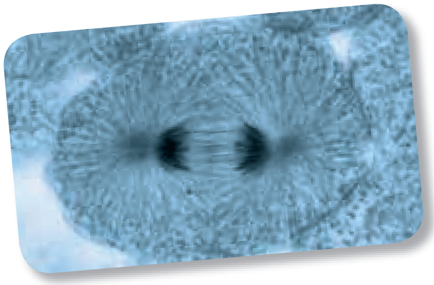
1858

Rudolf Virchow determines that all cells are produced from cells.



1873

Anton Schneider observes and accurately describes mitosis.



1937

The Golden Gate Bridge opens in San Francisco.

1941

George Beadle and Edward Tatum discover that genes control the chemical reactions in cells by directing protein production.

1956

The manufacture of protein in the cell is found to occur in ribosomes.

1971

Lynn Margulis proposes the endosymbiotic theory of the origin of cell organelles.

1997

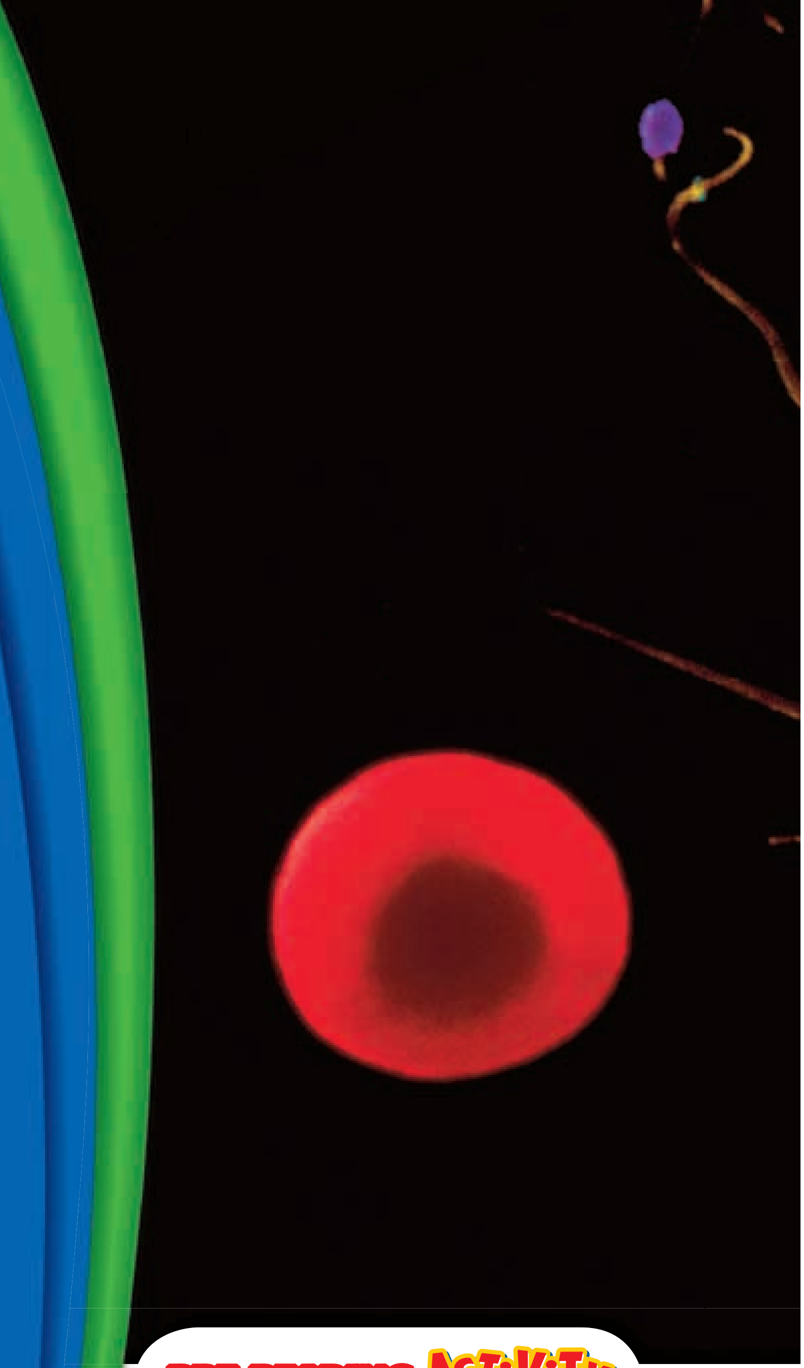
A sheep named Dolly becomes the first animal to be cloned from a single body cell.

2002

Scientists test a cancer vaccine that can be given orally. Tests on mice lead scientists to be hopeful that the vaccine can be tested on humans.

17

Cells: The Basic Units of Life



About the PHOTO

Harmful bacteria may invade your body and make you sick. But wait—your white blood cells come to the rescue! In this image, a white blood cell (the large, yellowish cell) reaches out its pseudopod to destroy bacteria (the purple cells). The red discs are red blood cells.

PRE-READING ACTIVITY

FOLDNOTES

Key-Term Fold Before you read the chapter, create the FoldNote entitled "Key-Term Fold" described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.

START-UP ACTIVITY

What Are Plants Made Of?

All living things, including plants, are made of cells. What do plant cells look like? Do this activity to find out.

Procedure

1. Tear off a **small leaf** from near the tip of an **Elodea sprig.**
2. Using **forceps,** place the whole leaf in a **drop of water** on a **microscope slide.**
3. Place a **coverslip** on top of the water drop by putting one edge of the coverslip on the slide near the water drop. Next, lower the coverslip slowly so that the coverslip does not trap air bubbles.
4. Place the slide on your **microscope.**
5. Using the lowest-powered lens first, find the plant cells. When you can see the cells under the lower-powered lens, switch to a higher-powered lens.
6. Draw a picture of what you see.

Analysis

1. Describe the shape of the *Elodea* cells. Are all of the cells in the *Elodea* the same?
2. Do you think human cells look like *Elodea* cells? How do you think they are different? How might they be similar?

SECTION 1

The Diversity of Cells

Most cells are so small they can't be seen by the naked eye. So how did scientists find cells? By accident, that's how! The first person to see cells wasn't even looking for them.

READING WARM-UP

Objectives

- State the parts of the cell theory.
- Explain why cells are so small.
- Describe the parts of a cell.
- Describe how eubacteria are different from archaebacteria.
- Explain the difference between prokaryotic cells and eukaryotic cells.

Terms to Learn

cell	nucleus
cell membrane	prokaryote
organelle	eukaryote

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

All living things are made of tiny structures called cells. A **cell** is the smallest unit that can perform all the processes necessary for life. Because of their size, cells weren't discovered until microscopes were invented in the mid-1600s.

Cells and the Cell Theory

Robert Hooke was the first person to describe cells. In 1665, he built a microscope to look at tiny objects. One day, he looked at a thin slice of cork. Cork is found in the bark of cork trees. The cork looked like it was made of little boxes. Hooke named these boxes *cells,* which means "little rooms" in Latin. Hooke's cells were really the outer layers of dead cork cells. Hooke's microscope and his drawing of the cork cells are shown in **Figure 1.**

Hooke also looked at thin slices of living plants. He saw that they too were made of cells. Some cells were even filled with "juice." The "juicy" cells were living cells.

Hooke also looked at feathers, fish scales, and the eyes of houseflies. But he spent most of his time looking at plants and fungi. The cells of plants and fungi have cell walls. This makes them easy to see. Animal cells do not have cell walls. This absence of cell walls makes it harder to see the outline of animal cells. Because Hooke couldn't see their cells, he thought that animals weren't made of cells.

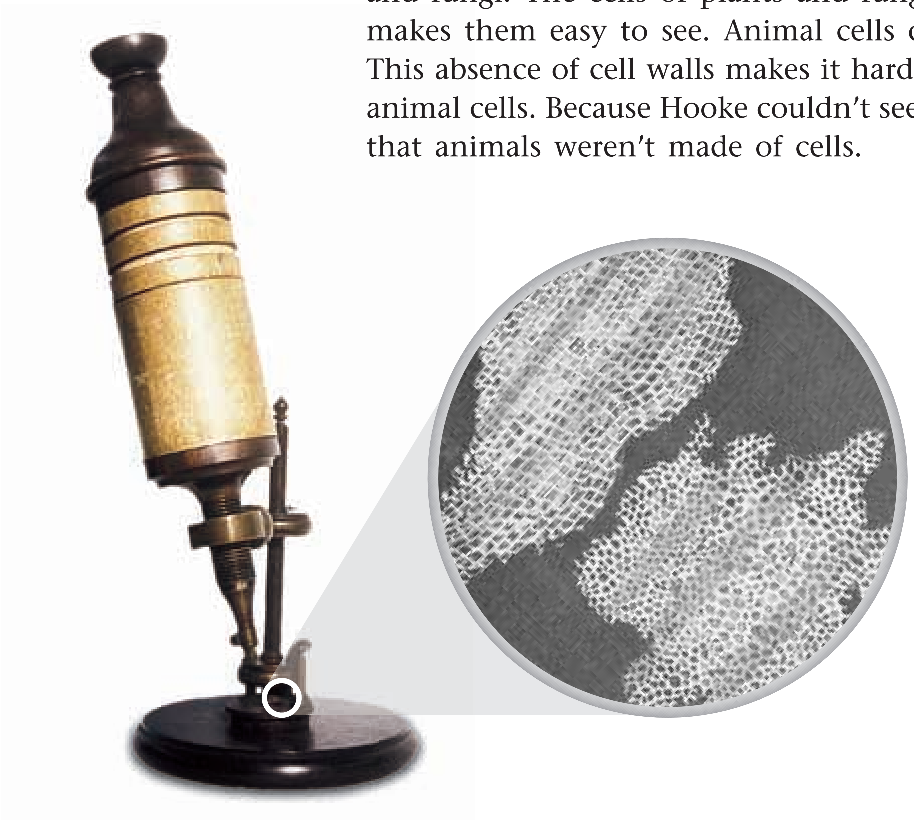


Figure 1 *Hooke discovered cells using this microscope. Hooke's drawing of cork cells is shown to the right of his microscope.*

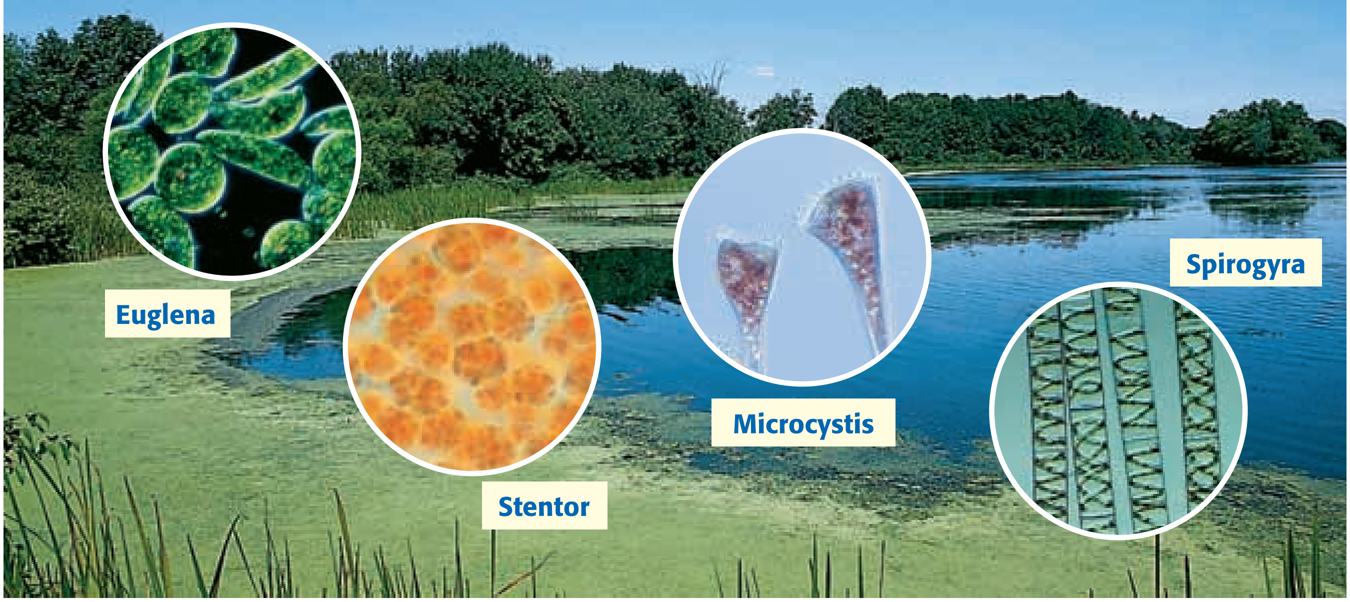


Figure 2 *The green area at the edge of the pond is a layer of pond scum. This pond scum contains organisms called* protists, *such as those shown above.*

Finding Cells in Other Organisms

In 1673, Anton van Leeuwenhoek (LAY vuhn HOOK), a Dutch merchant, made his own microscopes. Leeuwenhoek used one of his microscopes to look at pond scum. Leeuwenhoek saw small organisms in the water. He named these organisms *animalcules,* which means "little animals." Today, we call these single-celled organisms protists (PROH tists). Pond scum and some of the protists it contains are shown in **Figure 2.**

Leeuwenhoek also looked at animal blood. He saw differences in blood cells from different kinds of animals. For example, blood cells in fish, birds, and frogs are oval. Blood cells in humans and dogs are round and flat. Leeuwenhoek was also the first person to see bacteria. And he discovered that yeasts that make bread dough rise are single-celled organisms.

cell in biology, the smallest unit that can perform all life processes; cells are covered by a membrane and have DNA and cytoplasm

The Cell Theory

Almost 200 years passed before scientists concluded that cells are present in all living things. Scientist Matthias Schleiden (mah THEE uhs SHLIE duhn) studied plants. In 1838, he concluded that all plant parts were made of cells. Theodor Schwann (TAY oh dohr SHVAHN) studied animals. In 1839, Schwann concluded that all animal tissues were made of cells. Soon after that, Schwann wrote the first two parts of what is now known as the *cell theory*.

- All organisms are made of one or more cells.
- The cell is the basic unit of all living things.

Later, in 1858, Rudolf Virchow (ROO dawlf FIR koh), a doctor, stated that all cells could form only from other cells. Virchow then added the third part of the cell theory.

- All cells come from existing cells.

Reading Check **What are the three parts of the cell theory?** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Physics

Microscopes The microscope Hooke used to study cells was much different from microscopes today. Research different kinds of microscopes, such as light microscopes, scanning electron microscopes (SEMs), and transmission electron microscopes (TEMs). Select one type of microscope. Make a poster or other presentation to show to the class. Describe how the microscope works and how it is used. Be sure to include images.

ACTIVITY

Cell Size

Most cells are too small to be seen without a microscope. It would take 50 human cells to cover the dot on this letter *i*.

A Few Large Cells

Most cells are small. A few, however, are big. The yolk of a chicken egg, shown in **Figure 3,** is one big cell. The egg can be this large because it does not have to take in more nutrients.

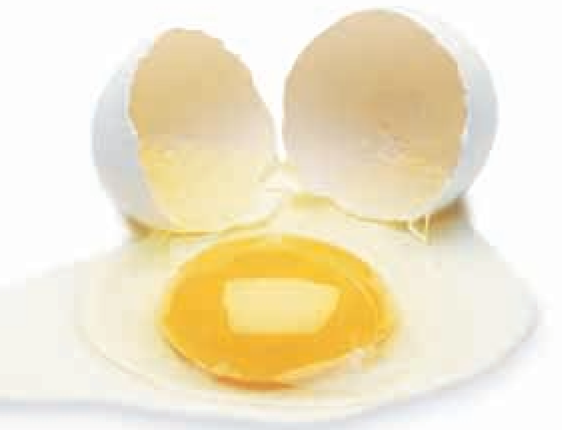


Figure 3 *The white and yolk of this chicken egg provide nutrients for the development of a chick.*

Many Small Cells

There is a physical reason why most cells are so small. Cells take in food and get rid of wastes through their outer surface. As a cell gets larger, it needs more food and produces more waste. Therefore, more materials pass through its outer surface.

As the cell's volume increases, its surface area grows too. But the cell's volume grows faster than its surface area. If a cell gets too large, the cell's surface area will not be large enough to take in enough nutrients or pump out enough wastes. So, the area of a cell's surface—compared with the cell's volume—limits the cell's size. The ratio of the cell's outer surface area to the cell's volume is called the *surface area–to-volume ratio,* which can be calculated by using the following equation:

$$\textit{surface area–to-volume ratio} = \frac{\textit{surface area}}{\textit{volume}}$$

Reading Check **Why are most cells small?**

MATH FOCUS

Surface Area-to-Volume Ratio Calculate the surface area–to-volume ratio of a cube whose sides measure 2 cm.

Step 1: Calculate the surface area.

$$\textit{surface area of cube} = \textit{number of sides} \times \textit{area of side}$$

$$\textit{surface area of cube} = 6 \times (2\text{ cm} \times 2\text{ cm})$$

$$\textit{surface area of cube} = 24\text{ cm}^2$$

Step 2: Calculate the volume.

$$\textit{volume of cube} = \textit{side} \times \textit{side} \times \textit{side}$$

$$\textit{volume of cube} = 2\text{ cm} \times 2\text{ cm} \times 2\text{ cm}$$

$$\textit{volume of cube} = 8\text{ cm}^3$$

Step 3: Calculate the surface area–to-volume ratio.

$$\textit{surface area–to-volume ratio} = \frac{\textit{surface area}}{\textit{volume}} = \frac{24}{8} = \frac{3}{1}$$

Now It's Your Turn

1. Calculate the surface area–to-volume ratio of a cube whose sides are 3 cm long.
2. Calculate the surface area–to-volume ratio of a cube whose sides are 4 cm long.
3. Of the cubes from questions 1 and 2, which has the greater surface area–to-volume ratio?
4. What is the relationship between the length of a side and the surface area–to-volume ratio of a cell?

Parts of a Cell

Cells come in many shapes and sizes. But all cells have the following parts in common.

The Cell Membrane and Cytoplasm

All cells are surrounded by a cell membrane. The **cell membrane** is a protective layer that covers the cell's surface and acts as a barrier. It separates the cell's contents from its environment. The cell membrane also controls materials going into and out of the cell. Inside the cell is a fluid. This fluid and almost all of its contents are called the *cytoplasm* (SIET oh PLAZ uhm).

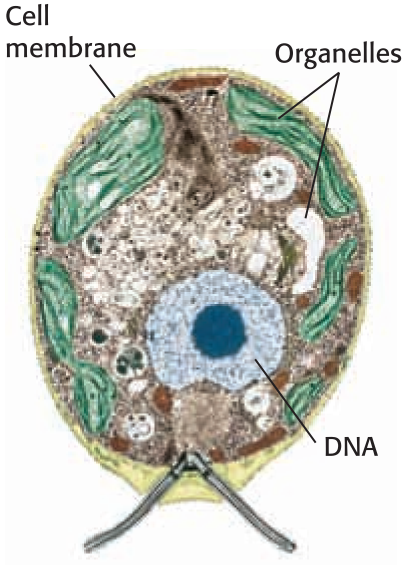


Figure 4 *This green alga has organelles. The organelles and the fluid surrounding them make up the cytoplasm.*

Organelles

Cells have organelles that carry out various life processes. **Organelles** are structures that perform specific functions within the cell. Different types of cells have different organelles. Most organelles are surrounded by membranes. For example, the algal cell in **Figure 4** has membrane-bound organelles. Some organelles float in the cytoplasm. Other organelles are attached to membranes or other organelles.

Reading Check What are organelles?

Genetic Material

All cells contain DNA (**d**eoxyribo**n**ucleic **a**cid) at some point in their life. *DNA* is the genetic material that carries information needed to make new cells and new organisms. DNA is passed on from parent cells to new cells and controls the activities of a cell. **Figure 5** shows the DNA of a bacterium.

In some cells, the DNA is enclosed inside an organelle called the **nucleus.** For example, your cells have a nucleus. In contrast, bacterial cells do not have a nucleus.

In humans, mature red blood cells lose their DNA. Red blood cells are made inside bones. When red blood cells are first made, they have a nucleus with DNA. But before they enter the bloodstream, red blood cells lose their nucleus and DNA. They survive with no new instructions from their DNA.

cell membrane a phospholipid layer that covers a cell's surface; acts as a barrier between the inside of a cell and the cell's environment

organelle one of the small bodies in a cell's cytoplasm that are specialized to perform a specific function

nucleus in a eukaryotic cell, a membrane-bound organelle that contains the cell's DNA and that has a role in processes such as growth, metabolism, and reproduction

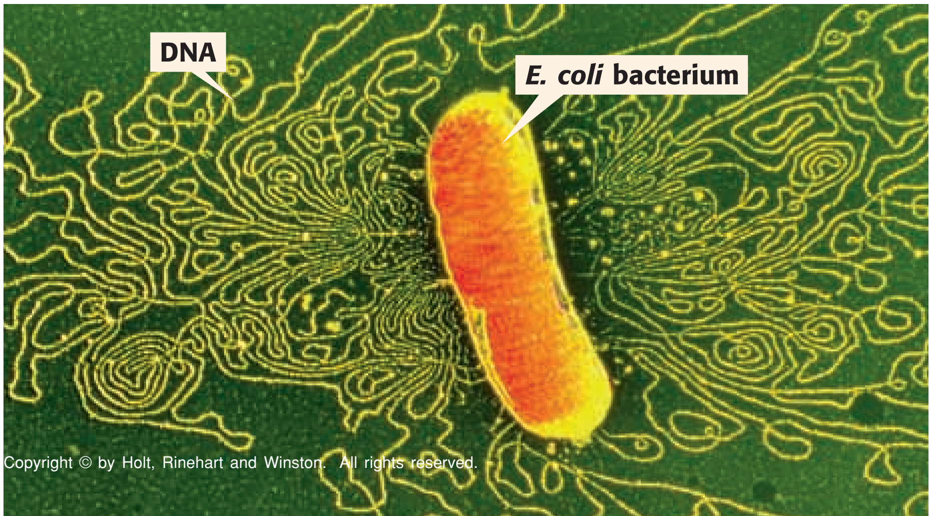


Figure 5 *This photo shows an* Escherichia coli *bacterium. The bacterium's cell membrane has been treated so that the cell's DNA is released.*

Two Kinds of Cells

All cells have cell membranes, organelles, cytoplasm, and DNA in common. But there are two basic types of cells—cells without a nucleus and cells with a nucleus. Cells with no nucleus are *prokaryotic* (proh KAR ee AHT ik) *cells*. Cells that have a nucleus are *eukaryotic* (yoo KAR ee AHT ik) *cells*. Prokaryotic cells are further classified into two groups: *eubacteria* (yoo bak TIR ee uh) and *archaebacteria* (AHR kee bak TIR ee uh).

Prokaryotes: Eubacteria and Archaebacteria

Eubacteria and archaebacteria are prokaryotes (pro KAR ee OHTS). **Prokaryotes** are single-celled organisms that do not have a nucleus or membrane-bound organelles.

Eubacteria

The most common prokaryotes are eubacteria (or just *bacteria*). Bacteria are the world's smallest cells. These tiny organisms live almost everywhere. Bacteria do not have a nucleus, but they do have DNA. A bacteria's DNA is a long, circular molecule, shaped sort of like a rubber band. Bacteria have no membrane-covered organelles. But they do have ribosomes. *Ribosomes* are tiny, round organelles made of protein and other material.

Bacteria also have a strong, weblike exterior cell wall. This wall helps the cell retain its shape. A bacterium's cell membrane is just inside the cell wall. Together, the cell wall and cell membrane allow materials into and out of the cell.

Some bacteria live in the soil and water. Others live in, or on, other organisms. For example, you have bacteria living on your skin and teeth. You also have bacteria living in your digestive system. These bacteria help the process of digestion. A typical bacterial cell is shown in **Figure 6.**

QuickLab

Bacteria in Your Lunch?

Most of the time, you don't want bacteria in your food. Many bacteria make toxins that will make you sick. However, some foods—such as yogurt—are supposed to have bacteria in them! The bacteria in these foods are not dangerous.

In yogurt, masses of rod-shaped bacteria feed on the sugar (lactose) in milk. The bacteria convert the sugar into lactic acid. Lactic acid causes milk to thicken. This thickened milk makes yogurt.

1. Using a **cotton swab,** put a **small dot of yogurt** on a **microscope slide.**
2. Add a **drop of water.** Use the cotton swab to stir.
3. Add a **coverslip**.
4. Use a **microscope** to examine the slide. Draw what you observe.

prokaryote an organism that consists of a single cell that does not have a nucleus

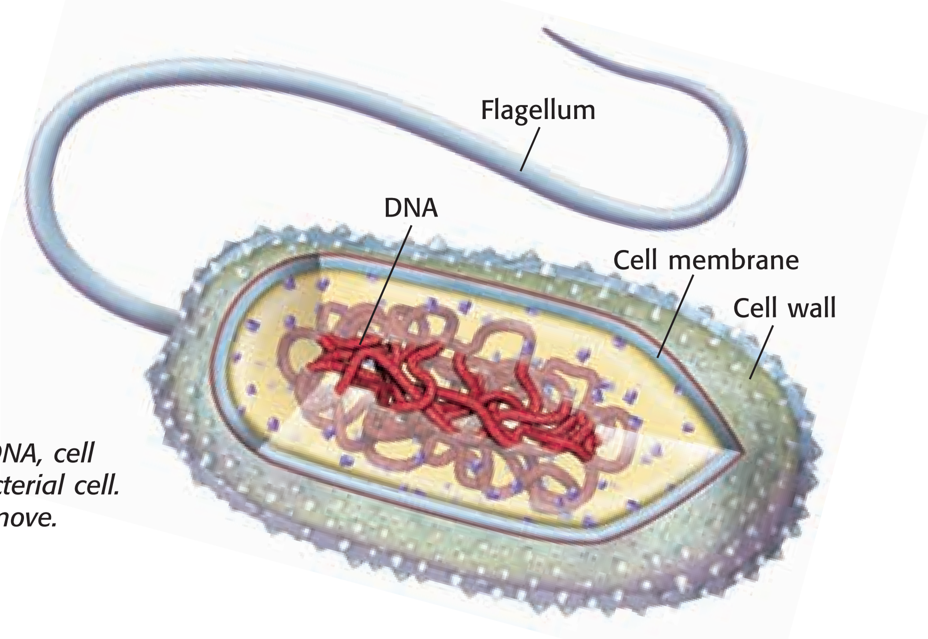


Figure 6 *This diagram shows the DNA, cell membrane, and cell wall of a eubacterial cell. The flagellum helps the bacterium move.*

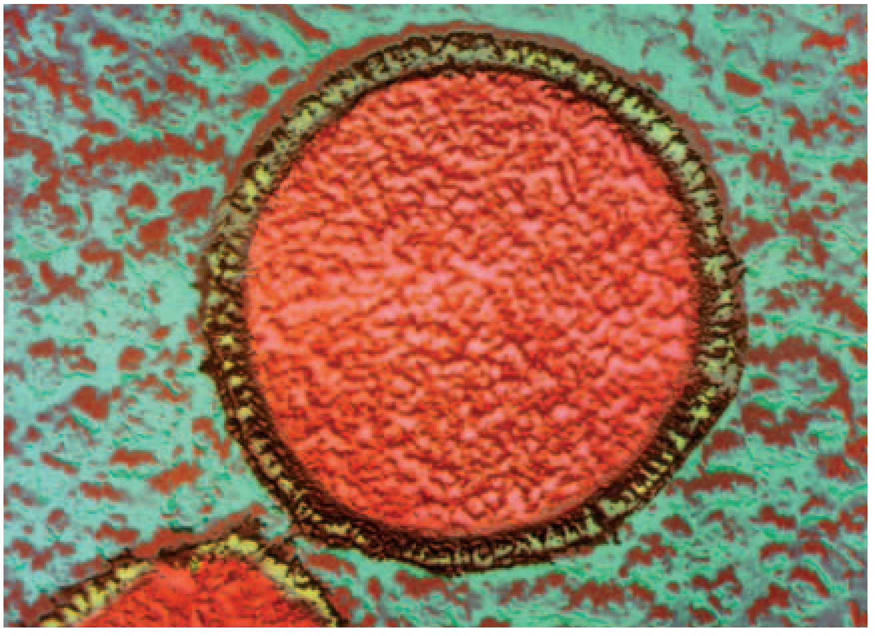


Figure 7 *This photograph, taken with an electron microscope, is of an archaebacterium that lives in the very high temperatures of deep-sea volcanic vents. The photograph has been colored so that the cell wall is green and the cell contents are pink.*

Archaebacteria

The second kind of prokaryote are the archaebacteria. These organisms are also called *archaea* (ahr KEE uh). Archaebacteria are similar to bacteria in some ways. For example, both are single-celled organisms. Both have ribosomes, a cell membrane, and circular DNA. And both lack a nucleus and membrane-bound organelles. But archaebacteria are different from bacteria. For example, archaebacterial ribosomes are different from eubacterial ribosomes.

Archaebacteria are similar to eukaryotic cells in some ways, too. For example, archaebacterial ribosomes are more like the ribosomes of eukaryotic cells. But archaebacteria also have some features that no other cells have. For example, the cell wall and cell membranes of archaebacteria are different from the cell walls of other organisms. And some archaebacteria live in places where no other organisms could live.

Three types of archaebacteria are *heat-loving, salt-loving,* and *methane-making*. Methane is a kind of gas frequently found in swamps. Heat-loving and salt-loving archaebacteria are sometimes called extremophiles. *Extremophiles* live in places where conditions are extreme. They live in very hot water, such as in hot springs, or where the water is extremely salty. **Figure 7** shows one kind of methane-making archaebacteria that lives deep in the ocean near volcanic vents. The temperature of the water from those vents is extreme: it is above the boiling point of water at sea level.

Reading Check **What is one difference between eubacteria and archaebacteria?**

CONNECTION TO Social Studies

Where Do They Live? While most archaebacteria live in extreme environments, scientists have found that archaebacteria live almost everywhere. Do research about archaebacteria. Select one kind of archaebacteria. Create a poster showing the geographical location where the organism lives, describing its physical environment, and explaining how it survives in its environment.

ACTIVITY

Eukaryotic Cells and Eukaryotes

eukaryote an organism made up of cells that have a nucleus enclosed by a membrane; eukaryotes include animals, plants, and fungi, but not archaebacteria or eubacteria

Eukaryotic cells are the largest cells. Most eukaryotic cells are still microscopic, but they are about 10 times larger than most bacterial cells. A typical eukaryotic cell is shown in **Figure 8.**

Unlike bacteria and archaebacteria, eukaryotic cells have a nucleus. The nucleus is one kind of membrane-bound organelle. A cell's nucleus holds the cell's DNA. Eukaryotic cells have other membrane-bound organelles as well. Organelles are like the different organs in your body. Each kind of organelle has a specific job in the cell. Together, organelles, such as the ones shown in **Figure 8,** perform all the processes necessary for life.

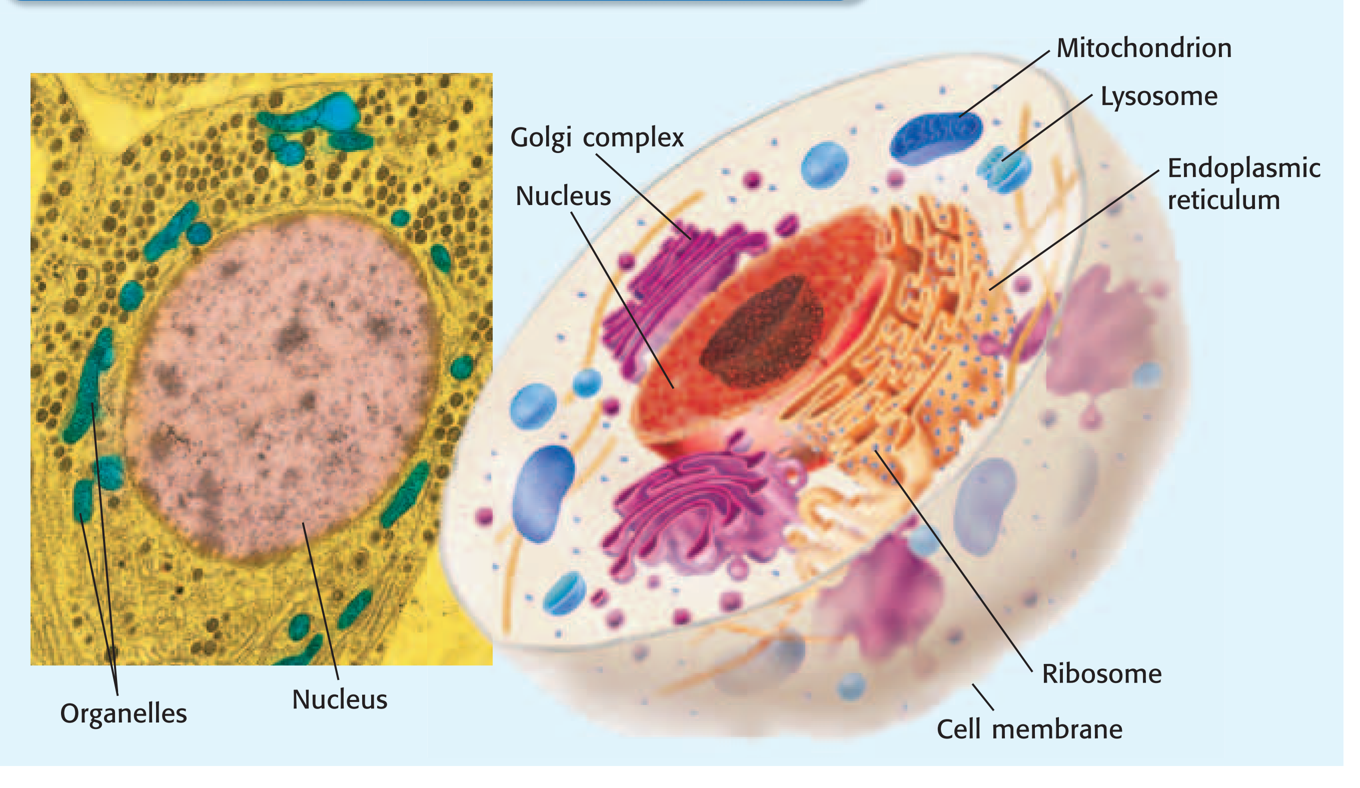
All living things that are not bacteria or archaebacteria are made of one or more eukaryotic cells. Organisms made of eukaryotic cells are called **eukaryotes.** Many eukaryotes are multicellular. *Multicellular* means "many cells." Multicellular organisms are usually larger than single-cell organisms. So, most organisms you see with your naked eye are eukaryotes. There are many types of eukaryotes. Animals, including humans, are eukaryotes. So are plants. Some protists, such as amoebas, are single-celled eukaryotes. Other protists, including some types of green algae, are multicellular eukaryotes. Fungi are organisms such as mushrooms or yeasts. Mushrooms are multicellular eukaryotes. Yeasts are single-celled eukaryotes.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5CELW.**

Reading Check How are eukaryotes different from prokaryotes?

Figure 8 **Organelles in a Typical Eukaryotic Cell**



SECTION
Review

Summary

- Cells were not discovered until microscopes were invented in the 1600s.
- Cell theory states that all organisms are made of cells, the cell is the basic unit of all living things, and all cells come from other cells.
- All cells have a cell membrane, cytoplasm, and DNA.
- Most cells are too small to be seen with the naked eye. A cell's surface area–to-volume ratio limits the size of a cell.
- The two basic kinds of cells are prokaryotic cells and eukaryotic cells. Eukaryotic cells have a nucleus and membrane-bound organelles. Prokaryotic cells do not.
- Prokaryotes are classified as archaebacteria and eubacteria.
- Archaebacterial cell walls and ribosomes are different from the cell walls and ribosomes of other organisms.
- Eukaryotes can be single-celled or multicellular.

Using Key Terms

1. In your own words, write a definition for the term *organelle.*

2. Use the following terms in the same sentence: *prokaryotic, nucleus,* and *eukaryotic.*

Understanding Key Ideas

3. Cell size is limited by the

a. thickness of the cell wall.

b. size of the cell's nucleus.

c. cell's surface area–to-volume ratio.

d. amount of cytoplasm in the cell.

4. What are the three parts of the cell theory?

5. Name three structures that every cell has.

6. Give two ways in which archaebacteria are different from bacteria.

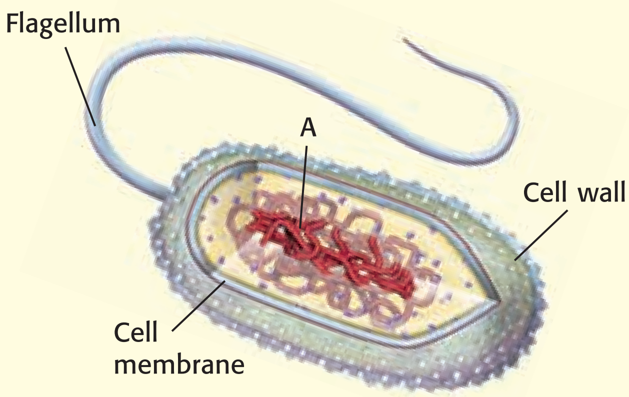
Critical Thinking

7. Applying Concepts You have discovered a new single-celled organism. It has a cell wall, ribosomes, and long, circular DNA. Is it a eukaryote or a prokaryote cell? Explain.

8. Identifying Relationships One of your students brings you a cell about the size of the period at the end of this sentence. It is a single cell, but it also forms chains. What characteristics would this cell have if the organism is a eukaryote? If it is a prokaryote? What would you look for first?

Interpreting Graphics

The picture below shows a particular organism. Use the picture to answer the questions that follow.



9. What type of organism does the picture represent? How do you know?

10. Which structure helps the organism move?

11. What part of the organism does the letter *A* represent?

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Topic: Prokaryotic Cells
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SECTION 2

Eukaryotic Cells

Most eukaryotic cells are small. For a long time after cells were discovered, scientists could not see what was going on inside cells. They did not know how complex cells are.

Now, scientists know a lot about eukaryotic cells. These cells have many parts that work together and keep the cell alive.

READING WARM-UP

Objectives

- Identify the different parts of a eukaryotic cell.
- Explain the function of each part of a eukaryotic cell.

Terms to Learn

cell wall	mitochondrion
ribosome	Golgi complex
endoplasmic reticulum	vesicle
	lysosome

READING STRATEGY

Reading Organizer As you read this section, make a table comparing plant cells and animal cells.

Cell Wall

Some eukaryotic cells have cell walls. A **cell wall** is a rigid structure that gives support to a cell. The cell wall is the outermost structure of a cell. Plants and algae have cell walls made of cellulose (SEL yoo LOHS) and other materials. *Cellulose* is a complex sugar that most animals can't digest.

The cell walls of plant cells allow plants to stand upright. In some plants, the cells must take in water for the cell walls to keep their shape. When such plants lack water, the cell walls collapse and the plant droops. **Figure 1** shows a cross section of a plant cell and a close-up of the cell wall.

Fungi, including yeasts and mushrooms, also have cell walls. Some fungi have cell walls made of *chitin* (KIE tin). Other fungi have cell walls made from a chemical similar to chitin. Eubacteria and archaebacteria also have cell walls, but those walls are different from plant or fungal cell walls.

cell wall a rigid structure that surrounds the cell membrane and provides support to the cell

Reading Check **What types of cells have cell walls?** (*See the Appendix for answers to Reading Checks.*)

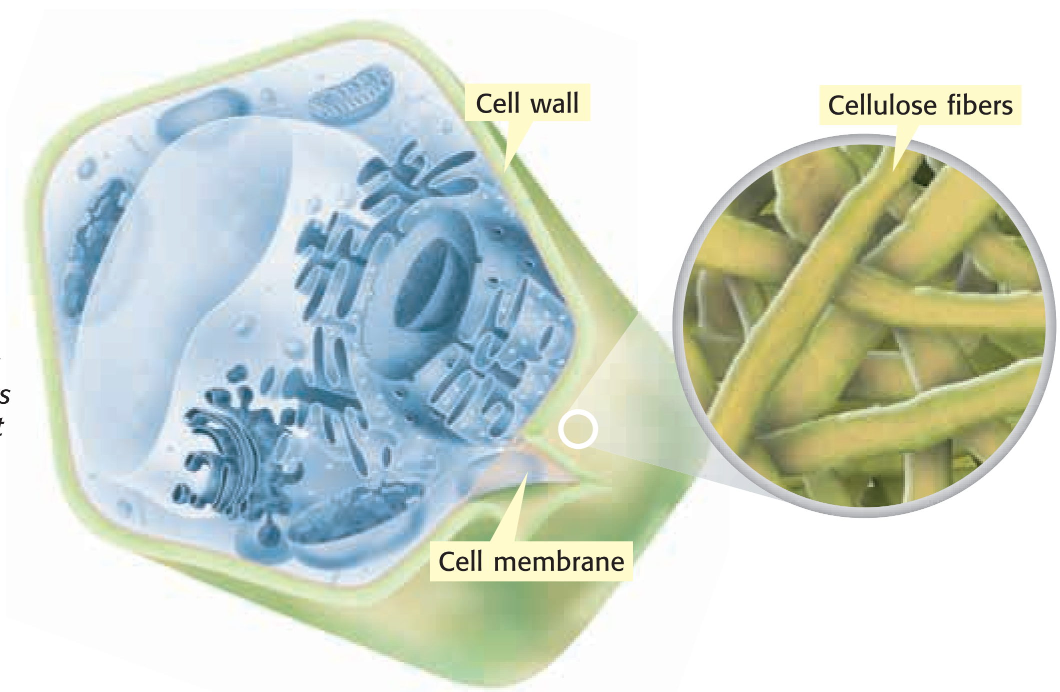


Figure 1 *The cell walls of plant cells help plants retain their shape. Plant cell walls are made of cellulose.*

Cell Membrane

All cells have a cell membrane. The *cell membrane* is a protective barrier that encloses a cell. It separates the cell's contents from the cell's environment. The cell membrane is the outermost structure in cells that lack a cell wall. In cells that have a cell wall, the cell membrane lies just inside the cell wall.

The cell membrane contains proteins, lipids, and phospholipids. *Lipids,* which include fats and cholesterol, are a group of compounds that do not dissolve in water. The cell membrane has two layers of phospholipids (FAHS foh LIP idz), shown in **Figure 2.** A *phospholipid* is a lipid that contains phosphorus. Lipids are "water fearing," or *hydrophobic*. Lipid ends of phospholipids form the inner part of the membrane. Phosphorus-containing ends of the phospholipids are "water loving," or *hydrophilic*. These ends form the outer part of the membrane.

Some of the proteins and lipids control the movement of materials into and out of the cell. Some of the proteins form passageways. Nutrients and water move into the cell, and wastes move out of the cell, through these protein passageways.

Reading Check **What are two functions of a cell membrane?**

CONNECTION TO Language Arts

WRITING SKILL **The Great Barrier** In your **science journal,** write a science fiction story about tiny travelers inside a person's body. These little explorers need to find a way into or out of a cell to solve a problem. You may need to do research to find out more about how the cell membrane works. Illustrate your story.

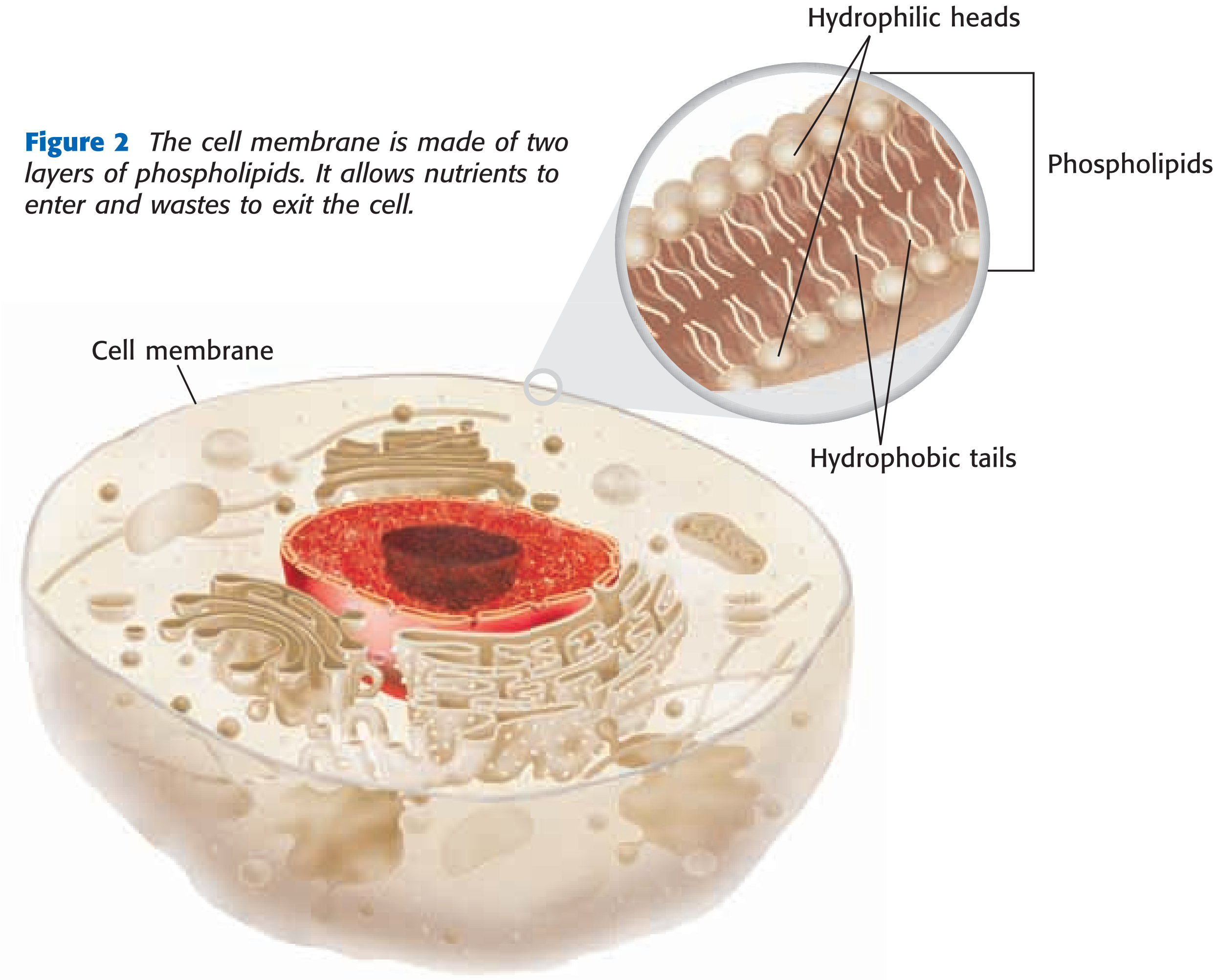


Figure 2 *The cell membrane is made of two layers of phospholipids. It allows nutrients to enter and wastes to exit the cell.*

Cytoskeleton

The *cytoskeleton* (SIET oh SKEL uh tuhn) is a web of proteins in the cytoplasm. The cytoskeleton, shown in **Figure 3,** acts as both a muscle and a skeleton. It keeps the cell's membranes from collapsing. The cytoskeleton also helps some cells move.

The cytoskeleton is made of three types of protein. One protein is a hollow tube. The other two are long, stringy fibers. One of the stringy proteins is also found in muscle cells.

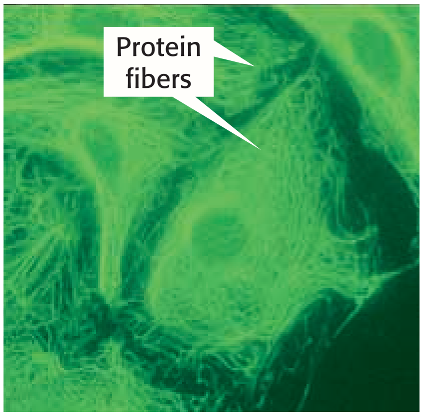


Figure 3 *The cytoskeleton, made of protein fibers, helps a cell retain its shape, move in its environment, and move its organelles.*

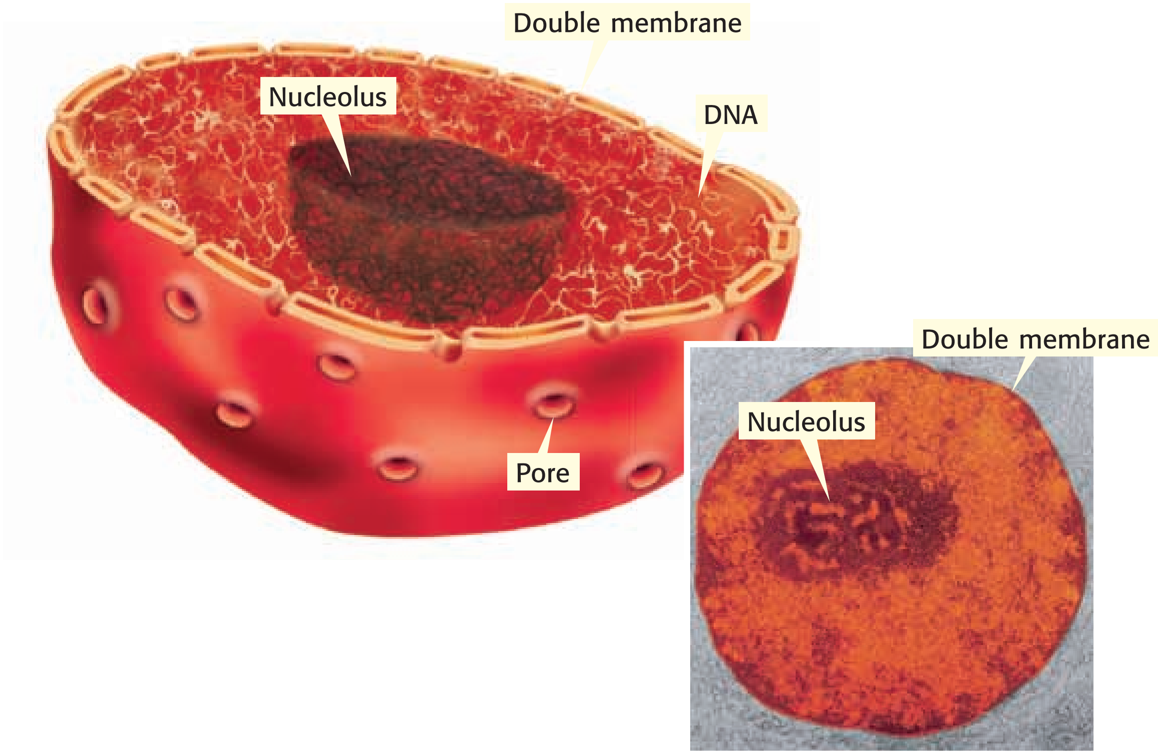
Reading Check **What is the cytoskeleton?**

Nucleus

All eukaryotic cells have the same basic membrane-bound organelles, starting with the nucleus. The *nucleus* is a large organelle in a eukaryotic cell. It contains the cell's DNA, or genetic material. DNA contains the information on how to make a cell's proteins. Proteins control the chemical reactions in a cell. They also provide structural support for cells and tissues. But proteins are not made in the nucleus. Messages for how to make proteins are copied from the DNA. These messages are then sent out of the nucleus through the membranes.

The nucleus is covered by two membranes. Materials cross this double membrane by passing through pores. **Figure 4** shows a nucleus and nuclear pores. The nucleus of many cells has a dark area called the nucleolus (noo KLEE uh luhs). The *nucleolus* is where a cell begins to make its ribosomes.

Figure 4 *The nucleus contains the cell's DNA. Pores allow materials to move between the nucleus and the cytoplasm.*



Ribosomes

Organelles that make proteins are called **ribosomes.** Ribosomes are the smallest of all organelles. And there are more ribosomes in a cell than there are any other organelles. Some ribosomes float freely in the cytoplasm. Others are attached to membranes or the cytoskeleton. Unlike most organelles, ribosomes are not covered by a membrane.

Proteins are made within the ribosomes. Proteins are made of amino acids. An *amino acid* is any one of about 20 different organic molecules that are used to make proteins. All cells need proteins to live. All cells have ribosomes.

ribosome cell organelle composed of RNA and protein; the site of protein synthesis

endoplasmic reticulum a system of membranes that is found in a cell's cytoplasm and that assists in the production, processing, and transport of proteins and in the production of lipids

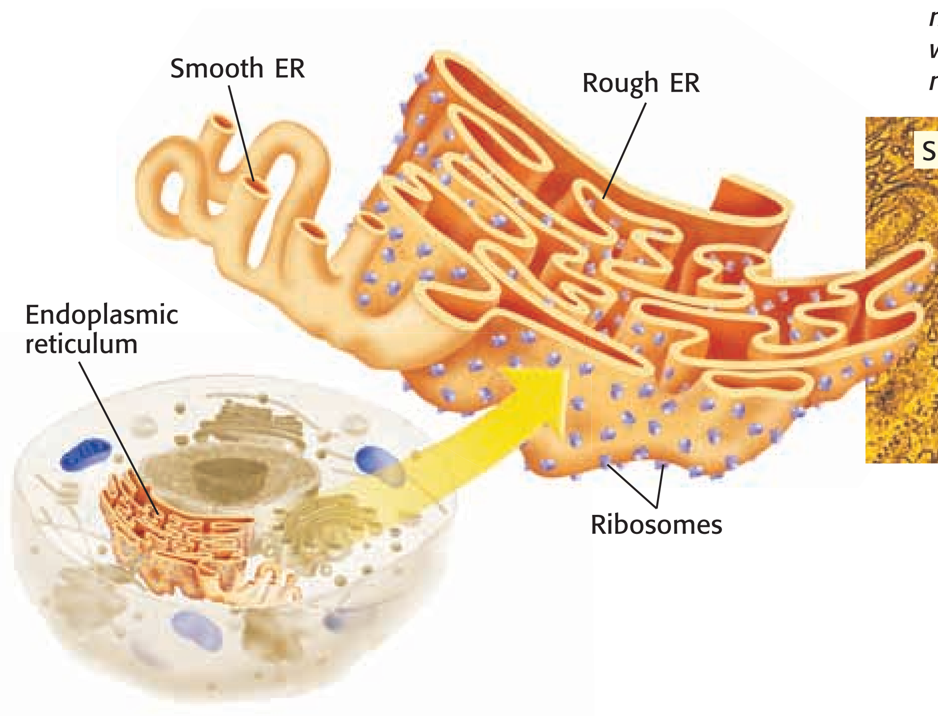
Endoplasmic Reticulum

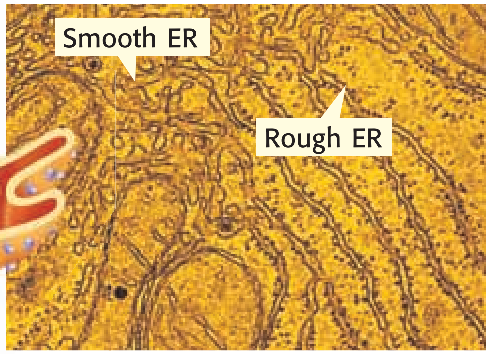
Many chemical reactions take place in a cell. Many of these reactions happen on or in the endoplasmic reticulum (EN doh PLAZ mik ri TIK yuh luhm). The **endoplasmic reticulum,** or ER, is a system of folded membranes in which proteins, lipids, and other materials are made. The ER is shown in **Figure 5.**

The ER is part of the internal delivery system of the cell. Its folded membrane contains many tubes and passageways. Substances move through the ER to different places in the cell.

Endoplasmic reticulum is either rough ER or smooth ER. The part of the ER covered in ribosomes is rough ER. Rough ER is usually found near the nucleus. Ribosomes on rough ER make many of the cell's proteins. The ER delivers these proteins throughout the cell. ER that lacks ribosomes is smooth ER. The functions of smooth ER include making lipids and breaking down toxic materials that could damage the cell.

Figure 5 *The endoplasmic reticulum (ER) is a system of membranes. Rough ER is covered with ribosomes. Smooth ER does not have ribosomes.*





Mitochondria

A mitochondrion (MIET oh KAHN dree uhn) is the main power source of a cell. A **mitochondrion** is the organelle in which sugar is broken down to produce energy. Mitochondria are covered by two membranes, as shown in **Figure 6.** Energy released by mitochondria is stored in a substance called *ATP* (**a**denosine **t**ri**p**hosphate). The cell then uses ATP to do work. ATP can be made at several places in a cell. But most of a cell's ATP is made in the inner membrane of the cell's mitochondria.

Most eukaryotic cells have mitochondria. Mitochondria are the size of some bacteria. Like bacteria, mitochondria have their own DNA, and mitochondria can divide within a cell.

Reading Check **Where is most of a cell's ATP made?**

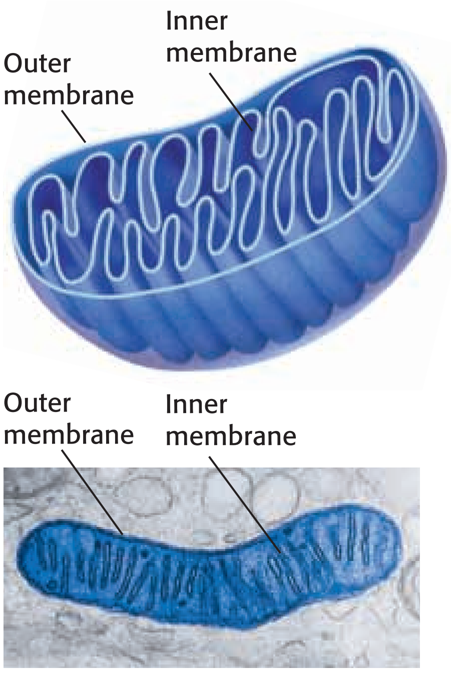


Figure 6 *Mitochondria break down sugar and make ATP. ATP is produced on the inner membrane.*

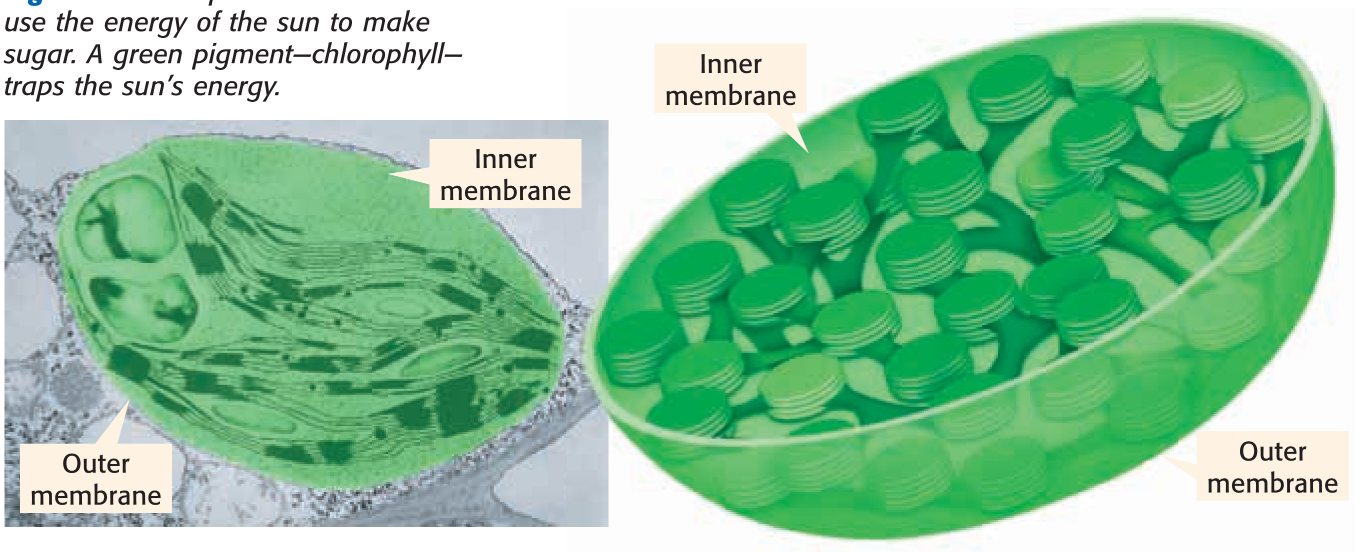
mitochondrion in eukaryotic cells, the cell organelle that is surrounded by two membranes and that is the site of cellular respiration

Chloroplasts

Animal cells cannot make their own food. Plants and algae are different. They have chloroplasts (KLAWR uh PLASTS) in some of their cells. *Chloroplasts* are organelles in plant and algae cells in which photosynthesis takes place. Like mitochondria, chloroplasts have two membranes and their own DNA. A chloroplast is shown in **Figure 7.** *Photosynthesis* is the process by which plants and algae use sunlight, carbon dioxide, and water to make sugar and oxygen.

Chloroplasts are green because they contain *chlorophyll,* a green pigment. Chlorophyll is found inside the inner membrane of a chloroplast. Chlorophyll traps the energy of sunlight, which is used to make sugar. The sugar produced by photosynthesis is then used by mitochondria to make ATP.

Figure 7 *Chloroplasts harness and use the energy of the sun to make sugar. A green pigment—chlorophyll—traps the sun's energy.*



Golgi Complex

The organelle that packages and distributes proteins is called the **Golgi complex** (GOHL jee KAHM PLEKS). It is named after Camillo Golgi, the Italian scientist who first identified the organelle.

The Golgi complex looks like smooth ER, as shown in **Figure 8.** Lipids and proteins from the ER are delivered to the Golgi complex. There, the lipids and proteins may be modified to do different jobs. The final products are enclosed in a piece of the Golgi complex's membrane. This membrane pinches off to form a small bubble. The bubble transports its contents to other parts of the cell or out of the cell.

Golgi complex cell organelle that helps make and package materials to be transported out of the cell

vesicle a small cavity or sac that contains materials in a eukaryotic cell

Cell Compartments

The bubble that forms from the Golgi complex's membrane is a vesicle. A **vesicle** (VES i kuhl) is a small sac that surrounds material to be moved into or out of a cell. All eukaryotic cells have vesicles. Vesicles also move material within a cell. For example, vesicles carry new protein from the ER to the Golgi complex. Other vesicles distribute material from the Golgi complex to other parts of the cell. Some vesicles form when part of the cell membrane surrounds an object outside the cell.

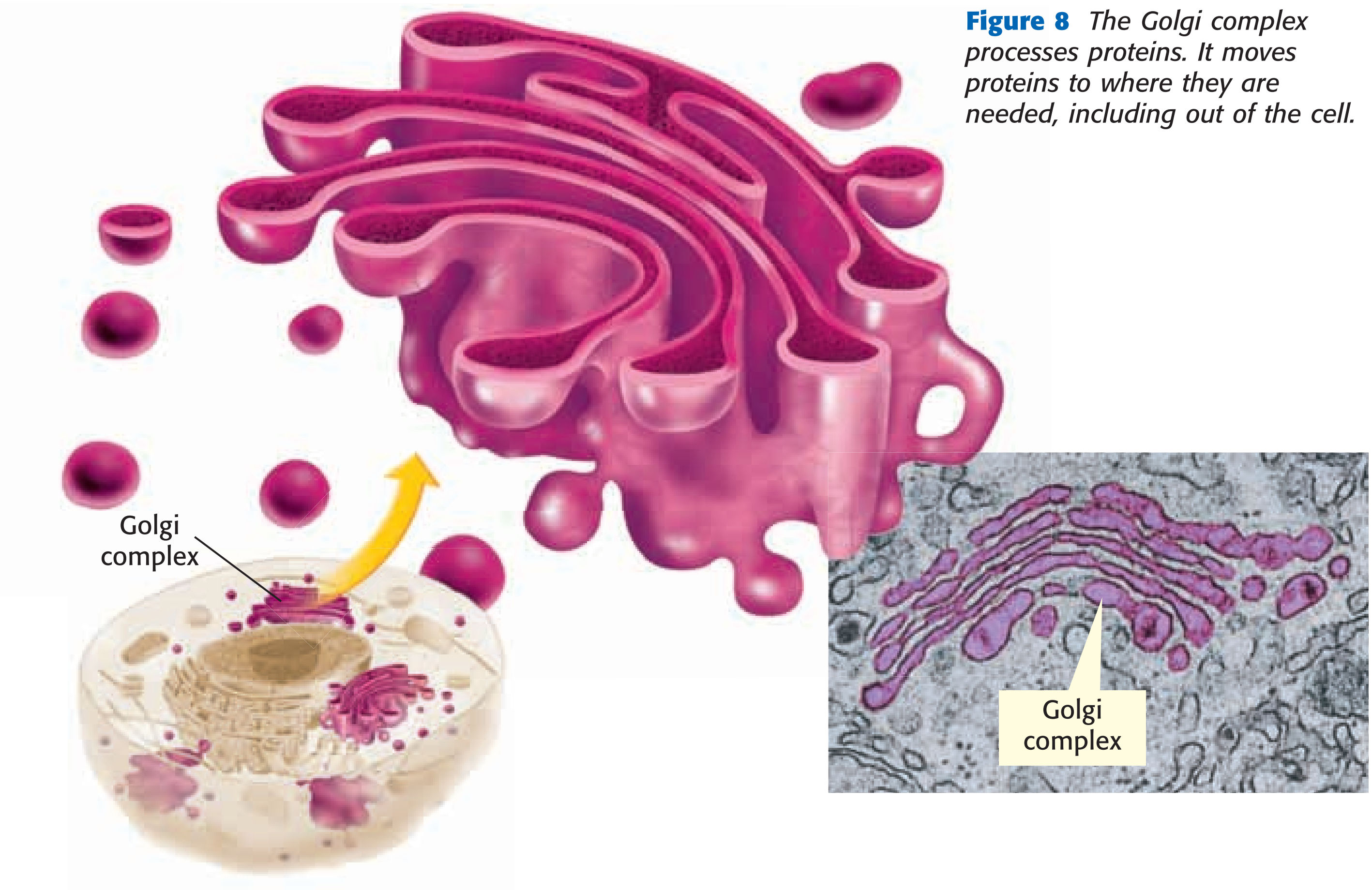


Figure 8 *The Golgi complex processes proteins. It moves proteins to where they are needed, including out of the cell.*

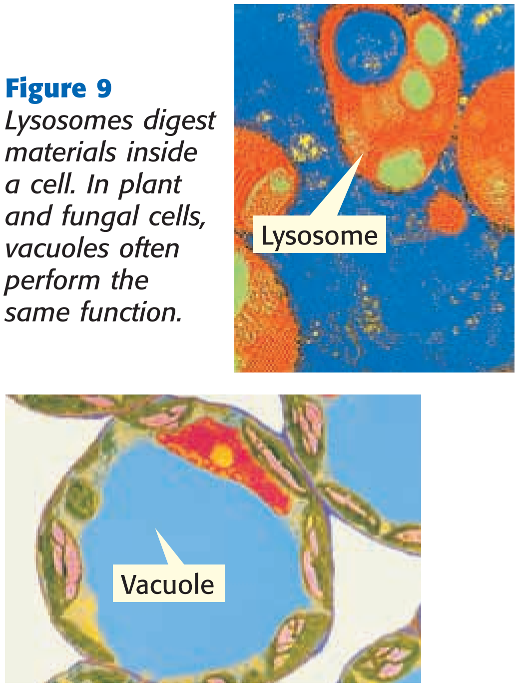


Figure 9 *Lysosomes digest materials inside a cell. In plant and fungal cells, vacuoles often perform the same function.*

lysosome a cell organelle that contains digestive enzymes

Cellular Digestion

Lysosomes (LIE suh SOHMZ) are vesicles that are responsible for digestion inside a cell. **Lysosomes** are organelles that contain digestive enzymes. They destroy worn-out or damaged organelles, get rid of waste materials, and protect the cell from foreign invaders. Lysosomes, which come in a wide variety of sizes and shapes, are shown in **Figure 9.**

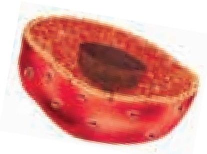
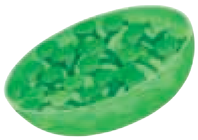
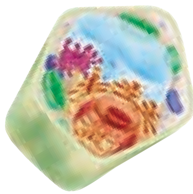
Lysosomes are found mainly in animal cells. When eukaryotic cells engulf particles, they enclose the particles in vesicles. Lysosomes bump into these vesicles and pour enzymes into them. These enzymes digest the particles in the vesicles.

Reading Check **Why are lysosomes important?**

Vacuoles

A *vacuole* (VAK yoo OHL) is a large vesicle. In plant and fungal cells, some vacuoles act like large lysosomes. They store digestive enzymes and aid in digestion within the cell. Other vacuoles in plant cells store water and other liquids. Vacuoles that are full of water, such as the one in **Figure 9,** help support the cell. Some plants wilt when their vacuoles lose water. **Table 1** shows some organelles and their functions.

Table 1 **Organelles and Their Functions**

	**Nucleus** the organelle that contains the cell's DNA and is the control center of the cell		**Chloroplast** the organelle that uses the energy of sunlight to make food
	**Ribosome** the organelle in which amino acids are hooked together to make proteins		**Golgi complex** the organelle that processes and transports proteins and other materials out of cell
	**Endoplasmic reticulum** the organelle that makes lipids, breaks down drugs and other substances, and packages proteins for Golgi complex		**Vacuole** the organelle that stores water and other materials
	**Mitochondria** the organelle that breaks down food molecules to make ATP		**Lysosome** the organelle that digests food particles, wastes, cell parts, and foreign invaders

SECTION Review

Summary

- Eukaryotic cells have organelles that perform functions that help cells remain alive.
- All cells have a cell membrane. Some cells have a cell wall. Some cells have a cytoskeleton.
- The nucleus of a eukaryotic cell contains the cell's genetic material, DNA.
- Ribosomes are the organelles that make proteins. Ribosomes are not covered by a membrane.
- The endoplasmic reticulum (ER) and the Golgi complex make and process proteins before the proteins are transported to other parts of the cell or out of the cell.
- Mitochondria and chloroplasts are energy-producing organelles.
- Lysosomes are organelles responsible for digestion within a cell. In plant cells, organelles called *vacuoles* store cell materials and sometimes act like large lysosomes.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *ribosome, lysosome,* and *cell wall.*

Understanding Key Ideas

2. Which of the following are found mainly in animal cells?

a. mitochondria
b. lysosomes
c. ribosomes
d. Golgi complexes

3. What is the function of a Golgi complex? What is the function of the endoplasmic reticulum?

Critical Thinking

4. Making Comparisons Describe three ways in which plant cells differ from animal cells.

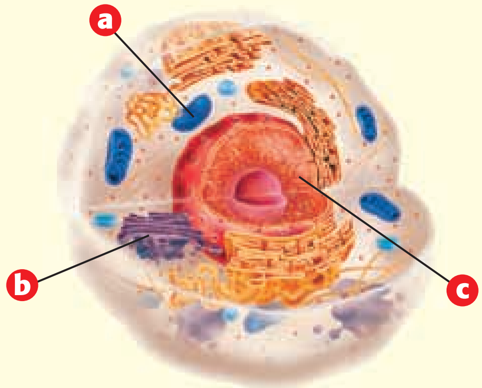
5. Applying Concepts Every cell needs ribosomes. Explain why.

6. Predicting Consequences A certain virus attacks the mitochondria in cells. What would happen to a cell if all of its mitochondria were destroyed?

7. Expressing Opinions Do you think that having chloroplasts gives plant cells an advantage over animal cells? Support your opinion.

Interpreting Graphics

Use the diagram below to answer the questions that follow.



8. Is this a diagram of a plant cell or an animal cell? Explain how you know.

9. What organelle does the letter *b* refer to?

SECTION 3

The Organization of Living Things

READING WARM-UP

Objectives

- List three advantages of being multicellular.
- Describe the four levels of organization in living things.
- Explain the relationship between the structure and function of a part of an organism.

Terms to Learn

tissue	organism
organ	structure
organ system	function

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

In some ways, organisms are like machines. Some machines have just one part. But most machines have many parts. Some organisms exist as a single cell. Other organisms have many—even trillions—of cells.

Most cells are smaller than the period that ends this sentence. Yet, every cell in every organism performs all the processes of life. So, are there any advantages to having many cells?

The Benefits of Being Multicellular

You are a *multicellular organism*. This means that you are made of many cells. Multicellular organisms grow by making more small cells, not by making their cells larger. For example, an elephant is bigger than you are, but its cells are about the same size as yours. An elephant just has more cells than you do. Some benefits of being multicellular are the following:

- **Larger Size** Many multicellular organisms are small. But they are usually larger than single-celled organisms. Larger organisms are prey for fewer predators. Larger predators can eat a wider variety of prey.
- **Longer Life** The life span of a multicellular organism is not limited to the life span of any single cell.
- **Specialization** Each type of cell has a particular job. Specialization makes the organism more efficient. For example, the cardiac muscle cell in **Figure 1** is a specialized muscle cell. Heart muscle cells contract and make the heart pump blood.

Reading Check **List three advantages of being multicellular.**
(*See the Appendix for answers to Reading Checks.*)

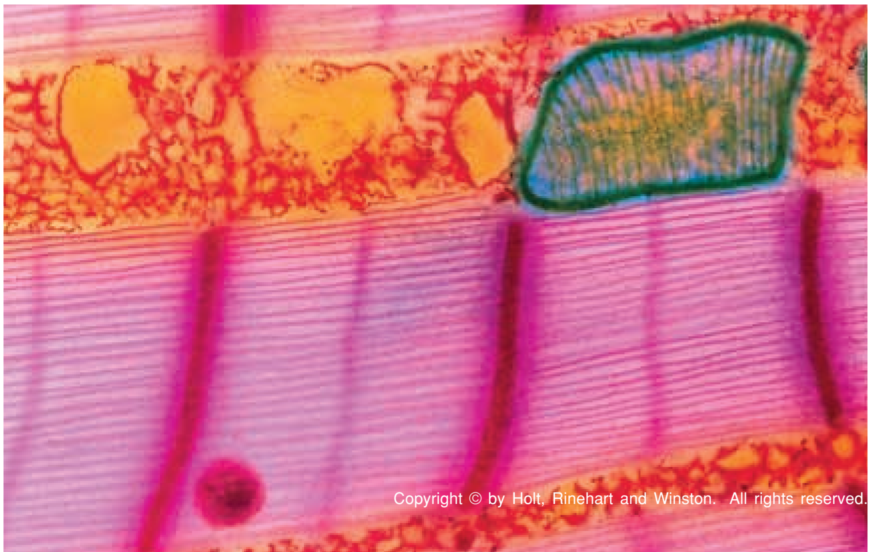


Figure 1 *This photomicrograph shows a small part of one heart muscle cell. The green line surrounds one of many mitochondria, the powerhouses of the cell. The pink areas are muscle filaments.*

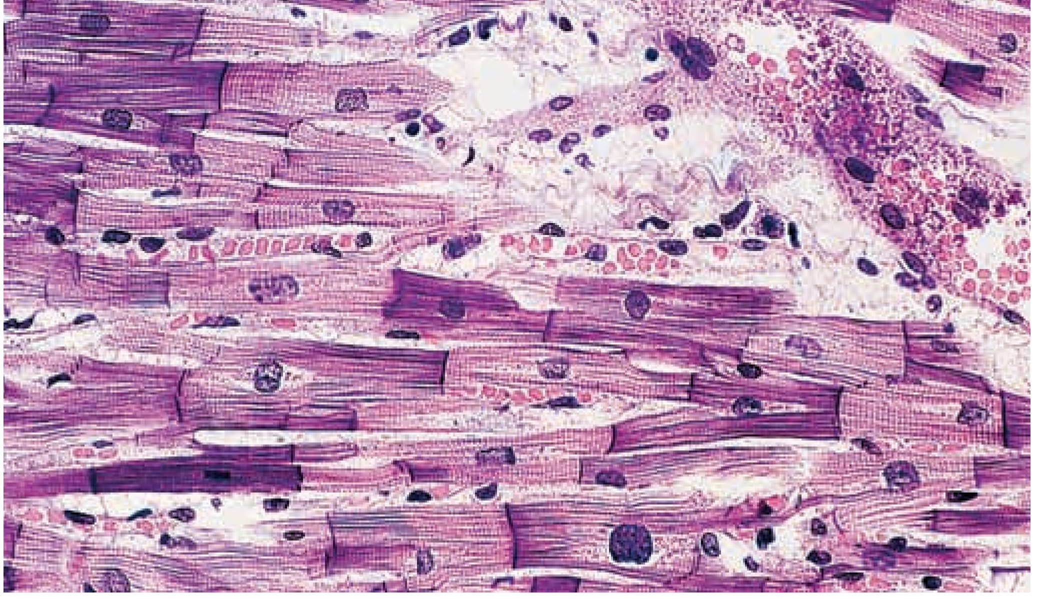


Figure 2 *This photomicrograph shows cardiac muscle tissue. Cardiac muscle tissue is made up of many cardiac cells.*

Cells Working Together

A **tissue** is a group of cells that work together to perform a specific job. The material around and between the cells is also part of the tissue. The cardiac muscle tissue, shown in **Figure 2,** is made of many cardiac muscle cells. Cardiac muscle tissue is just one type of tissue in a heart.

Animals have four basic types of tissues: nerve tissue, muscle tissue, connective tissue, and protective tissue. In contrast, plants have three types of tissues: transport tissue, protective tissue, and ground tissue. Transport tissue moves water and nutrients through a plant. Protective tissue covers the plant. It helps the plant retain water and protects the plant against damage. Photosynthesis takes place in ground tissue.

tissue a group of similar cells that perform a common function

organ a collection of tissues that carry out a specialized function of the body

Tissues Working Together

A structure that is made up of two or more tissues working together to perform a specific function is called an **organ.** For example, your heart is an organ. It is made mostly of cardiac muscle tissue. But your heart also has nerve tissue and tissues of the blood vessels that all work together to make your heart the powerful pump that it is.

Another organ is your stomach. It also has several kinds of tissue. In the stomach, muscle tissue makes food move in and through the stomach. Special tissues make chemicals that help digest your food. Connective tissue holds the stomach together, and nervous tissue carries messages back and forth between the stomach and the brain. Other organs include the intestines, brain, and lungs.

Plants also have different kinds of tissues that work together as organs. A leaf is a plant organ that contains tissue that traps light energy to make food. Other examples of plant organs are stems and roots.

Reading Check What is an organ?

MATH PRACTICE

A Pet Protist

Imagine that you have a tiny box-shaped protist for a pet. To care for your pet protist properly, you have to figure out how much to feed it. The dimensions of your protist are roughly 25 µm × 20 µm × 2 µm. If seven food particles per second can enter through each square micrometer of surface area, how many particles can your protist eat in 1 min?

organ system a group of organs that work together to perform body functions

organism a living thing; anything that can carry out life processes independently

structure the arrangement of parts in an organism

function the special, normal, or proper activity of an organ or part

Organs Working Together

A group of organs working together to perform a particular function is called an **organ system.** Each organ system has a specific job to do in the body.

For example, the digestive system is made up of several organs, including the stomach and intestines. The digestive system's job is to break down food into small particles. Other parts of the body then use these small particles as fuel. In turn, the digestive system depends on the respiratory and cardiovascular systems for oxygen. The cardiovascular system, shown in **Figure 3,** includes organs and tissues such as the heart and blood vessels. Plants also have organ systems. They include leaf systems, root systems, and stem systems.

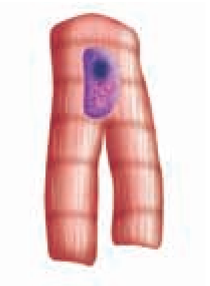
Reading Check **List the levels of organization in living things.**

Organisms

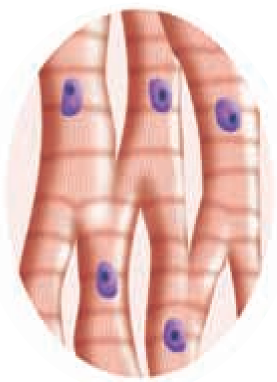
Anything that can perform life processes by itself is an **organism.** An organism made of a single cell is called a *unicellular organism.* Bacteria, most protists, and some kinds of fungi are unicellular. Although some of these organisms live in colonies, they are still unicellular. They are unicellular organisms living together, and all of the cells in the colony are the same. Each cell must carry out all life processes in order for that cell to survive. In contrast, even the simplest multicellular organism has specialized cells that depend on each other for the organism to survive.

Figure 3 **Levels of Organization in the Cardiovascular System**

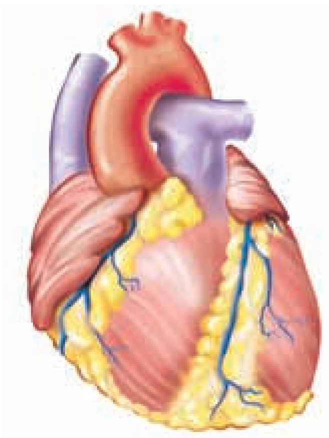
Cell
Cells form tissues.



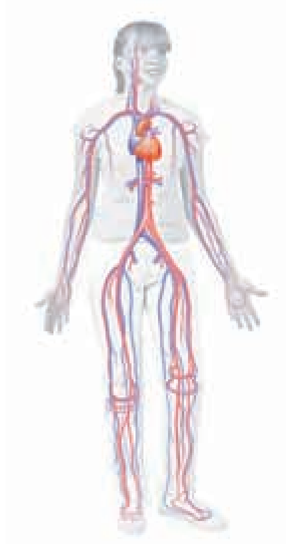
Tissue
Tissues form organs.



Organ
Organs form organ systems.



Organ system
And organ systems form organisms such as you!

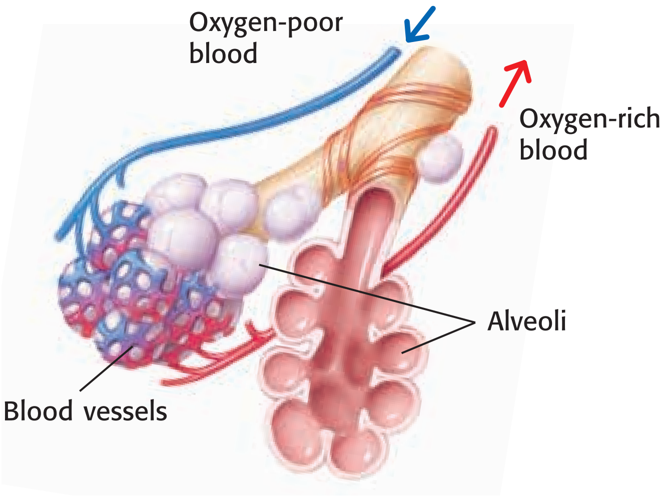


Structure and Function

In organisms, structure and function are related. **Structure** is the arrangement of parts in an organism. It includes the shape of a part and the material of which the part is made. **Function** is the job the part does. For example, the structure of the lungs is a large, spongy sac. In the lungs, there are millions of tiny air sacs called *alveoli*. Blood vessels wrap around the alveoli, as shown in **Figure 4.** Oxygen from air in the alveoli enters the blood. Blood then brings oxygen to body tissues. Also, in the alveoli, carbon dioxide leaves the blood and is exhaled.

The structures of alveoli and blood vessels enable them to perform a function. Together, they bring oxygen to the body and get rid of its carbon dioxide.

Figure 4 The Structure and Function of Alveoli



SECTION Review

Summary

- Advantages of being multicellular are larger size, longer life, and cell specialization.
- Four levels of organization are cell, tissue, organ, and organ system.
- A *tissue* is a group of cells working together. An *organ* is two or more tissues working together. An *organ system* is two or more organs working together.
- In organisms, a part's structure and function are related.

Using Key Terms

1. Use each of the following terms in a separate sentence: *tissue, organ,* and *function*.

Understanding Key Ideas

2. What are the four levels of organization in living things?
   a. cell, multicellular, organ, organ system
   b. single cell, multicellular, tissue, organ
   c. larger size, longer life, specialized cells, organs
   d. cell, tissue, organ, organ system

Math Skills

3. One multicellular organism is a cube. Each of its sides is 3 cm long. Each of its cells is 1 cm^3. How many cells does it have? If each side doubles in length, how many cells will it then have?

Critical Thinking

4. **Applying Concepts** Explain the relationship between structure and function. Use alveoli as an example. Be sure to include more than one level of organization.

5. **Making Inferences** Why can multicellular organisms be more complex than unicellular organisms? Use the three advantages of being multicellular to help explain your answer.

Model-Making Lab

Elephant-Sized Amoebas?

An amoeba is a single-celled organism. Like most cells, amoebas are microscopic. Why can't amoebas grow as large as elephants? If an amoeba grew to the size of a quarter, the amoeba would starve to death. To understand how this can be true, build a model of a cell and see for yourself.

OBJECTIVES

Explore why a single-celled organism cannot grow to the size of an elephant.

Create a model of a cell to illustrate the concept of surface area–to-volume ratio.

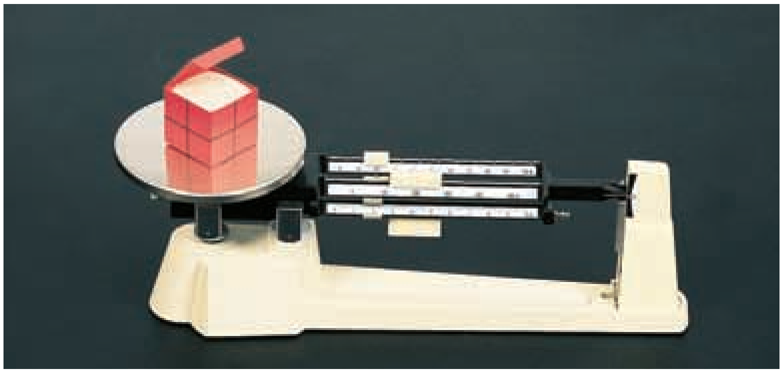
MATERIALS

- calculator (optional)
- cubic cell patterns
- heavy paper or poster board
- sand, fine
- scale or balance
- scissors
- tape, transparent

SAFETY

Procedure

1. Use heavy paper or poster board to make four cube-shaped cell models from the patterns supplied by your teacher. Cut out each cell model, fold the sides to make a cube, and tape the tabs on the sides. The smallest cell model has sides that are each one unit long. The next larger cell has sides of two units. The next cell has sides of three units, and the largest cell has sides of four units. These paper models represent the cell membrane, the part of a cell's exterior through which food and wastes pass.



Data Table for Measurements				
Length of side	**Area of one side** ($A = S \times S$)	**Total surface area of cube cell** ($TA = S \times S \times 6$)	**Volume of cube cell** ($V = S \times S \times S$)	**Mass of filled cube cell**
1 unit	1 unit^2	6 unit^2	1 unit^3	
2 unit				
3 unit		DO NOT WRITE IN BOOK		
4 unit				

Key to Formula Symbols

S = the length of one side

A = area

6 = number of sides

V = volume

TA = total area

2. Copy the data table shown above. Use each formula to calculate the data about your cell models. Record your calculations in the table. Calculations for the smallest cell have been done for you.
3. Carefully fill each model with fine sand until the sand is level with the top edge of the model. Find the mass of the filled models by using a scale or a balance. What does the sand in your model represent?
4. Record the mass of each filled cell model in your Data Table for Measurements. (Always remember to use the appropriate mass unit.)

Analyze the Results

1. **Constructing Tables** Make a data table like the one shown at right.
2. **Organizing Data** Use the data from your Data Table for Measurements to find the ratios for each of your cell models. For each of the cell models, fill in the Data Table for Ratios .

Draw Conclusions

3. **Interpreting Information** As a cell grows larger, does the ratio of total surface area to volume increase, decrease, or stay the same?
4. **Interpreting Information** As a cell grows larger, does the total surface area–to-mass ratio increase, decrease, or stay the same?
5. **Drawing Conclusions** Which is better able to supply food to all the cytoplasm of the cell: the cell membrane of a small cell or the cell membrane of a large cell? Explain your answer.
6. **Evaluating Data** In the experiment, which is better able to feed all of the cytoplasm of the cell: the cell membrane of a cell that has high mass or the cell membrane of a cell that has low mass? You may explain your answer in a verbal presentation to the class, or you may choose to write a report and illustrate it with drawings of your models.

Data Table for Ratios		
Length of side	**Ratio of total surface area to volume**	**Ratio of total surface area to mass**
1 unit		
2 unit		
3 unit	DO NOT WRITE IN BOOK	
4 unit		

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

cell	organ
cell membrane	prokaryote
organelles	eukaryote
cell wall	tissue
structure	function

1. A(n) ___ is the most basic unit of all living things.

2. The job that an organ does is the ___ of that organ.

3. Ribosomes and mitochondria are types of ___.

4. A(n) ___ is an organism whose cells have a nucleus.

5. A group of cells working together to perform a specific function is a(n) ___.

6. Only plant cells have a(n) ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Which of the following best describes an organ?
   - **a.** a group of cells that work together to perform a specific job
   - **b.** a group of tissues that belong to different systems
   - **c.** a group of tissues that work together to perform a specific job
   - **d.** a body structure, such as muscles or lungs

8. The benefits of being multicellular include
   - **a.** small size, long life, and cell specialization.
   - **b.** generalized cells, longer life, and ability to prey on small animals.
   - **c.** larger size, more enemies, and specialized cells.
   - **d.** longer life, larger size, and specialized cells.

9. In eukaryotic cells, which organelle contains the DNA?
   - **a.** nucleus
   - **b.** Golgi complex
   - **c.** smooth ER
   - **d.** vacuole

10. Which of the following statements is part of the cell theory?
    - **a.** All cells suddenly appear by themselves.
    - **b.** All cells come from other cells.
    - **c.** All organisms are multicellular.
    - **d.** All cells have identical parts.

11. The surface area–to-volume ratio of a cell limits
    - **a.** the number of organelles that the cell has.
    - **b.** the size of the cell.
    - **c.** where the cell lives.
    - **d.** the types of nutrients that a cell needs.

12. Two types of organisms whose cells do not have a nucleus are
    - **a.** prokaryotes and eukaryotes.
    - **b.** plants and animals.
    - **c.** eubacteria and archaebacteria.
    - **d.** single-celled and multicellular organisms.

Short Answer

13. Explain why most cells are small.

14. Describe the four levels of organization in living things.

15. What is the difference between the structure of an organ and the function of the organ?

16. Name two functions of a cell membrane.

17. What are the structure and function of the cytoskeleton in a cell?

CRITICAL THINKING

18. **Concept Mapping** Use the following terms to create a concept map: *cells, organisms, Golgi complex, organ systems, organs, nucleus, organelle,* and *tissues.*

19. **Making Comparisons** Compare and contrast the functions of the endoplasmic reticulum and the Golgi complex.

20. **Identifying Relationships** Explain how the structure and function of an organism's parts are related. Give an example.

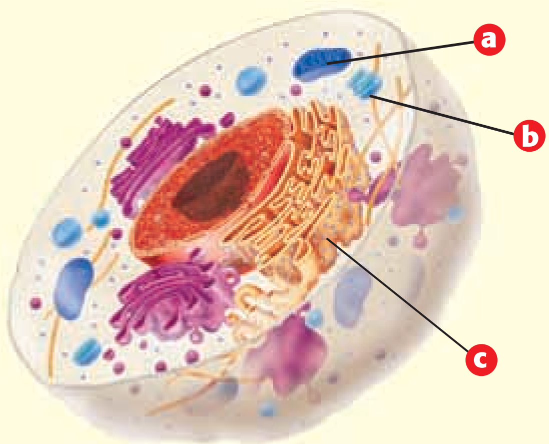
21. **Evaluating Hypotheses** One of your classmates states a hypothesis that all organisms must have organ systems. Is your classmate's hypothesis valid? Explain your answer.

22. **Predicting Consequences** What would happen if all of the ribosomes in your cells disappeared?

23. **Expressing Opinions** Scientists think that millions of years ago the surface of the Earth was very hot and that the atmosphere contained a lot of methane. In your opinion, which type of organism, a eubacterium or an archaebacterium, is the older form of life? Explain your reasoning.

INTERPRETING GRAPHICS

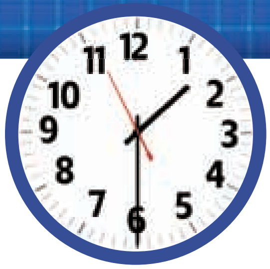
Use the diagram below to answer the questions that follow.



24. What is the name of the structure identified by the letter *a*?

25. Which letter identifies the structure that digests food particles and foreign invaders?

26. Which letter identifies the structure that makes proteins, lipids, and other materials and that contains tubes and passageways that enable substances to move to different places in the cell?



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Exploring caves can be dangerous but can also lead to interesting discoveries. For example, deep in the darkness of Cueva de Villa Luz, a cave in Mexico, are slippery formations called *snottites*. They were named snottites because they look just like a two-year-old's runny nose. If you use an electron microscope to look at them, you see that snottites are bacteria; thick, sticky fluids; and small amounts of minerals produced by the bacteria. As tiny as they are, these bacteria can build up snottite structures that may eventually turn into rock. Formations in other caves look like hardened snottites. The bacteria in snottites are acidophiles. Acidophiles live in environments that are highly acidic. Snottite bacteria produce sulfuric acid and live in an environment that is similar to the inside of a car battery.

1. Which statement best describes snottites?

- **A** Snottites are bacteria that live in car batteries.
- **B** Snottites are rock formations found in caves.
- **C** Snottites were named for a cave in Mexico.
- **D** Snottites are made of bacteria, sticky fluids, and minerals.

2. Based on this passage, which conclusion about snottites is most likely to be correct?

- **F** Snottites are found in caves everywhere.
- **G** Snottite bacteria do not need sunlight.
- **H** You could grow snottites in a greenhouse.
- **I** Snottites create other bacteria in caves.

3. What is the main idea of this passage?

- **A** Acidophiles are unusual organisms.
- **B** Snottites are strange formations.
- **C** Exploring caves is dangerous.
- **D** Snottites are large, slippery bacteria.

Passage 2 The world's smallest mammal may be a bat about the size of a jelly bean. The scientific name for this tiny animal, which was unknown until 1974, is *Craseonycteris thonglongyai*. It is so small that it is sometimes called the *bumblebee bat*. Another name for this animal is the *hog-nosed bat*. Hog-nosed bats were given their name because one of their distinctive features is a piglike muzzle. Hog-nosed bats differ from other bats in another way: they do not have a tail. But, like other bats, hog-nosed bats do eat insects that they catch in mid-air. Scientists think that the bats eat small insects that live on the leaves at the tops of trees. Hog-nosed bats live deep in limestone caves and have been found in only one country, Thailand.

1. According to the passage, which statement about hog-nosed bats is most accurate?

- **A** They are the world's smallest animal.
- **B** They are about the size of a bumblebee.
- **C** They eat leaves at the tops of trees.
- **D** They live in hives near caves in Thailand.

2. Which of the following statements describes distinctive features of hog-nosed bats?

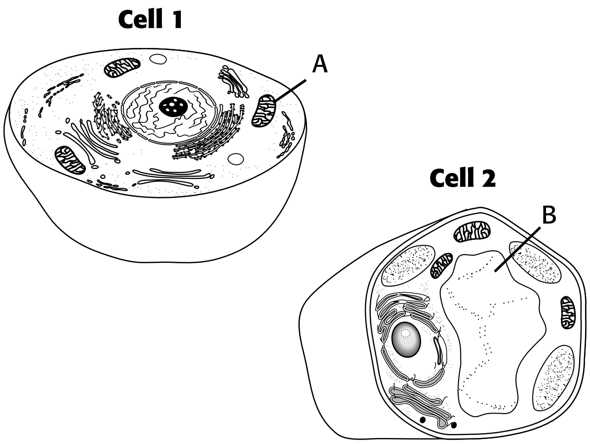
- **F** The bats are very small and eat leaves.
- **G** The bats live in caves and have a tail.
- **H** The bats live in Thailand and are birds.
- **I** The bats have a piglike muzzle and no tail.

3. From the information in this passage, which conclusion is most likely to be correct?

- **A** Hog-nosed bats are similar to other bats.
- **B** Hog-nosed bats are probably rare.
- **C** Hog-nosed bats can sting like a bumblebee.
- **D** Hog-nosed bats probably eat fruit.

INTERPRETING GRAPHICS

The diagrams below show two kinds of cells. Use these cell diagrams to answer the questions that follow.



1. What is the name of the organelle labeled *A* in Cell 1?

A endoplasmic reticulum
B mitochondrion
C vacuole
D nucleus

2. What type of cell is Cell 1?

F a bacterial cell
G a plant cell
H an animal cell
I a prokaryotic cell

3. What is the name and function of the organelle labeled *B* in Cell 2?

A The organelle is a vacuole, and it stores water and other materials.
B The organelle is the nucleus, and it contains the DNA.
C The organelle is the cell wall, and it gives shape to the cell.
D The organelle is a ribosome, where proteins are put together.

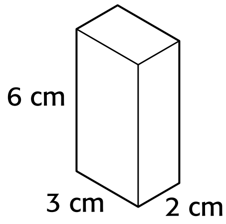
4. What type of cell is Cell 2? How do you know?

F prokaryotic; because it does not have a nucleus
G eukaryotic; because it does not have a nucleus
H prokaryotic; because it has a nucleus
I eukaryotic; because it has a nucleus

MATH

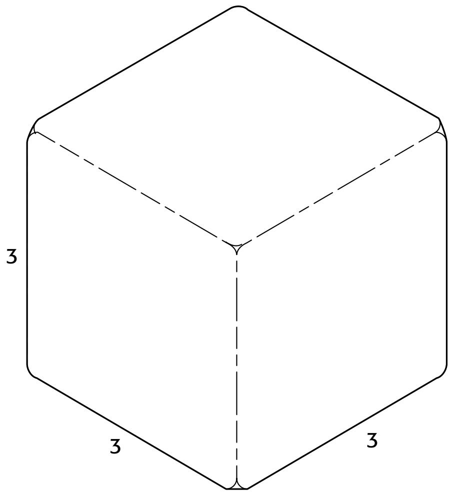
Read each question below, and choose the best answer.

1. What is the surface area–to-volume ratio of the rectangular solid shown in the diagram below?



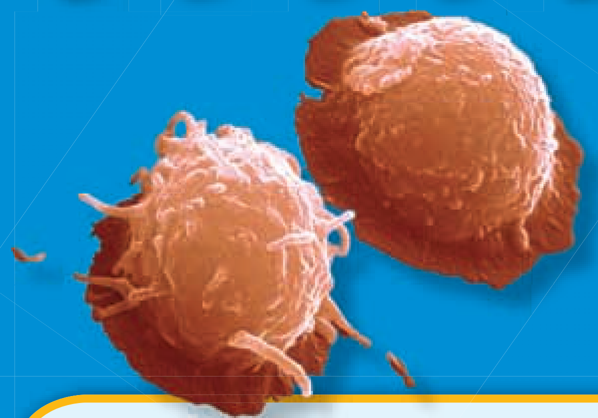
A 0.5:1
B 2:1
C 36:1
D 72:1

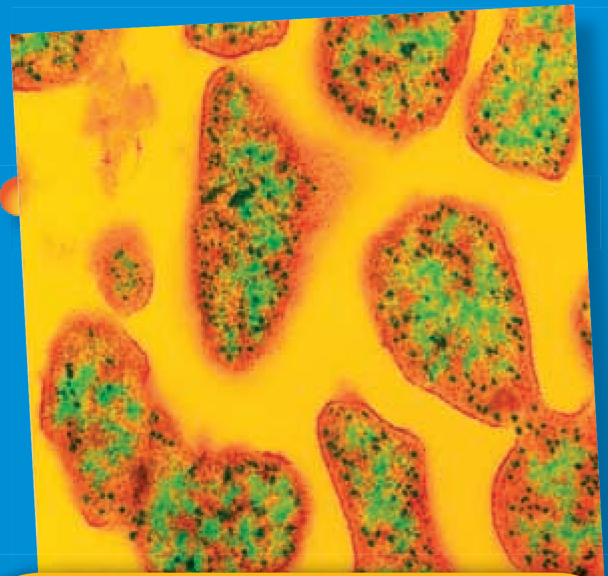
2. Look at the diagram of the cell below. Three molecules of food per cubic unit of volume per minute are required for the cell to survive. One molecule of food can enter through each square unit of surface area per minute. What will happen to this cell?



F The cell is too small, and it will starve.
G The cell is too large, and it will starve.
H The cell is at a size that will allow it to survive.
I There is not enough information to determine the answer.

Science in Action





Scientific Discoveries

Discovery of the Stem Cell

What do Parkinson's disease, diabetes, aplastic anemia, and Alzheimer's disease have in common? All of these diseases are diseases for which stem cells may provide treatment or a cure. Stem cells are unspecialized cells from which all other kinds of cells can grow. And research on stem cells has been going on almost since microscopes were invented. But scientists have been able to culture, or grow, stem cells in laboratories for only about the last 20 years. Research during these 20 years has shown scientists that stem cells can be useful in treating—and possibly curing—a variety of diseases.

Language Arts ACTIVITY

WRITING SKILL Imagine that you are a doctor who treats diseases such as Parkinson's disease. Design and create a pamphlet or brochure that you could use to explain what stem cells are. Include in your pamphlet a description of how stem cells might be used to treat one of your patients who has Parkinson's disease. Be sure to include information about Parkinson's disease.

Weird Science

Extremophiles

Are there organisms on Earth that can give scientists clues about possible life elsewhere? Yes, there are! These organisms are called *extremophiles,* and they live where the environment is extreme. For example, some extremophiles live in the hot volcanic thermal vents deep in the ocean. Other extremophiles live in the extreme cold of Antarctica. But these organisms do not live only in extreme environments. Research shows that extremophiles may be abundant in plankton in the ocean. And not all extremophiles are archaebacteria; some extremophiles are eubacteria.

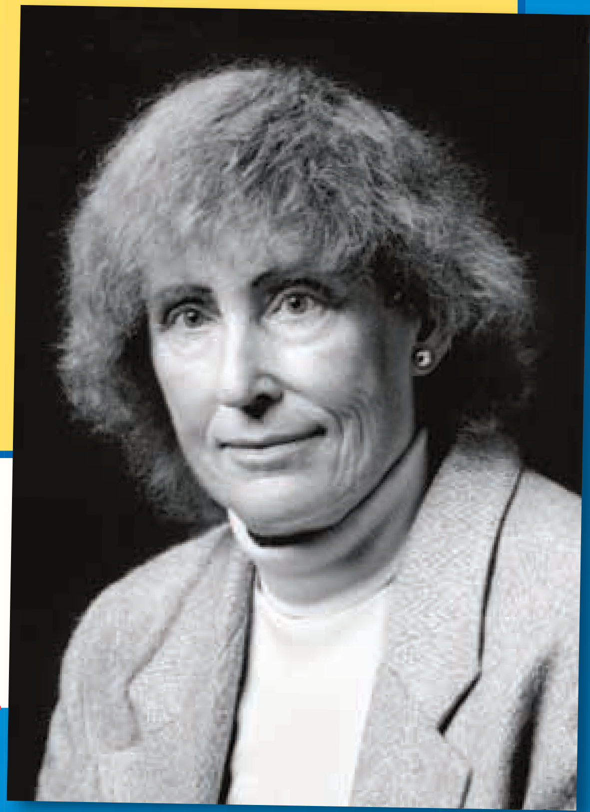
Social Studies ACTIVITY

Choose one of the four types of extremophiles. Do some research about the organism you have chosen and make a poster showing what you learned about it, including where it can be found, under what conditions it lives, how it survives, and how it is used.

Caroline Schooley

Microscopist Imagine that your assignment is the following: Go outside. Look at 1 ft^2 of the ground for 30 min. Make notes about what you observe. Be prepared to describe what you see. If you look at the ground with just your naked eyes, you may quickly run out of things to see. But what would happen if you used a microscope to look? How much more would you be able to see? And how much more would you have to talk about? Caroline Schooley could tell you.

Caroline Schooley joined a science club in middle school. That's when her interest in looking at things through a microscope began. Since then, Schooley has spent many years studying life through a microscope. She is a microscopist. A *microscopist* is someone who uses a microscope to look at small things. Microscopists use their tools to explore the world of small things that cannot be seen by the naked eye. And with today's powerful electron microscopes, microscopists can study things we could never see before, things as small as atoms.



Math ACTIVITY

An average bacterium is about 0.000002 m long. A pencil point is about 0.001 m wide. Approximately how many bacteria would fit on a pencil point?

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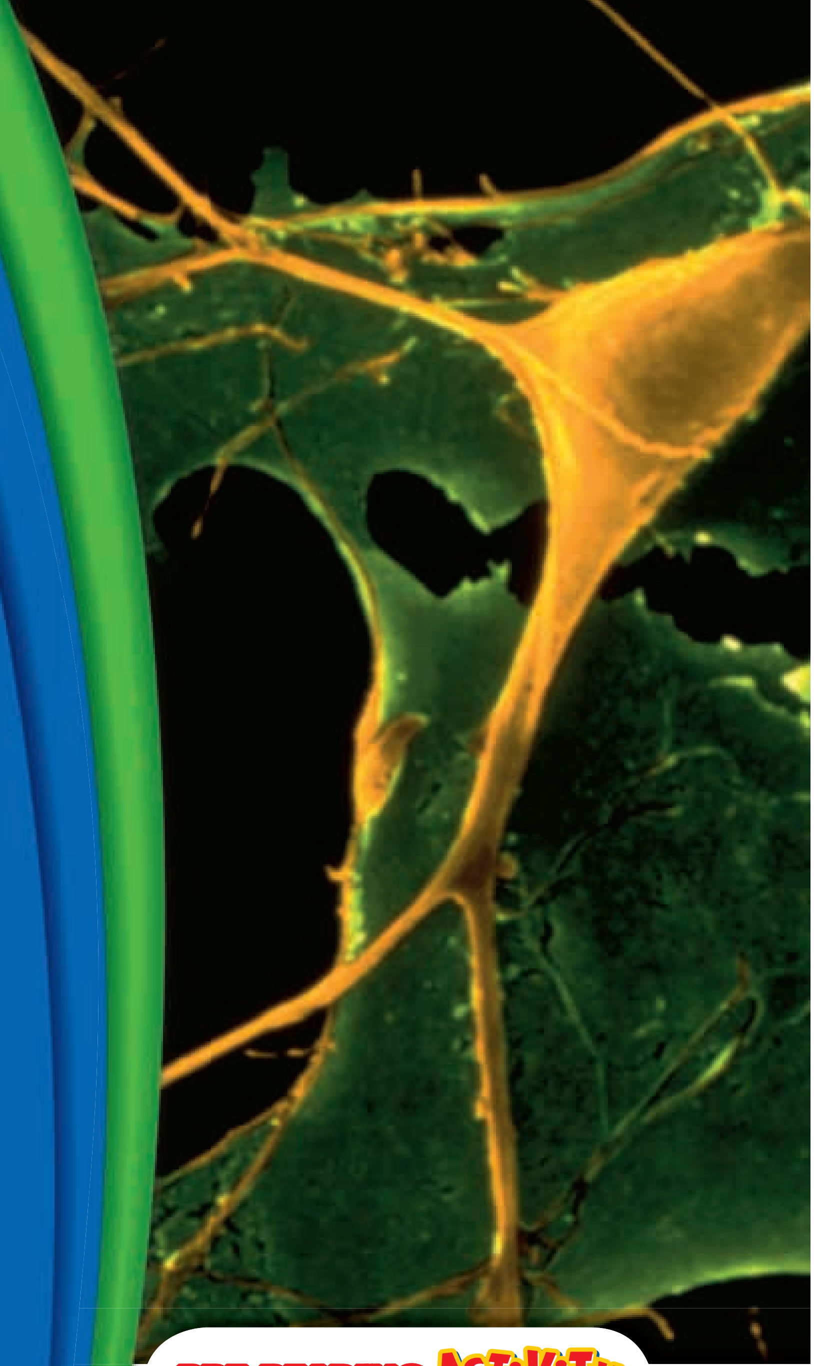
18

The Working Cell



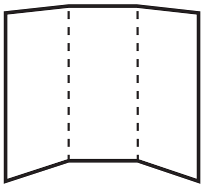
About the PHOTO

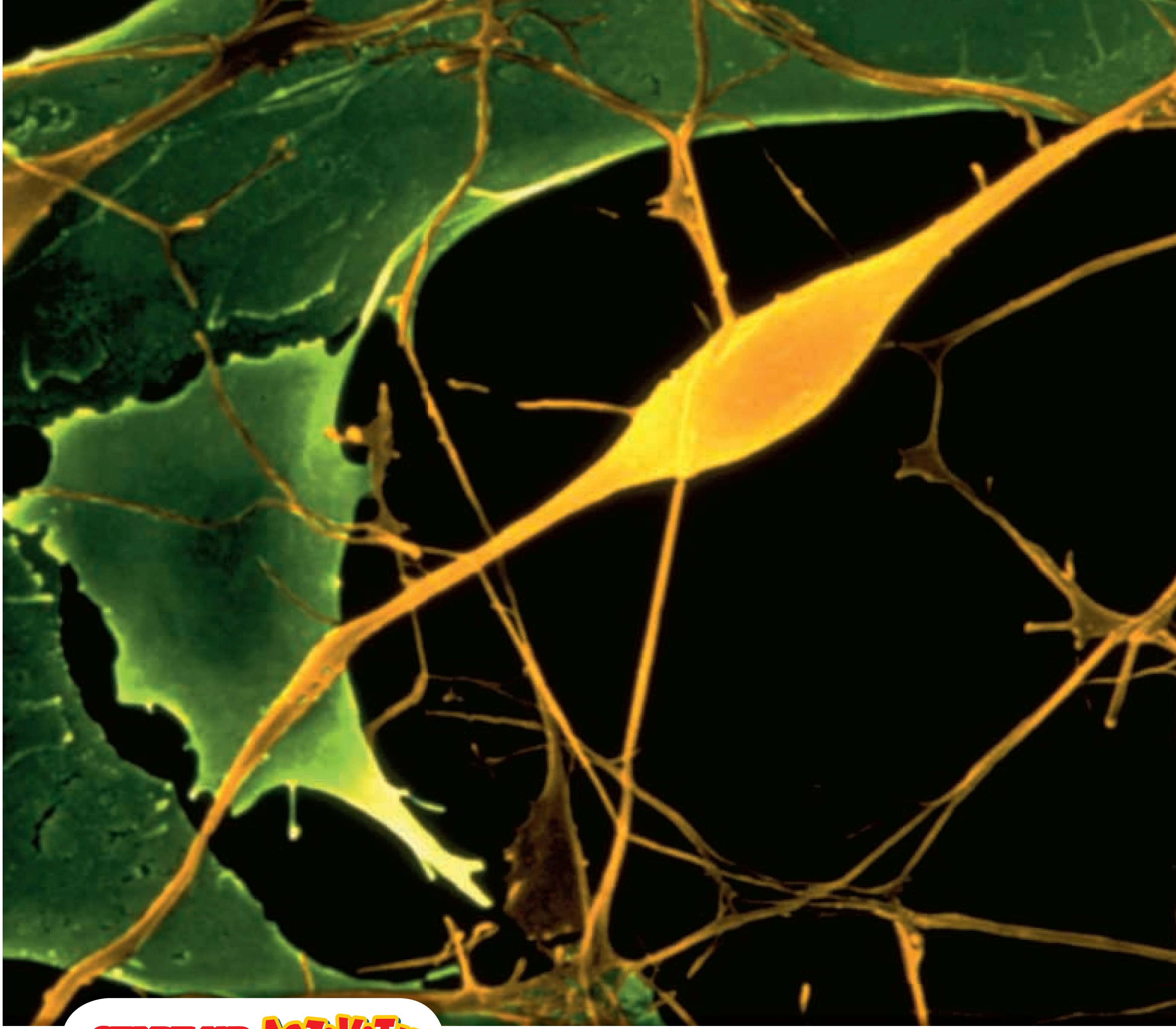
Nerve cells, such as the ones in this picture, interact with each other and with other cells in the body. In fact, no cell in the body exists independently of other cells. Cell interactions of different types benefit the body in many ways, such as maintaining homeostasis. The long, threadlike structures in the picture are dendrites and axons.

PRE-READING ACTIVITY

FOLDNOTES

Tri-Fold Before you read the chapter, create the FoldNote entitled "Tri-Fold" described in the **Study Skills** section of the Appendix. Write what you know about the actions of cells in the column labeled "Know." Then, write what you want to know in the column labeled "Want." As you read the chapter, write what you learn about the actions of cells in the column labeled "Learn."





START-UP ACTIVITY

Cells in Action

Yeast are single-celled fungi that are an important ingredient in bread. Yeast cells break down sugar molecules to release energy. In the process, carbon dioxide gas is produced, which causes bread dough to rise.

Procedure

1. Add **4 mL of a sugar solution** to **10 mL of a yeast-and-water mixture**. Use a **stirring rod** to thoroughly mix the two liquids.
2. Pour the stirred mixture into a small test tube.
3. Place a slightly **larger test tube** over the **small test tube.** The top of the small test tube should touch the bottom of the larger test tube.
4. Hold the test tubes together, and quickly turn both test tubes over. Place the test tubes in a test-tube rack.
5. Use a **ruler** to measure the height of the fluid in the large test tube. Wait 20 min, and then measure the height of the liquid again.

Analysis

1. What is the difference between the first height measurement and the second height measurement?
2. What do you think caused the change in the fluid's height?

SECTION 1

Exchange with the Environment

READING WARM-UP

Objectives

- Explain the process of diffusion.
- Describe how osmosis occurs.
- Compare passive transport with active transport.
- Explain how large particles get into and out of cells.

Terms to Learn

diffusion
osmosis
passive transport
active transport
endocytosis
exocytosis

READING STRATEGY

Reading Organizer As you read this section, make a table comparing active transport and passive transport.

What would happen to a factory if its power were shut off or its supply of raw materials never arrived? What would happen if the factory couldn't get rid of its garbage?

Like a factory, an organism must be able to obtain energy and raw materials and get rid of wastes. An organism's cells perform all of these functions. These functions keep cells healthy so that they can divide. Cell division allows organisms to grow and repair injuries.

The exchange of materials between a cell and its environment takes place at the cell's membrane. To understand how materials move into and out of the cell, you need to know about diffusion.

What Is Diffusion?

What happens if you pour dye on top of a layer of gelatin? At first, it is easy to see where the dye ends and the gelatin begins. But over time, the line between the two layers will blur, as shown in **Figure 1.** Why? Everything, including the gelatin and the dye, is made up of tiny moving particles. Particles travel from where they are crowded to where they are less crowded. This movement from areas of high concentration (crowded) to areas of low concentration (less crowded) is called **diffusion** (di FYOO zhuhn). Dye particles diffuse from where they are crowded (near the top of the glass) to where they are less crowded (in the gelatin). Diffusion also happens within and between living cells. Cells do not need to use energy for diffusion.

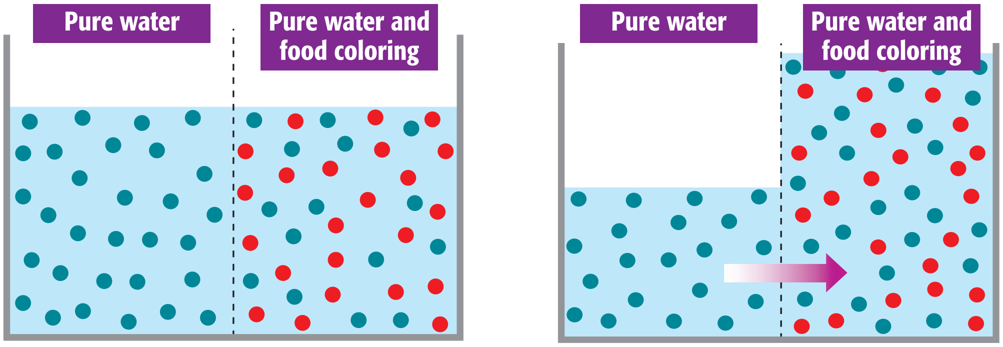
diffusion the movement of particles from regions of higher density to regions of lower density

Figure 1 *The particles of the dye and the gelatin slowly mix by diffusion.*

Figure 2 **Osmosis**

1 The side that holds only pure water has the higher concentration of water particles.

2 During osmosis, water particles move to where they are less concentrated.



Diffusion of Water

The cells of organisms are surrounded by and filled with fluids that are made mostly of water. The diffusion of water through cell membranes is so important to life processes that it has been given a special name—**osmosis** (ahs MOH sis).

osmosis the diffusion of water through a semipermeable membrane

Water is made up of particles, called *molecules*. Pure water has the highest concentration of water molecules. When you mix something, such as food coloring, sugar, or salt, with water, you lower the concentration of water molecules. **Figure 2** shows how water molecules move through a membrane that is semipermeable (SEM i PUHR mee uh buhl). *Semipermeable* means that only certain substances can pass through. The picture on the left in **Figure 2** shows liquids that have different concentrations of water. Over time, the water molecules move from the liquid with the high concentration of water molecules to the liquid with the lower concentration of water molecules.

The Cell and Osmosis

Osmosis is important to cell functions. For example, red blood cells are surrounded by plasma. Plasma is made up of water, salts, sugars, and other particles. The concentration of these particles is kept in balance by osmosis. If red blood cells were in pure water, water molecules would flood into the cells and cause them to burst. When red blood cells are put into a salty solution, the concentration of water molecules inside the cell is higher than the concentration of water outside. This difference makes water move out of the cells, and the cells shrivel up. Osmosis also occurs in plant cells. When a wilted plant is watered, osmosis makes the plant firm again.

Reading Check **Why would red blood cells burst if you placed them in pure water?** (*See the Appendix for answers to Reading Checks.*)

Quick Lab

Bead Diffusion

1. Put three groups of **colored beads** on the bottom of a **plastic bowl.** Each group should be made up of five beads of the same color.
2. Stretch some **clear plastic wrap** tightly over the top of the bowl. Gently shake the bowl for 10 seconds while watching the beads.
3. How is the scattering of the beads like the diffusion of particles? How is it different from the diffusion of particles?

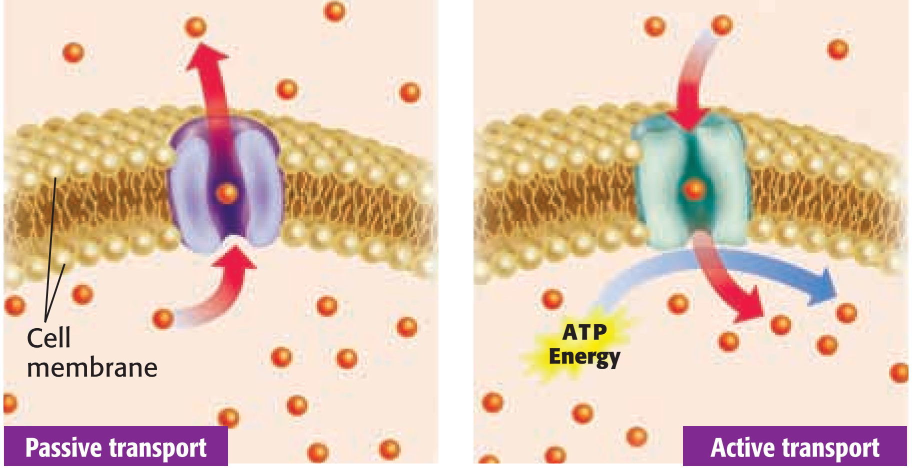


Figure 3 *In passive transport, particles travel through proteins to areas of lower concentration. In active transport, cells use energy to move particles, usually to areas of higher concentration.*

Moving Small Particles

Small particles, such as water and sugars, cross the cell membrane through passageways called *channels*. These channels are made up of proteins in the cell membrane. Particles travel through these channels by either passive or active transport. The movement of particles across a cell membrane without the use of energy by the cell is called **passive transport**, and is shown in **Figure 3.** During passive transport, particles move from an area of high concentration to an area of low concentration. Diffusion and osmosis are examples of passive transport.

A process of transporting particles that requires the cell to use energy is called **active transport.** Active transport usually involves the movement of particles from an area of low concentration to an area of high concentration.

passive transport the movement of substances across a cell membrane without the use of energy by the cell

active transport the movement of substances across the cell membrane that requires the cell to use energy

endocytosis the process by which a cell membrane surrounds a particle and encloses the particle in a vesicle to bring the particle into the cell

Moving Large Particles

Small particles cross the cell membrane by diffusion, passive transport, and active transport. Large particles move into and out of the cell by processes called *endocytosis* and *exocytosis*.

Endocytosis

The active-transport process by which a cell surrounds a large particle, such as a large protein, and encloses the particle in a vesicle to bring the particle into the cell is called **endocytosis** (EN doh sie TOH sis). *Vesicles* are sacs formed from pieces of cell membrane. **Figure 4** shows endocytosis.

Figure 4 **Endocytosis**

1. The cell comes into contact with a particle.
2. The cell membrane begins to wrap around the particle.
3. Once the particle is completely surrounded, a vesicle pinches off.

This photo shows the end of *endocytosis*, which means "within the cell."

Figure 5 **Exocytosis**

❶ Large particles that must leave the cell are packaged in vesicles.

❷ The vesicle travels to the cell membrane and fuses with it.

❸ The cell releases the particle to the outside of the cell.

Exocytosis means "outside the cell."

Exocytosis

When large particles, such as wastes, leave the cell, the cell uses an active-transport process called **exocytosis** (EK soh sie TOH sis). During exocytosis, a vesicle forms around a large particle within the cell. The vesicle carries the particle to the cell membrane. The vesicle fuses with the cell membrane and releases the particle to the outside of the cell. **Figure 5** shows exocytosis.

exocytosis the process in which a cell releases a particle by enclosing the particle in a vesicle that then moves to the cell surface and fuses with the cell membrane

Reading Check **What is exocytosis?**

SECTION Review

Summary

- Diffusion is the movement of particles from an area of high concentration to an area of low concentration.
- Osmosis is the diffusion of water through a semipermeable membrane.
- Cells move small particles by diffusion, which is an example of passive transport, and by active transport.
- Large particles enter the cell by endocytosis, and exit the cell by exocytosis.

Using Key Terms

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

1. *diffusion* and *osmosis*
2. *active transport* and *passive transport*
3. *endocytosis* and *exocytosis*

Understanding Key Ideas

4. The movement of particles from a less crowded area to a more crowded area requires
   - **a.** sunlight.
   - **b.** energy.
   - **c.** a membrane.
   - **d.** osmosis.
5. What structures allow small particles to cross cell membranes?

Math Skills

6. The area of particle 1 is 2.5 mm^2. The area of particle 2 is 0.5 mm^2. The area of particle 1 is how many times as big as the area of particle 2?

Critical Thinking

7. **Predicting Consequences** What would happen to a cell if its channel proteins were damaged and unable to transport particles? What would happen to the organism if many of its cells were damaged in this way? Explain your answer.
8. **Analyzing Ideas** Why does active transport require energy?

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For a variety of links related to this chapter, go to www.scilinks.org

Topics: Diffusion; Osmosis

SciLinks code: HSM0406; HSM1090

SECTION 2

Cell Energy

Why do you get hungry? Feeling hungry is your body's way of telling you that your cells need energy.

All cells need energy to live, grow, and reproduce. Plant cells get their energy from the sun. Many animal cells get the energy they need from food.

READING WARM-UP

Objectives

- Describe photosynthesis and cellular respiration.
- Compare cellular respiration with fermentation.

Terms to Learn

photosynthesis
cellular respiration
fermentation

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

From Sun to Cell

Nearly all of the energy that fuels life comes from the sun. Plants capture energy from the sun and change it into food through a process called **photosynthesis.** The food that plants make supplies them with energy. This food also becomes a source of energy for the organisms that eat the plants.

photosynthesis the process by which plants, algae, and some bacteria use sunlight, carbon dioxide, and water to make food

Photosynthesis

Plant cells have molecules that absorb light energy. These molecules are called *pigments*. Chlorophyll (KLAWR uh FIL), the main pigment used in photosynthesis, gives plants their green color. Chlorophyll is found in chloroplasts.

Plants use the energy captured by chlorophyll to change carbon dioxide and water into food. The food is in the form of the simple sugar glucose. Glucose is a carbohydrate. When plants make glucose, they convert the sun's energy into a form of energy that can be stored. The energy in glucose is used by the plant's cells. Photosynthesis also produces oxygen. Photosynthesis is summarized in **Figure 1.**

Photosynthesis

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \text{Light energy} \rightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

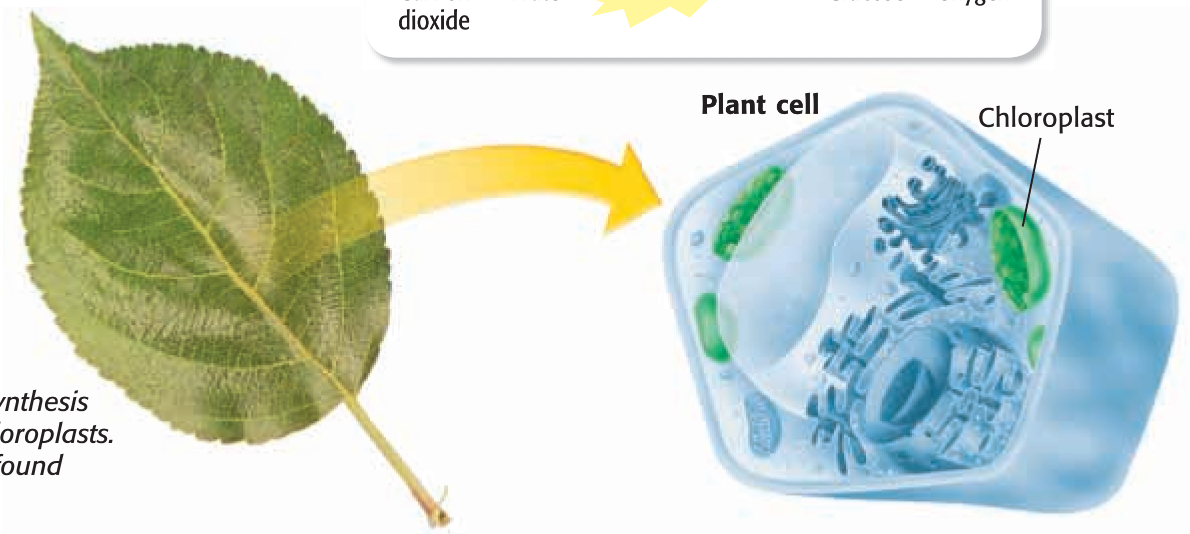


Figure 1 *Photosynthesis takes place in chloroplasts. Chloroplasts are found inside plant cells.*

Getting Energy from Food

Animal cells have different ways of getting energy from food. One way, called **cellular respiration,** uses oxygen to break down food. Many cells can get energy without using oxygen through a process called **fermentation.** Cellular respiration will release more energy from a given food than fermentation will.

Cellular Respiration

The word *respiration* means "breathing," but cellular respiration is different from breathing. Breathing supplies the oxygen needed for cellular respiration. Breathing also removes carbon dioxide, which is a waste product of cellular respiration. But cellular respiration is a chemical process that occurs in cells.

Most complex organisms, such as the cow in **Figure 2,** obtain energy through cellular respiration. During cellular respiration, food (such as glucose) is broken down into CO_2 and H_2O, and energy is released. Most of the energy released maintains body temperature. Some of the energy is used to form adenosine triphosphate (ATP). ATP supplies energy that fuels cell activities.

Most of the process of cellular respiration takes place in the cell membrane of prokaryotic cells. But in the cells of eukaryotes, cellular respiration takes place mostly in the mitochondria. The process of cellular respiration is summarized in **Figure 2.** Does the equation in the figure remind you of the equation for photosynthesis? **Figure 3** on the next page shows how photosynthesis and respiration are related.

Reading Check **What is the difference between cellular respiration and breathing?** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Chemistry

Earth's Early Atmosphere

Scientists think that Earth's early atmosphere lacked oxygen. Because of this lack of oxygen, early organisms used fermentation to get energy from food. When organisms began to photosynthesize, the oxygen they produced entered the atmosphere. How do you think this oxygen changed how other organisms got energy?

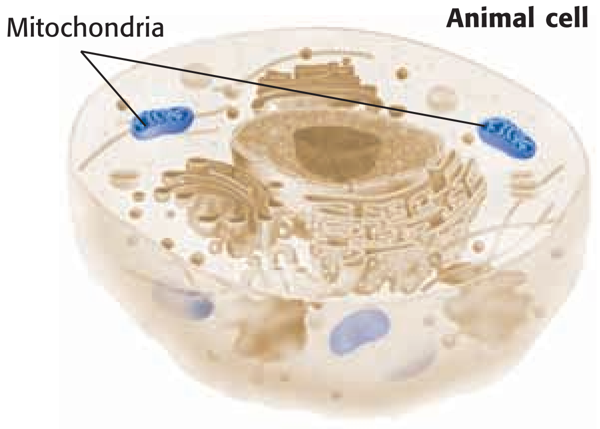
cellular respiration the process by which cells use oxygen to produce energy from food

fermentation the breakdown of food without the use of oxygen

Cellular Respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy (ATP)}$$

Glucose	Oxygen	Carbon dioxide	Water



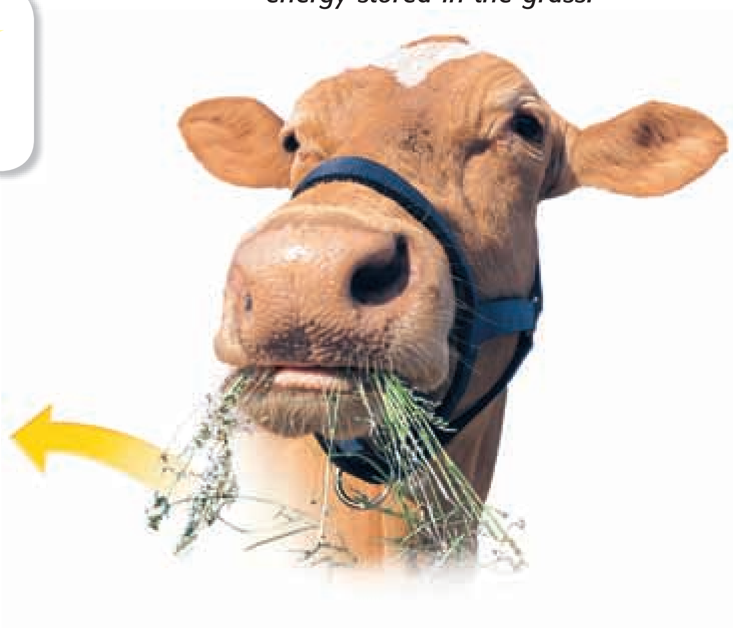
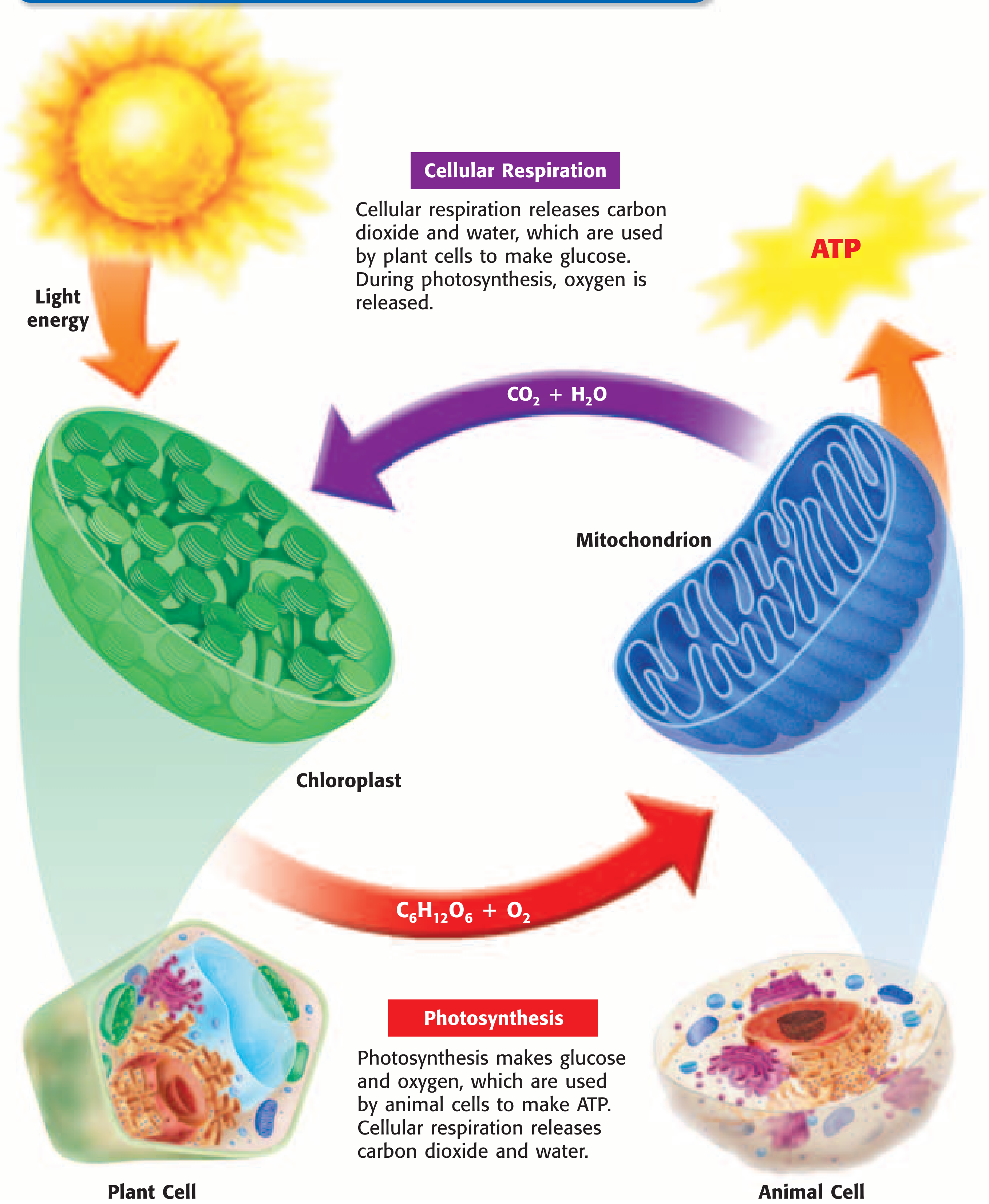


Figure 2 *The mitochondria in the cells of this cow will use cellular respiration to release the energy stored in the grass.*

Figure 3 The Connection Between Photosynthesis and Respiration



Connection Between Photosynthesis and Respiration

As shown in **Figure 3,** photosynthesis transforms energy from the sun into glucose. During photosynthesis, cells use CO_2 to make glucose, and the cells release O_2. During cellular respiration, cells use O_2 to break down glucose and release energy and CO_2. Each process makes the materials that are needed for the other process to occur elsewhere.

Fermentation

Have you ever felt a burning sensation in your leg muscles while you were running? When muscle cells can't get the oxygen needed for cellular respiration, they use the process of fermentation to get energy. One kind of fermentation happens in your muscles and produces lactic acid. The buildup of lactic acid contributes to muscle fatigue and causes a burning sensation. This kind of fermentation also happens in the muscle cells of other animals and in some fungi and bacteria. Another type of fermentation occurs in some types of bacteria and in yeast as described in **Figure 4.**

Figure 4 *Yeast forms carbon dioxide during fermentation. The bubbles of CO_2 gas cause the dough to rise and leave small holes in bread after it is baked.*

Reading Check What are two kinds of fermentation?

SECTION Review

Summary

- Most of the energy that fuels life processes comes from the sun.
- The sun's energy is converted into food by the process of photosynthesis.
- Cellular respiration breaks down glucose into water, carbon dioxide, and energy.
- Fermentation is a way that cells get energy from their food without using oxygen.

Using Key Terms

1. In your own words, write a definition for the term *fermentation*.

Understanding Key Ideas

2. O_2 is released during
   - **a.** cellular respiration.
   - **b.** photosynthesis.
   - **c.** breathing.
   - **d.** fermentation.
3. How are photosynthesis and cellular respiration related?
4. How are respiration and fermentation similar? How are they different?

Math Skills

5. Cells of plant A make 120 molecules of glucose an hour. Cells of plant B make half as much glucose as plant A does. How much glucose does plant B make every minute?

Critical Thinking

6. **Analyzing Relationships** Why are plants important to the survival of all other organisms?
7. **Applying Concepts** You have been given the job of restoring life to a barren island. What types of organisms would you put on the island? If you want to have animals on the island, what other organisms must you bring? Explain your answer.

SECTION 3

The Cell Cycle

In the time that it takes you to read this sentence, your body will have made millions of new cells! Making new cells allows you to grow and replace cells that have died.

The environment in your stomach is so acidic that the cells lining your stomach must be replaced every few days. Other cells are replaced less often, but your body is constantly making new cells.

READING WARM-UP

Objectives

- Explain how cells produce more cells.
- Describe the process of mitosis.
- Explain how cell division differs in animals and plants.

Terms to Learn

cell cycle
chromosome
homologous chromosomes
mitosis
cytokinesis

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

The Life of a Cell

As you grow, you pass through different stages in life. Your cells also pass through different stages in their life cycle. The life cycle of a cell is called the **cell cycle.**

The cell cycle begins when the cell is formed and ends when the cell divides and forms new cells. Before a cell divides, it must make a copy of its deoxyribonucleic acid (DNA). DNA is the hereditary material that controls all cell activities, including the making of new cells. The DNA of a cell is organized into structures called **chromosomes.** Copying chromosomes ensures that each new cell will be an exact copy of its parent cell. How does a cell make more cells? It depends on whether the cell is prokaryotic (with no nucleus) or eukaryotic (with a nucleus).

cell cycle the life cycle of a cell

chromosome in a eukaryotic cell, one of the structures in the nucleus that are made up of DNA and protein; in a prokaryotic cell, the main ring of DNA

Making More Prokaryotic Cells

Prokaryotic cells are less complex than eukaryotic cells are. Bacteria, which are prokaryotes, have ribosomes and a single, circular DNA molecule but don't have membrane-enclosed organelles. Cell division in bacteria is called *binary fission,* which means "splitting into two parts." Binary fission results in two cells that each contain one copy of the circle of DNA. A few of the bacteria in **Figure 1** are undergoing binary fission.

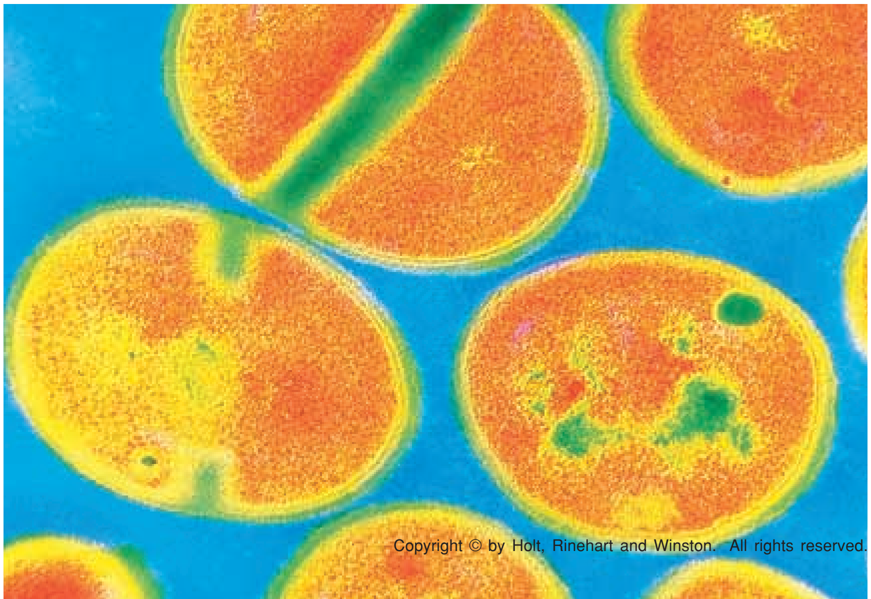


Figure 1 *Bacteria reproduce by binary fission.*

Eukaryotic Cells and Their DNA

Eukaryotic cells are more complex than prokaryotic cells are. The chromosomes of eukaryotic cells contain more DNA than those of prokaryotic cells do. Different kinds of eukaryotes have different numbers of chromosomes. More-complex eukaryotes do not necessarily have more chromosomes than simpler eukaryotes do. For example, fruit flies have 8 chromosomes, potatoes have 48, and humans have 46. **Figure 2** shows the 46 chromosomes of a human body cell lined up in pairs. These pairs are made up of similar chromosomes known as **homologous chromosomes** (hoh MAHL uh guhs KROH muh SOHMZ).

Reading Check **Do more-complex organisms always have more chromosomes than simpler organisms do?** (*See the Appendix for answers to Reading Checks.*)

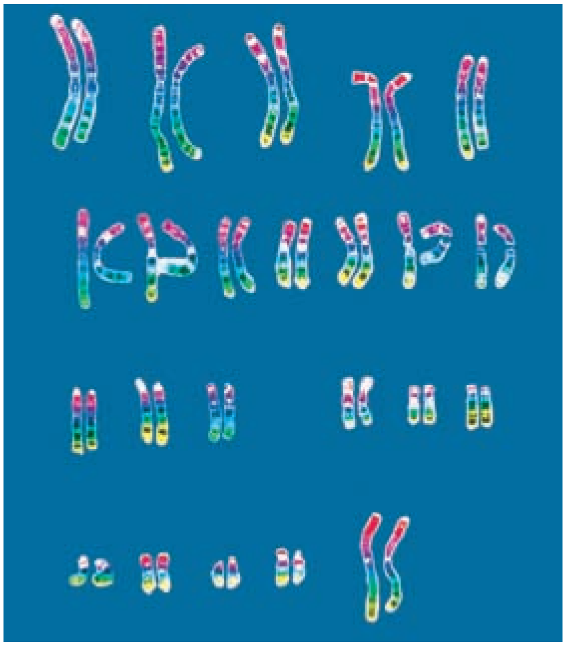


Figure 2 *Human body cells have 46 chromosomes, or 23 pairs of chromosomes.*

Making More Eukaryotic Cells

The eukaryotic cell cycle includes three stages. In the first stage, called *interphase,* the cell grows and copies its organelles and chromosomes. After each chromosome is duplicated, the two copies are called *chromatids*. Chromatids are held together at a region called the *centromere*. The joined chromatids twist and coil and condense into an X shape, as shown in **Figure 3.** After this step, the cell enters the second stage of the cell cycle.

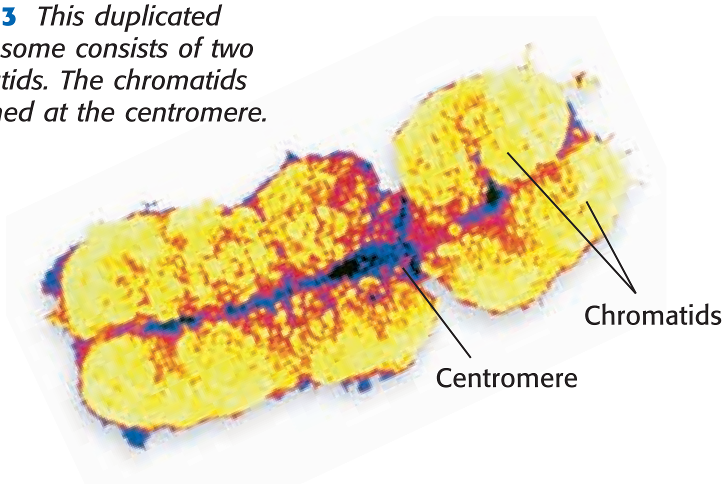
In the second stage, the chromatids separate. The complicated process of chromosome separation is called **mitosis.** Mitosis ensures that each new cell receives a copy of each chromosome. Mitosis is divided into four phases, as shown on the following pages.

In the third stage, the cell splits into two cells. These cells are identical to each other and to the original cell.

homologous chromosomes chromosomes that have the same sequence of genes and the same structure

mitosis in eukaryotic cells, a process of cell division that forms two new nuclei, each of which has the same number of chromosomes

Figure 3 *This duplicated chromosome consists of two chromatids. The chromatids are joined at the centromere.*



CONNECTION TO Language Arts

Picking Apart Vocabulary

Brainstorm what words are similar to the parts of the term *homologous chromosome*. What can you guess about the meaning of the term's root words? Look up the roots of the words, and explain how they help describe the concept.

ACTIVITY

Figure 4 **The Cell Cycle**

Copying DNA (Interphase)

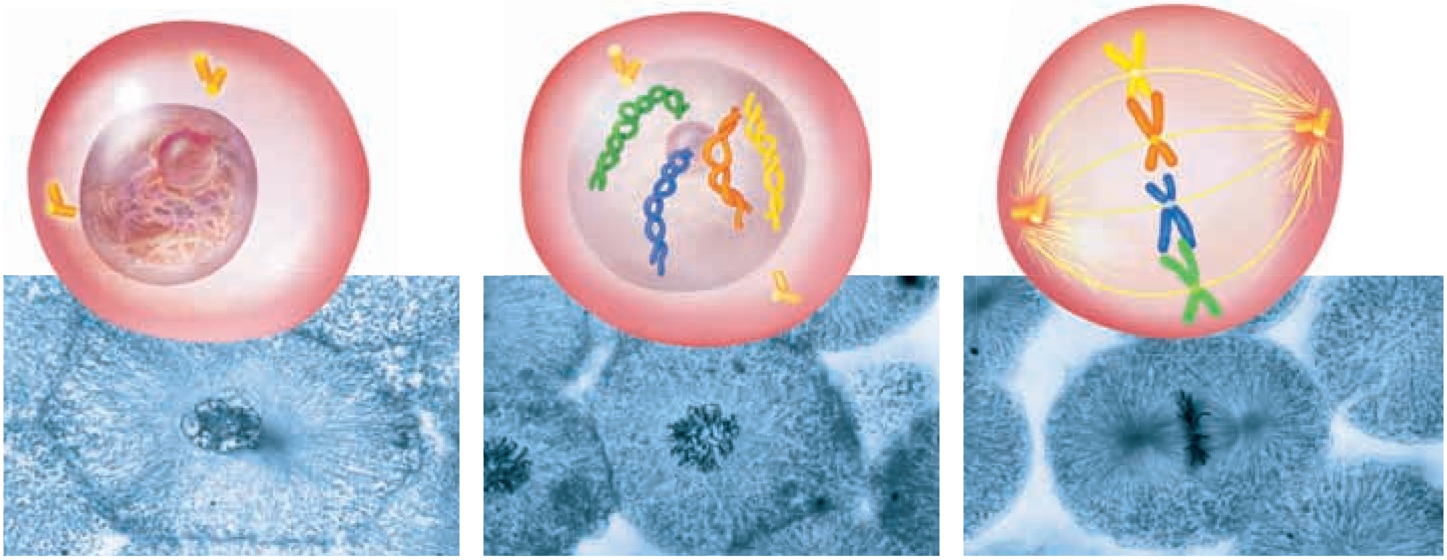
Before mitosis begins, chromosomes are copied. Each chromosome is then two chromatids.

Mitosis Phase 1 (Prophase)

Mitosis begins. The nuclear membrane dissolves. Chromosomes condense into rodlike structures.

Mitosis Phase 2 (Metaphase)

The chromosomes line up along the equator of the cell. Homologous chromosomes pair up.



cytokinesis the division of the cytoplasm of a cell

Mitosis and the Cell Cycle

Figure 4 shows the cell cycle and the phases of mitosis in an animal cell. Mitosis has four phases that are shown and described above. This diagram shows only four chromosomes to make it easy to see what's happening inside the cell.

Cytokinesis

In animal cells and other eukaryotes that do not have cell walls, division of the cytoplasm begins at the cell membrane. The cell membrane begins to pinch inward to form a groove, which eventually pinches all the way through the cell, and two daughter cells form. The division of cytoplasm is called **cytokinesis** and is shown at the last step of **Figure 4.**

Eukaryotic cells that have a cell wall, such as the cells of plants, algae, and fungi, reproduce differently. In these cells, a *cell plate* forms in the middle of the cell. The cell plate contains the materials for the new cell membranes and the new cell walls that will separate the new cells. After the cell splits into two, a new cell wall forms where the cell plate was. The cell plate and a late stage of cytokinesis in a plant cell are shown in **Figure 5.**

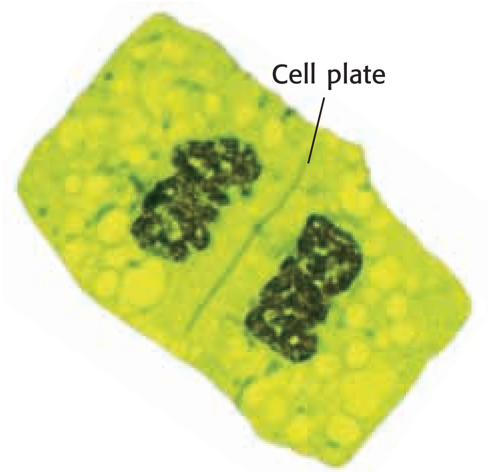
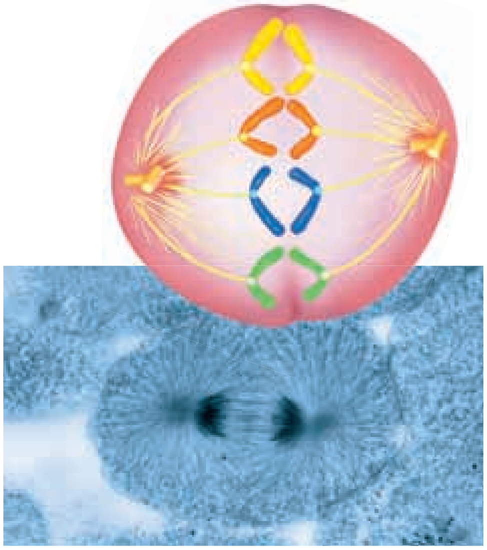


Figure 5 *When a plant cell divides, a cell plate forms and the cell splits into two cells.*

Reading Check **What is the difference between cytokinesis in an animal cell and cytokinesis in a plant cell?**

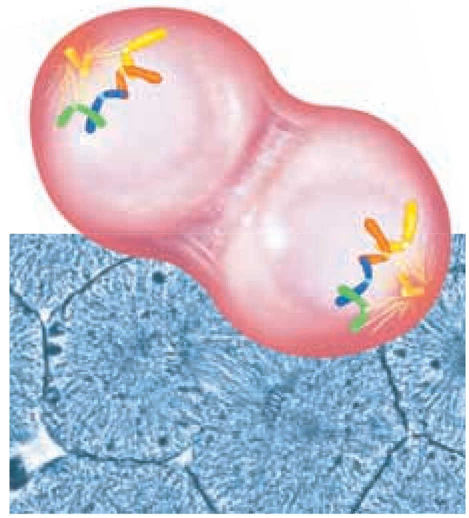
Mitosis Phase 3 (Anaphase)

The chromatids separate and move to opposite sides of the cell.



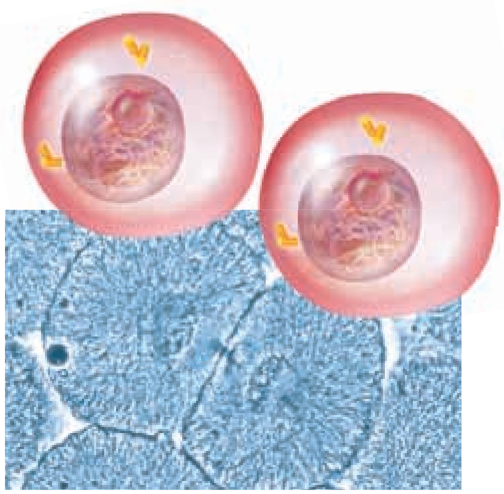
Mitosis Phase 4 (Telophase)

A nuclear membrane forms around each set of chromosomes, and the chromosomes unwind. Mitosis is complete.



Cytokinesis

In cells that lack a cell wall, the cell pinches in two. In cells that have a cell wall, a cell plate forms between the two new cells.



SECTION Review

Summary

- A cell produces more cells by first copying its DNA.
- Eukaryotic cells produce more cells through the four phases of mitosis.
- Mitosis produces two cells that have the same number of chromosomes as the parent cell.
- At the end of mitosis, a cell divides the cytoplasm by cytokinesis.
- In plant cells, a cell plate forms between the two new cells during cytokinesis.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *cell cycle* and *cytokinesis*.

Understanding Key Ideas

2. Eukaryotic cells
   a. do not divide.
   b. undergo binary fission.
   c. undergo mitosis.
   d. have cell walls.
3. Why is it important for chromosomes to be copied before cell division?
4. Describe mitosis.

Math Skills

5. Cell A takes 6 h to complete division. Cell B takes 8 h to complete division. After 24 h, how many more copies of cell A would there be than cell B?

Critical Thinking

6. **Predicting Consequences** What would happen if cytokinesis occurred without mitosis?
7. **Applying Concepts** How does mitosis ensure that a new cell is just like its parent cell?
8. **Making Comparisons** Compare the processes that animal cells and plant cells use to make new cells. How are the processes different?

SCILINKS

NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Cell Cycle
SciLinks code: HSM0235

SECTION 4

Feedback Mechanisms

Imagine jumping into a cold lake. Your body temperature drops. You feel cold. Quickly, your cells react and your body adjusts to the cold water. How?

READING WARM-UP

Objectives

- Explain how feedback mechanisms work.
- Describe how cells use feedback mechanisms internally.
- Describe how the body uses feedback mechanisms to maintain homeostasis.

Terms to Learn

feedback mechanism

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Your body adjusts through homeostasis (hoh mee oh STAY sis). *Homeostasis* is the maintenance of a stable internal environment in the body. When your body temperature drops a little, your body adjusts. For example, to raise your temperature back to normal, you may shiver to warm up. And to help, some of your cells burn extra glucose to give you energy to shiver.

Feedback Mechanisms and Information

Maintaining homeostasis is not easy. What triggers your body to respond to a change in the internal environment? For example, what triggers your cells to convert more of the energy stored in food into energy to warm you? Information from inside and outside triggers the cell to adjust.

Your cells may be responding to a feedback mechanism. A **feedback mechanism** is a cycle of events in which information from one step controls or affects a previous step. **Figure 1** is an example of a familiar feedback mechanism. A thermostat uses information about air temperature to tell the heater to turn on or off. Similarly, cells respond to information from their environment. Some cells may convert more energy stored in food into usable energy. Other cells may trigger a neural impulse or release more of a particular hormone.

feedback mechanism a cycle of events in which information from one step controls or affects a previous step

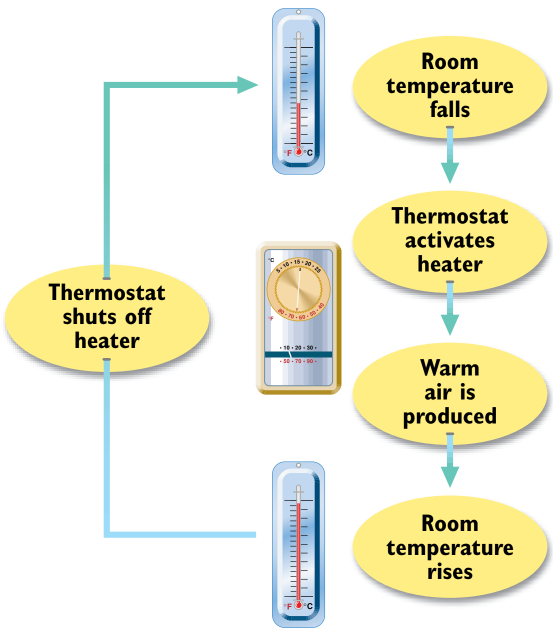
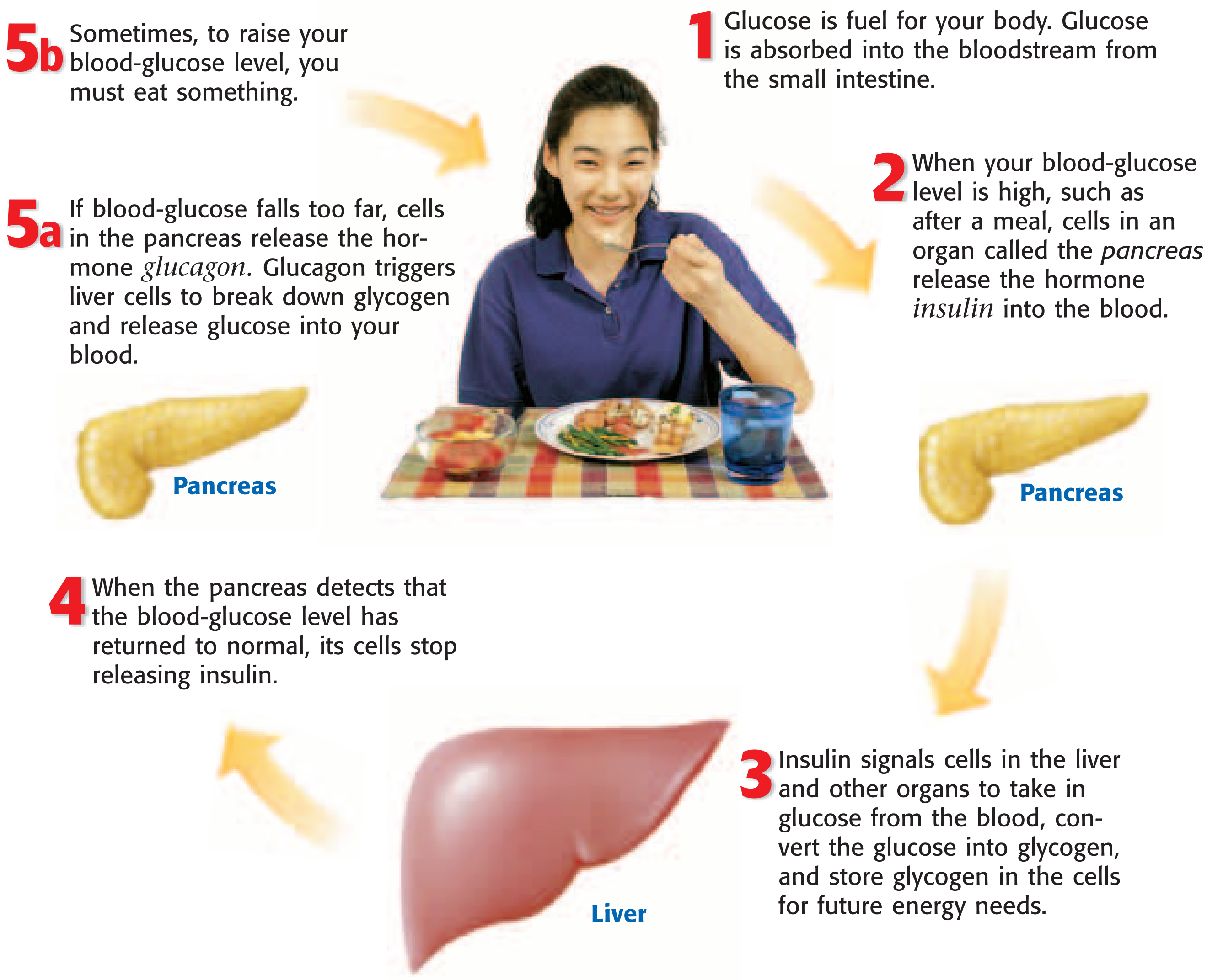


Figure 1 *Your body has a feedback mechanism similar to a thermostat. If your body temperature falls too far, your body responds by shivering to increase your body temperature.*

Figure 2 Blood-Glucose Feedback Mechanism



Different Levels of Feedback Mechanisms

Feedback mechanisms, such as the one shown in **Figure 2,** depend on chemical and electrical signals. These signals generally affect activities within cells, but the cells' responses may affect the whole body. The blood-glucose feedback mechanism affects the whole body. At the cellular level, some cells respond to these signals by taking in more glucose. But glucose molecules are large and cannot enter most cells on their own. Instead, cells have structures called *transport proteins* in their cell membranes. These transport proteins help move glucose molecules through the cell membrane and into the cell.

Reading Check **Describe the blood-glucose feedback mechanism.** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Chemistry

Thyroid Gland Hormones

Thyroid hormones help regulate many body functions. Calicitonin, another thyroid hormone, helps regulate calcium deposits in bones. Research the thyroid gland. Select one hormone produced by the thyroid. Make a poster showing how that hormone uses a feedback mechanism to trigger hormone level changes.

ACTIVITY

Feedback Mechanisms and the Body

The body relies on two systems to maintain homeostasis. First is the nervous system, which senses your internal and external environments. This system uses electrical impulses and chemical messengers to respond to what it senses. Second is the endocrine system, a collection of glands and groups of cells that produce chemical messengers called hormones. Both systems use feedback mechanisms to regulate their actions.

CONNECTION TO Chemistry

Neurotransmitters When an electrical impulse reaches the end of an axon (the *axon terminal*), the impulse triggers the release of neurotransmitters. These chemical messengers cross the synapse and trigger an electrical impulse in the receiving cell. Use the library or the Internet to research neurotransmitters, especially those in the brain. Scientists are studying the role that neurotransmitters play in drug addiction and in diseases such as Parkinson's disease.

ACTIVITY

Feedback in the Nervous System

The nervous system gathers and responds to information about your internal and external environments. Nerves carry responses to the appropriate part of the body. These messages are carried by electrical impulses and by chemicals called neurotransmitters (NOO roh TRANS MIT uhrz). **Figure 3** shows how an electrical impulse is transmitted from one cell to the next.

Regulating Body Temperature

The nervous system sends information about body temperature to the hypothalamus (HIE poh THAL uh muhs), which is a part of the lower brain. As body temperature rises, the hypothalamus sends messages to sweat glands and to muscles in the walls of capillaries in the skin. These messages trigger the sweat glands to release more sweat. As sweat evaporates from the skin, the skin is cooled. The capillaries dilate (open wider) and bring more blood and more heat close to the surface of the skin. Thermal energy in your blood moves from your body to the air around you. This process also helps cool your body. When the body has cooled back to normal, the hypothalamus sends signals to the sweat glands and the capillaries to stop the cooling processes.

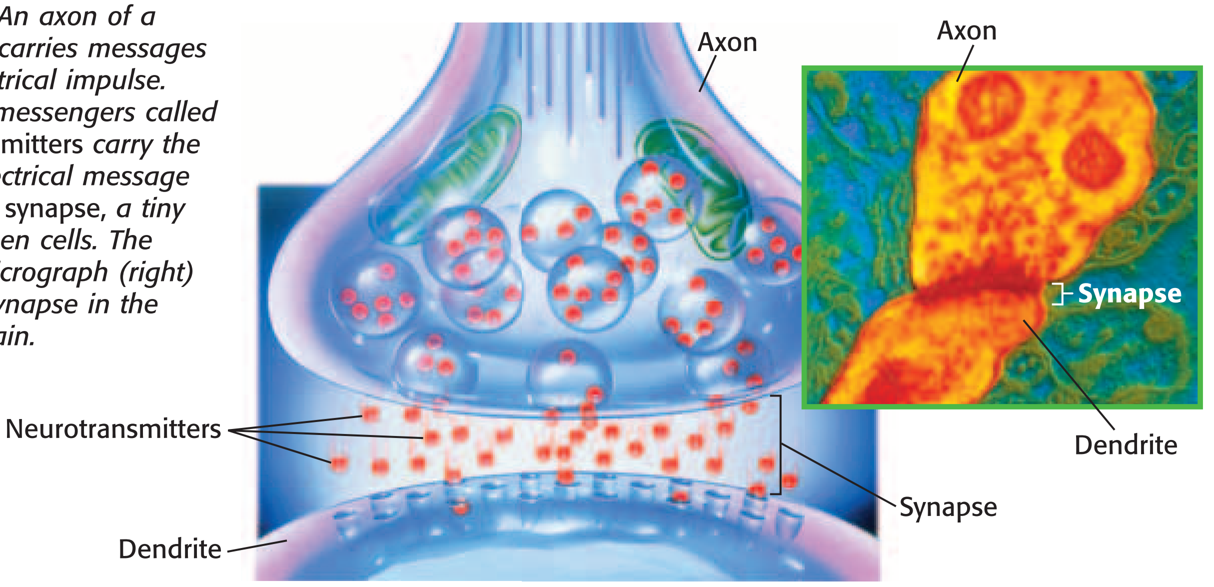


Figure 3 *An axon of a nerve cell carries messages as an electrical impulse. Chemical messengers called* neurotransmitters *carry the nerve's electrical message across the* synapse, *a tiny gap between cells. The colored micrograph (right) shows a synapse in the human brain.*

Feedback in the Endocrine System

Endocrine system hormones regulate many of the body's important functions. Growth and development, energy metabolism and water balance, responding to stress and injury, and absorption of nutrients are all controlled by endocrine system hormones. These hormones are the messengers in feedback mechanisms that control all of these bodily functions.

The Body's Water Level

As blood passes through the hypothalamus, the hypothalamus constantly checks the blood's water content. If the water content drops, the hypothalamus instructs the pituitary gland to release antidiuretic hormone (AN tee DIE uh RET ik HAWR MOHN), or ADH, into the bloodstream. ADH is carried to the kidneys. There, ADH signals the kidneys to reabsorb more water into the blood. More water enters the blood and the blood's water content returns to normal. At that point, the hypothalamus signals the pituitary and the kidneys to return to normal levels of water absorption.

Reading Check **Why is ADH important?**

SCHOOL to HOME

Drinking Electrolytes

First, research what electrolytes are. Then, go with a parent to the store and examine the label of several sports drinks. Discuss with your parent when this type of drink might be necessary and when plain water might be as good. Research what experts think about the use of sports drinks. Finally, make a poster showing how you can use this information to make an informed consumer decision about these drinks.

ACTIVITY

SECTION Review

Summary

- A feedback mechanism is a process in which information from one step affects another step.
- Feedback mechanisms operate to maintain homeostasis within cells.
- Feedback mechanisms operate to maintain homeostasis in the body.
- The endocrine and nervous systems are the body's two main systems for maintaining homeostasis.

Using Key Terms

1. In your own words, write a definition for the term *feedback mechanism*.

Understanding Key Ideas

2. Feedback mechanisms are found
   a. only inside cells.
   b. only in the body.
   c. only in animals.
   d. in many different places.
3. Give two examples of how the body uses feedback mechanisms to maintain homeostasis.

Math Skills

4. Ty usually has a bedtime blood-glucose level of 140 mg/dL. Tonight, Ty's bedtime blood-glucose level is 189 mg/dL. What percentage above 140 mg/dL is Ty's blood-glucose level tonight? Show your calculations.

Critical Thinking

5. **Making Inferences** Some medications slow messages transmitted in the nervous system. Explain why it is important for a person to know of this effect.
6. **Applying Concepts** You may use feedback mechanisms more than you think. Write a paragraph explaining how learning a new skill, such as riding a skateboard, may involve a feedback mechanism.

Using Scientific Methods

Inquiry Lab

The Perfect Taters Mystery

OBJECTIVES

Examine osmosis in potato cells.

Design a procedure that will give the best results.

MATERIALS

- cups, clear plastic, small
- potato pieces, freshly cut
- potato samples (A, B, and C)
- salt
- water, distilled

SAFETY

You are the chief food detective at Perfect Taters Food Company. The boss, Mr. Fries, wants you to find a way to keep his potatoes fresh and crisp before they are cooked. His workers have tried several methods, but these methods have not worked. Workers in Group A put the potatoes in very salty water, and something unexpected happened to the potatoes. Workers in Group B put the potatoes in water that did not contain any salt, and something else happened! Workers in Group C didn't put the potatoes in any water, and that didn't work either. Now, you must design an experiment to find out what can be done to make the potatoes stay crisp and fresh.

- Before you plan your experiment, review what you know. You know that potatoes are made of cells. Plant cells contain a large amount of water. Cells have membranes that hold water and other materials inside and keep some things out. Water and other materials must travel across cell membranes to get into and out of the cell.
- Mr. Fries has told you that you can obtain as many samples as you need from the workers in Groups A, B, and C. Your teacher will have these samples ready for you to observe.
- Make a data table like the one below. List your observations in the data table. Make as many observations as you can about the potatoes tested by workers in Groups A, B, and C.

Observations	
Group A	
Group B	
Group C	

Ask a Question

1. Now that you have made your observations, state Mr. Fries's problem in the form of a question that can be answered by your experiment.

Form a Hypothesis

2. Form a hypothesis based on your observations and your questions. The hypothesis should be a statement about what causes the potatoes not to be crisp and fresh. Based on your hypothesis, make a prediction about the outcome of your experiment. State your prediction in an if-then format.

Test the Hypothesis

3. Once you have made a prediction, design your investigation. Check your experimental design with your teacher before you begin. Mr. Fries will give you potato pieces, water, salt, and no more than six containers.

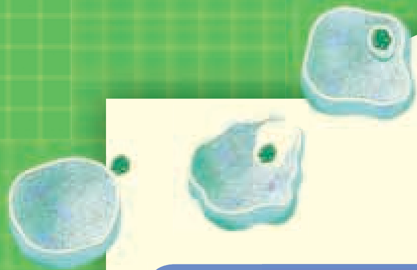
4. Keep very accurate records. Write your plan and procedure. Make data tables. To be sure your data is accurate, measure all materials carefully and make drawings of the potato pieces before and after the experiment.

Analyze the Results

1. **Explaining Events** Explain what happened to the potato cells in Groups A, B, and C in your experiment. Include a discussion of the cell membrane and the process of osmosis.

Draw Conclusions

2. **Analyzing Results** Write a letter to Mr. Fries that explains your experimental method, results, and conclusion. Then, make a recommendation about how he should handle the potatoes so that they will stay fresh and crisp.



Chapter Review

USING KEY TERMS

1 Use the following terms in the same sentence: *diffusion* and *osmosis*.

2 In your own words, write a definition for the term *feedback mechanism*.

Complete each of the following sentences by choosing the correct term from the word bank.

cellular respiration
photosynthesis
fermentation

3 Plants use ___ to make glucose.

4 During ___, oxygen is used to break down food molecules releasing large amounts of energy.

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

5 *cytokinesis* and *mitosis*

6 *active transport* and *passive transport*

7 *cellular respiration* and *fermentation*

UNDERSTANDING KEY IDEAS

Multiple Choice

8 The process in which particles move through a membrane from a region of low concentration to a region of high concentration is

a. diffusion.
b. passive transport.
c. active transport.
d. fermentation.

9 What is the result of mitosis and cytokinesis?

a. two identical cells
b. two nuclei
c. chloroplasts
d. two different cells

10 Before the energy in food can be used by a cell, the energy must first be transferred to molecules of

a. proteins.
b. carbohydrates.
c. DNA.
d. ATP.

11 Which of the following cells would form a cell plate during the cell cycle?

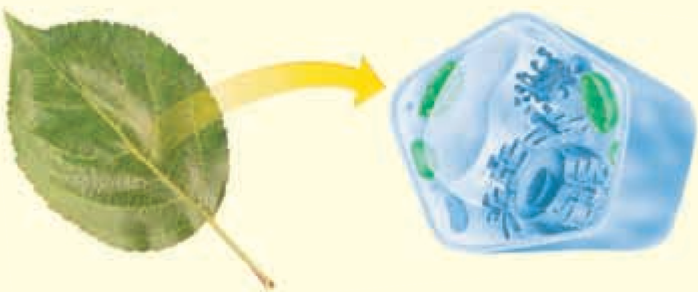
a. a human cell
b. a prokaryotic cell
c. a plant cell
d. All of the above

Short Answer

12 Are exocytosis and endocytosis examples of active or passive transport? Explain your answer.

13 Name the cell structures that are needed for photosynthesis and the cell structures that are needed for cellular respiration.

14 Describe the three stages of the cell cycle of a eukaryotic cell.



CRITICAL THINKING

15. **Concept Mapping** Use the following terms to create a concept map: *chromosome duplication, cytokinesis, prokaryote, mitosis, cell cycle, binary fission,* and *eukaryote*.

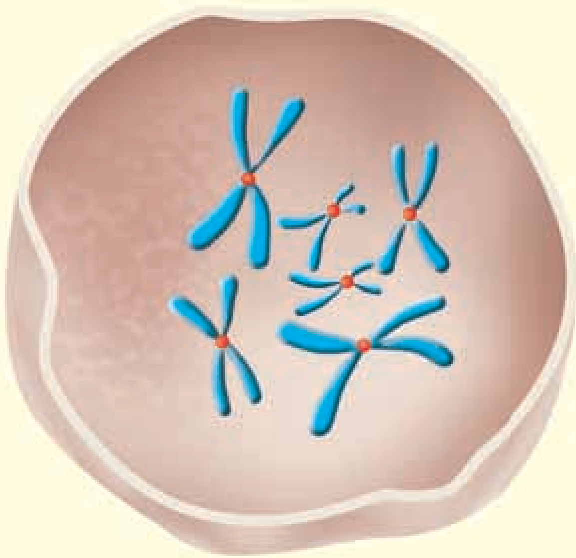
16. **Making Inferences** Which of the plants below was given water mixed with salt, and which one was given pure water? Explain how you know, and be sure to use the word *osmosis* in your answer.

17. **Identifying Relationships** Imagine that you are walking home from a friend's house. It is getting dark. Suddenly, you hear footsteps following behind you. How would your heart muscle cells and your brain use a feedback mechanism in this situation? What would this feedback mechanism do when you find out it is your friend behind you?

18. **Applying Concepts** A parent cell has 10 chromosomes.
    - **a.** Will the cell go through binary fission or mitosis and cytokinesis to produce new cells?
    - **b.** How many chromosomes will each new cell have after the parent cell divides?

INTERPRETING GRAPHICS

The picture below shows a cell. Use the picture below to answer the questions that follow.

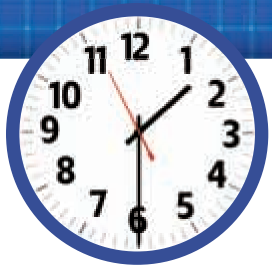


19. Is the cell prokaryotic or eukaryotic?

20. Which stage of the cell cycle is this cell in?

21. How many chromatids are present? How many pairs of homologous chromosomes are present?

22. How many chromosomes will be present in each of the new cells after the cell divides?



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Perhaps you have heard that jogging or some other kind of exercise "burns" a lot of Calories. The word *burn* is often used to describe what happens when your cells release stored energy from food. The burning of food in living cells is not the same as the burning of logs in a campfire. When logs burn, the energy stored in wood is released as thermal energy and light in a single reaction. But this kind of reaction is not the kind that happens in cells. Instead, the energy that cells get from food molecules is released at each step of a series of chemical reactions.

1. According to the passage, how do cells release energy from food?

A in a single reaction
B as thermal energy and light
C in a series of reactions
D by burning

2. Which of the following statements is a fact in the passage?

F Wood burns better than food does.
G Both food and wood have stored energy.
H Food has more stored energy than wood does.
I When it is burned, wood releases only thermal energy.

3. According to the passage, why might people be confused between what happens in a living cell and what happens in a campfire?

A The word *burn* may describe both processes.
B Thermal energy is released during both processes.
C Wood can be burned and broken down by living cells.
D Jogging and other exercises use energy.

Passage 2 The word *respiration* means "breathing," but cellular respiration is different from breathing. Breathing supplies your cells with the oxygen that they need for cellular respiration. Breathing also rids your body of carbon dioxide, which is a waste product of cellular respiration. Cellular respiration is the chemical process that releases energy from food. Most organisms obtain energy from food through cellular respiration. During cellular respiration, oxygen is used to break down food (glucose) into CO_2 and H_2O, and energy is released. In humans, most of the energy released is used to maintain body temperature.

1. According to the passage, what is glucose?

A a type of chemical process
B a type of waste product
C a type of organism
D a type of food

2. According to the passage, how does cellular respiration differ from breathing?

F Breathing releases carbon dioxide, but cellular respiration releases oxygen.
G Cellular respiration is a chemical process that uses oxygen to release energy from food, but breathing supplies cells with oxygen.
H Cellular respiration requires oxygen, but breathing does not.
I Breathing rids your body of waste products, but cellular respiration stores wastes.

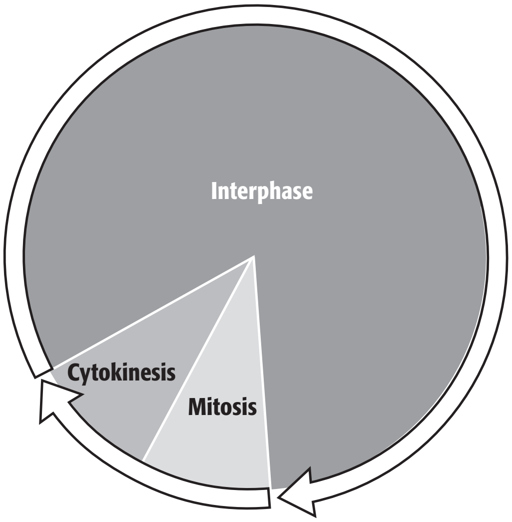
3. According to the passage, how do humans use most of the energy released?

A to break down food
B to obtain oxygen
C to maintain body temperature
D to get rid of carbon dioxide

INTERPRETING GRAPHICS

The graph below shows the cell cycle. Use this graph to answer the questions that follow.

The Cell Cycle



1. Which part of the cell cycle lasts longest?
   A interphase
   B mitosis
   C cytokinesis
   D There is not enough information to determine the answer.

2. Which of the following lists the parts of the cell cycle in the proper order?
   F mitosis, cytokinesis, mitosis
   G interphase, cytokinesis, mitosis
   H interphase, mitosis, interphase
   I mitosis, cytokinesis, interphase

3. Which part of the cell cycle is the briefest?
   A interphase
   B cell division
   C cytokinesis
   D There is not enough information to determine the answer.

4. Why is the cell cycle represented by a circle?
   F The cell cycle is a continuous process that begins again after it finishes.
   G The cell cycle happens only in cells that are round.
   H The cell cycle is a linear process.
   I The cell is in interphase for more than half of the cell cycle.

MATH

Read each question below, and choose the best answer.

1. A normal cell spends 90% of its time in interphase. How is 90% expressed as a fraction?
   A 3/4
   B 4/5
   C 85/100
   D 9/10

2. If a cell lived for 3 weeks and 4 days, how many days did it live?
   F 7
   G 11
   H 21
   I 25

3. How is $2 \times 3 \times 3 \times 3 \times 3$ expressed in exponential notation?
   A 3×2^4
   B 2×3^3
   C 3^4
   D 2×3^4

4. Cell A has 3 times as many chromosomes as cell B has. After cell B's chromosomes double during mitosis, cell B has 6 chromosomes. How many chromosomes does cell A have?
   F 3
   G 6
   H 9
   I 18

5. If $x + 2 = 3$, what does $x + 1$ equal?
   A 4
   B 3
   C 2
   D 1

6. If $3x + 2 = 26$, what does $x + 1$ equal?
   F 7
   G 8
   H 9
   I 10

Science in Action

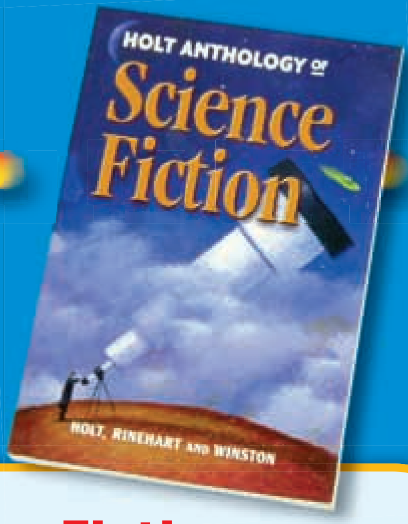
Scientific Discoveries

Electrifying News About Microbes

Your car is out of fuel, and there isn't a service station in sight. What to do? Well, in the future, this common problem may be solved by new technology. Your car's motor may use electricity supplied by trillions of microorganisms. Some chemists think that living batteries may someday power everything from watches to entire cities. Scientists at King's College in London demonstrated that some microorganisms convert food, such as table sugar and molasses, into usable electrical energy. Efficient microorganisms convert more than 90% of these foods into compounds that fuel electrical reactions. Less efficient microbes convert about 50% of their food into these compounds. A car could go a long way with this new system!

Math Activity

An efficient microorganism converts 90% of its food into fuel compounds, and an inefficient microorganism converts only 50%. If the inefficient microorganism makes 60 g of fuel out of a possible 120 g of food, how much fuel would an efficient microorganism make out of the same amount of food?



Science Fiction

"Contagion" by Katherine MacLean

A quarter mile from their spaceship, the *Explorer,* a team of doctors walk carefully along a narrow forest trail. Around them, the forest looks like a forest on Earth in the fall—the leaves are green, copper, purple, and fiery red. But it isn't fall. And the team is not on Earth.

Minos is enough like Earth to be the home of another colony of humans. But Minos might also be home to unknown organisms that could cause severe illness or death among the crew of *Explorer*. These diseases might be enough like diseases on Earth to be contagious, but they might be different enough to be very difficult to treat.

Something large moves among the shadows—it looks like a man. What happens next? Read Katherine's MacLean's "Contagion" in the *Holt Anthology of Science Fiction* to find out.

Language Arts Activity

WRITING SKILL Write two to three paragraphs that describe what you think might happen next in the story.

Careers

Jerry Yakel

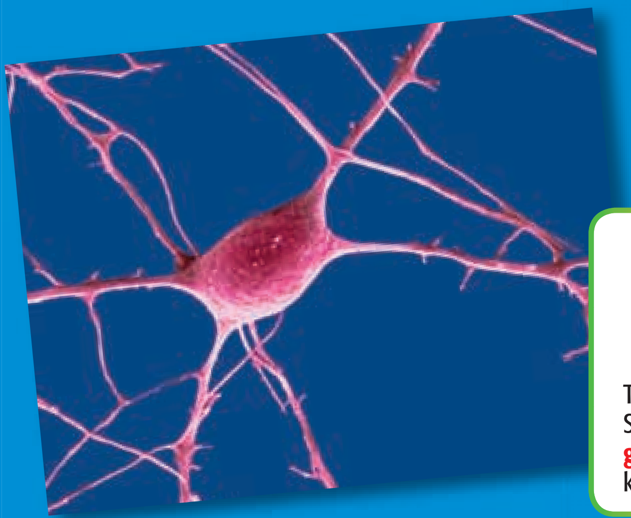
Neuroscientist Jerry Yakel credits a sea slug for making him a neuroscientist. In a college class studying neurons, or nerve cells, Yakel got to see firsthand how ions move across the cell membrane of *Aplysia californica,* also known as a sea hare. He says, "I was totally hooked. I knew that I wanted to be a neurophysiologist then and there. I haven't wavered since."

Today, Yakel is a senior investigator for the National Institutes of Environmental Health Sciences, which is part of the U.S. government's National Institutes of Health. "We try to understand how the normal brain works," says Yakel of his team. "Then, when we look at a diseased brain, we train to understand where the deficits are. Eventually, someone will have an idea about a drug that will tweak the system in this or that way."

Yakel's technique is to study the ways in which nicotine affects the human brain. "It is one of the most prevalent and potent neurotoxins in the environment," says Yakel. "I'm amazed that it isn't higher on the list of worries for the general public."

Social Studies ACTIVITY

WRITING SKILL Research a famous or historical figure in science. Write a short report that outlines how he or she became interested in science.



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Current Science

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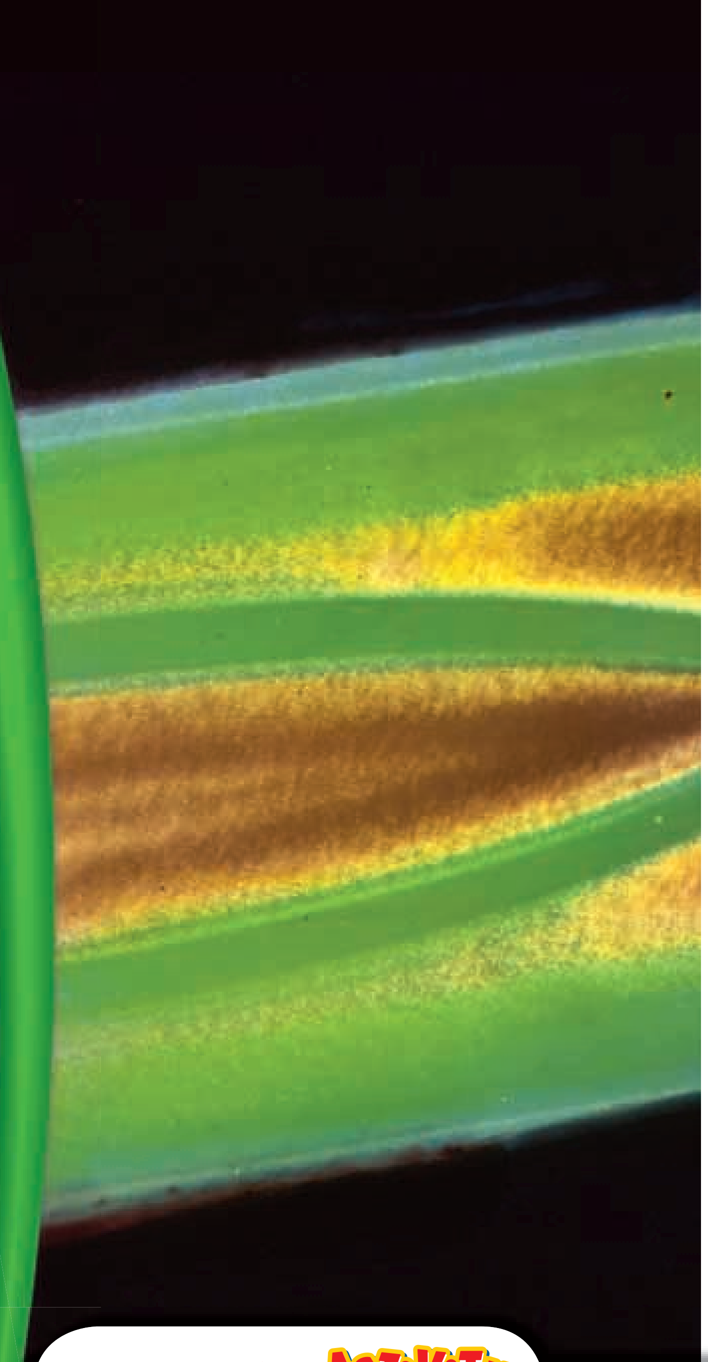
19

Understanding DNA



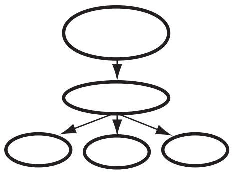
About the PHOTO

This photograph shows a very early stage of a new mouse that will have exactly the same DNA that an adult mouse has. This new mouse will be a clone of the original mouse. A clone develops by using DNA taken from another organism. Here, mouse DNA is being inserted into a mouse embryo. The embryo will develop by using the information encoded in this DNA.

PRE-READING ACTIVITY

Graphic Organizer

Concept Map Before you read the chapter, create the graphic organizer entitled "Concept Map" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the concept map with details about DNA.



START-UP ACTIVITY

Fingerprint Your Friends

One way to identify people is by taking their fingerprints. Does it really work? Are everyone's fingerprints unique? Try this activity to find out.

Procedure

1. Rub the tip of a **pencil** back and forth across a **piece of tracing paper.** Make a large, dark mark.
2. Rub the tip of one of your fingers on the pencil mark. Then place a small **piece of transparent tape** over the darkened area on your finger.
3. Remove the tape, and stick it on **a piece of white paper.** Repeat steps 1–3 for the rest of your fingers.
4. Look at the fingerprints with a **magnifying lens.** What patterns do you see? Is the pattern the same on every finger?

Analysis

1. Compare your fingerprints with those of your classmates. Do any two people in your class have the same prints? Try to explain your findings.

SECTION 1

What Does DNA Look Like?

For many years, the structure of a DNA molecule was a puzzle to scientists. In the 1950s, two scientists deduced the structure while experimenting with chemical models. They later won a Nobel Prize for helping solve this puzzle!

READING WARM-UP

Objectives

- List three important events that led to understanding the structure of DNA.
- Describe the basic structure of a DNA molecule.
- Explain how DNA molecules can be copied.

Terms to Learn

DNA
nucleotide

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Inherited characteristics are determined by genes, and genes are passed from one generation to the next. Genes are parts of chromosomes, which are structures in the nucleus of most cells. Chromosomes are made of protein and DNA. **DNA** stands for ***d**eoxyribo**n**ucleic **a**cid* (dee AHKS ee RIE boh noo KLEE ik AS id). DNA is the genetic material—the material that determines inherited characteristics. But what does DNA look like?

The Pieces of the Puzzle

Scientists knew that the material that makes up genes must be able to do two things. First, it must be able to give instructions for building and maintaining cells. Second, it must be able to be copied each time a cell divides, so that each cell contains identical genes. Scientists thought that these things could be done only by complex molecules, such as proteins. They were surprised to learn how much the DNA molecule could do.

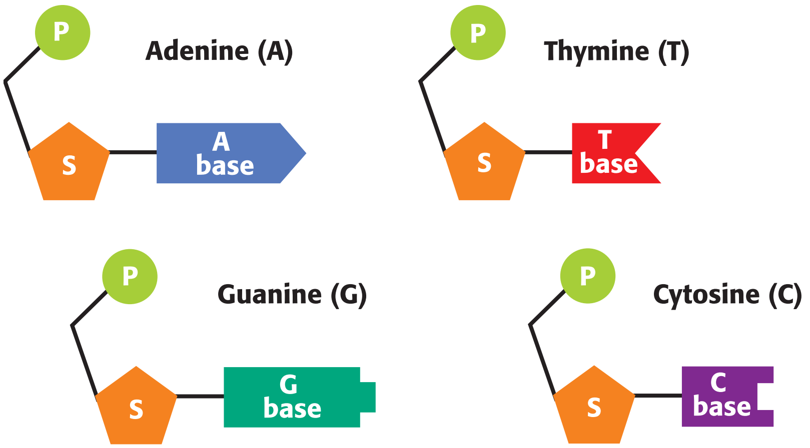
Nucleotides: The Subunits of DNA

DNA is made of subunits called nucleotides. A **nucleotide** consists of a sugar, a phosphate, and a base. The nucleotides are identical except for the base. The four bases are *adenine, thymine, guanine,* and *cytosine*. Each base has a different shape. Scientists often refer to a base by the first letter of the base, *A, T, G,* and *C*. **Figure 1** shows models of the four nucleotides.

DNA **d**eoxyribo**n**ucleic **a**cid, a molecule that is present in all living cells and that contains the information that determines the traits that a living thing inherits and needs to live

nucleotide in a nucleic-acid chain, a subunit that consists of a sugar, a phosphate, and a nitrogenous base

Figure 1 The Four Nucleotides of DNA



Chargaff's Rules

In the 1950s, a biochemist named Erwin Chargaff found that the amount of adenine in DNA always equals the amount of thymine. And he found that the amount of guanine always equals the amount of cytosine. His findings are known as *Chargaff's rules*. At the time of his discovery, no one knew the importance of these findings. But Chargaff's rules later helped scientists understand the structure of DNA.

Reading Check **Summarize Chargaff's rules.** (*See the Appendix for answers to Reading Checks.*)

Franklin's Discovery

More clues about the structure of DNA came from scientists in Britain. There, chemist Rosalind Franklin, shown in **Figure 2,** was able to make images of DNA molecules. She used a process known as *X-ray diffraction* to make these images. In this process, X rays are aimed at the DNA molecule. When an X ray hits a part of the molecule, the ray bounces off. The pattern made by the bouncing rays is captured on film. Franklin's images suggested that DNA has a spiral shape.

Watson and Crick's Model

At about the same time, two other scientists were also trying to solve the mystery of DNA's structure. They were James Watson and Francis Crick, shown in **Figure 3.** After seeing Franklin's X-ray images, Watson and Crick concluded that DNA must look like a long, twisted ladder. They were then able to build a model of DNA by using simple materials from their laboratory. Their model perfectly fit with both Chargaff's and Franklin's findings. The model eventually helped explain how DNA is copied and how it functions in the cell.

CONNECTION TO Chemistry

WRITING SKILL **Linus Pauling** Many scientists contributed to the discovery of DNA's structure. In fact, some scientists competed to be the first to make the discovery. One of these competitors was a chemist named Linus Pauling. Research and write a paragraph about how Pauling's work helped Watson and Crick.

Figure 2 *Rosalind Franklin used X-ray diffraction to make images of DNA that helped reveal the structure of DNA.*

Figure 3 *This photo shows James Watson (left) and Francis Crick (right) with their model of DNA.*

DNA's Double Structure

The shape of DNA is shown in **Figure 4.** As you can see, a strand of DNA looks like a twisted ladder. This shape is known as a *double helix* (DUB uhl HEE LIKS). The two sides of the ladder are made of alternating sugar parts and phosphate parts. The rungs of the ladder are made of a pair of bases. Adenine on one side of a rung always pairs with thymine on the other side. Guanine always pairs with cytosine.

Notice how the double helix structure matches Chargaff's observations. When Chargaff separated the parts of a sample of DNA, he found that the matching bases were always present in equal amounts. To model how the bases pair, Watson and Crick tried to match Chargaff's observations. They also used information from chemists about the size and shape of each of the nucleotides. As it turned out, the width of the DNA ladder matches the combined width of the matching bases. Only the correct pairs of bases fit within the ladder's width.

Making Copies of DNA

The pairing of bases allows the cell to *replicate*, or make copies of, DNA. Each base always bonds with only one other base. Thus, pairs of bases are *complementary* to each other, and both sides of a DNA molecule are complementary. For example, the sequence CGAC will bond to the sequence GCTG.

Quick Lab

Making a Model of DNA

1. Gather assorted simple materials that you could use to build a basic model of DNA. You might use **clay, string, toothpicks, paper, tape, plastic foam,** or **pieces of food.**
2. Work with a partner or a small team to build your model. Use your book and other resources to check the details of your model.
3. Show your model to your classmates. Give your classmates feedback about the scientific aspects of their models.

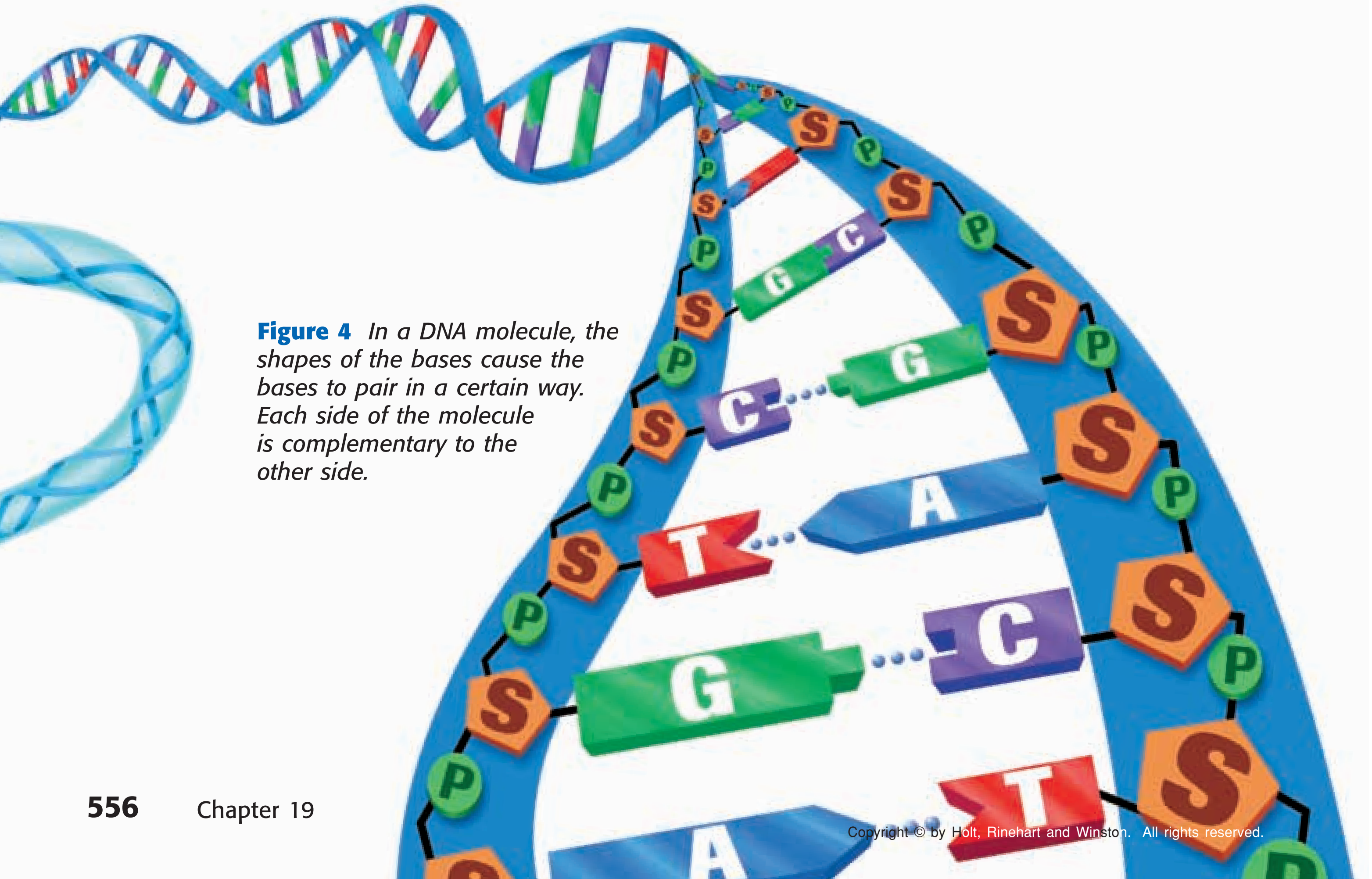


Figure 4 *In a DNA molecule, the shapes of the bases cause the bases to pair in a certain way. Each side of the molecule is complementary to the other side.*

How Copies Are Made

During replication, as shown in **Figure 5,** a DNA molecule is split down the middle, where the bases meet. The bases on each side of the molecule are used as a pattern for a new strand. As the bases on the original molecule are exposed, complementary nucleotides are added to each side of the ladder. Two DNA molecules are formed. Half of each of the molecules is old DNA, and half is new DNA.

When Copies Are Made

DNA is copied every time a cell divides. Each new cell gets a complete copy of all the DNA. The job of unwinding, copying, and re-winding the DNA is done by proteins within the cell. So, DNA is usually found with several kinds of proteins. Other proteins help with the process of carrying out the instructions written in the code of the DNA.

Reading Check **How often is DNA copied?**

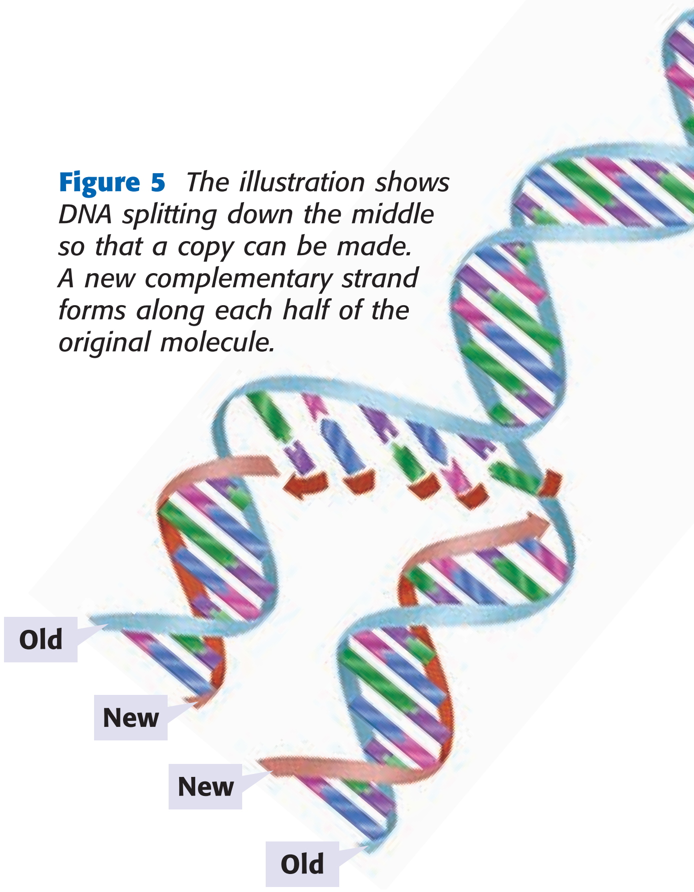


Figure 5 *The illustration shows DNA splitting down the middle so that a copy can be made. A new complementary strand forms along each half of the original molecule.*

SECTION Review

Summary

- DNA is the material that makes up genes. It carries coded information that is copied in each new cell.
- The DNA molecule looks like a twisted ladder. The two halves are long strings of nucleotides. The rungs are complementary pairs of bases.
- Because each base has a complementary base, DNA can be replicated accurately.

Using Key Terms

1. Use the term *DNA* in a sentence.
2. In your own words, write a definition for the term *nucleotide*.

Understanding Key Ideas

3. List three important events that led to understanding the structure of DNA.
4. Which of the following is NOT part of a nucleotide?
   a. base
   b. sugar
   c. fat
   d. phosphate

Math Skills

5. If a sample of DNA contained 20% cytosine, what percentage of guanine would be in this sample? What percentage of adenine would be in the sample? Explain.

Critical Thinking

6. **Making Inferences** Explain what is meant by the statement "DNA unites all organisms."
7. **Applying Concepts** What would the complementary strand of DNA be for the sequence of bases below?

   C T T A G G C T T A C C A

8. **Analyzing Processes** How are copies of DNA made? Draw a picture as part of your answer.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: DNA; Genes and Traits

SciLinks code: HSM0418; HSM0647

SECTION 2

How DNA Works

Almost every cell in your body contains about 2 m of DNA. How does all of the DNA fit in a cell? And how does the DNA hold a code that affects your traits?

READING WARM-UP

Objectives

- Explain the relationship between DNA, genes, and proteins.
- Outline the basic steps in making a protein.
- Describe three types of mutations, and provide an example of a gene mutation.
- Describe two examples of uses of genetic knowledge.

Terms to Learn

RNA
ribosome
mutation

READING STRATEGY

Reading Organizer As you read this section, make a flowchart of the steps of how DNA codes for proteins.

DNA is found in the cells of all organisms, including bacteria, mosquitoes, and humans. Each organism has a unique set of DNA. But DNA functions the same way in all organisms.

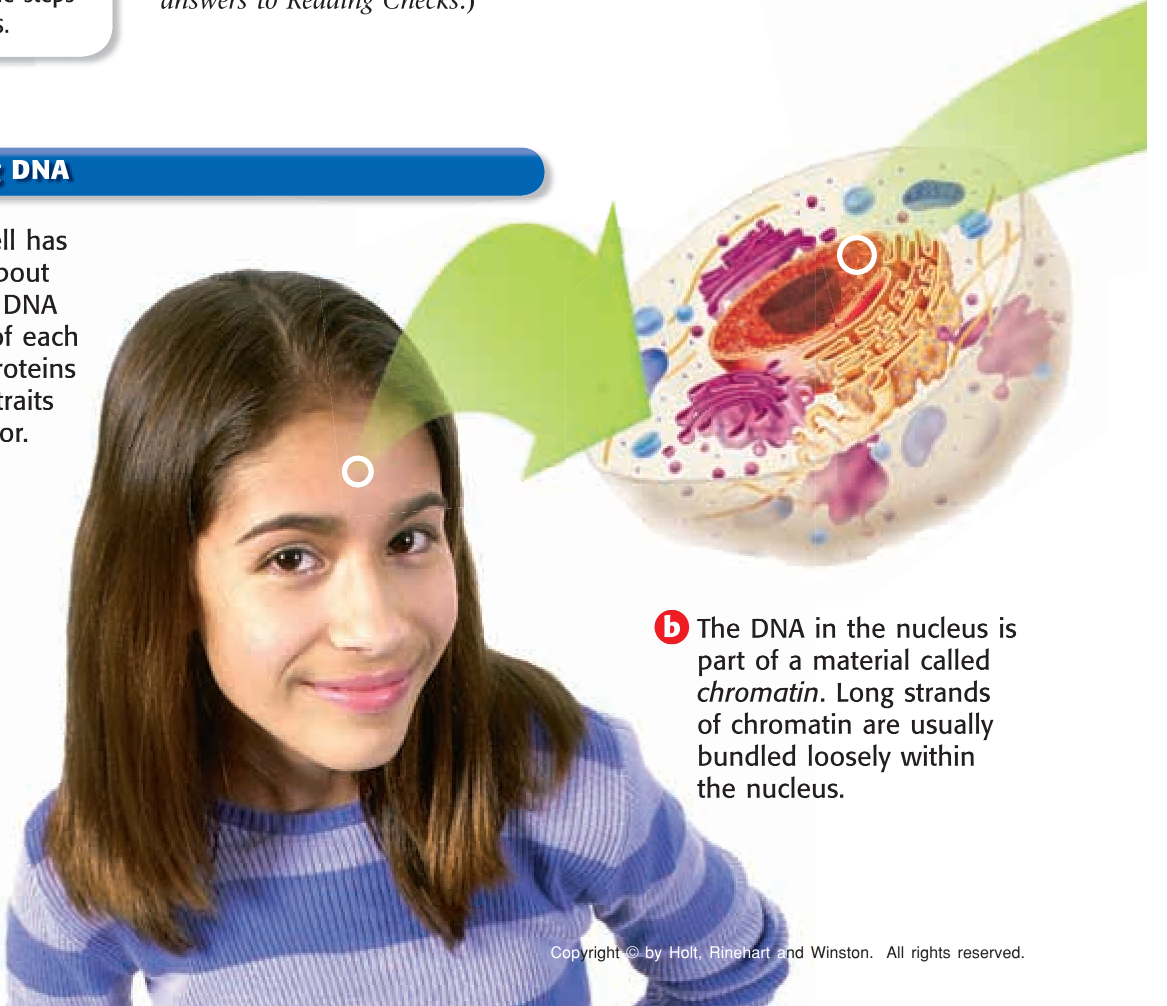
Unraveling DNA

DNA is often wound around proteins, coiled into strands, and then bundled up even more. In a cell that lacks a nucleus, each strand of DNA forms a loose loop within the cell. In a cell that has a nucleus, the strands of DNA and proteins are bundled into chromosomes, as shown in **Figure 1.**

The structure of DNA allows DNA to hold information. The order of the bases on one side of the molecule is a code that carries information. A *gene* consists of a string of nucleotides that give the cell information about how to make a specific trait. There is an enormous amount of DNA, so there can be a large variety of genes.

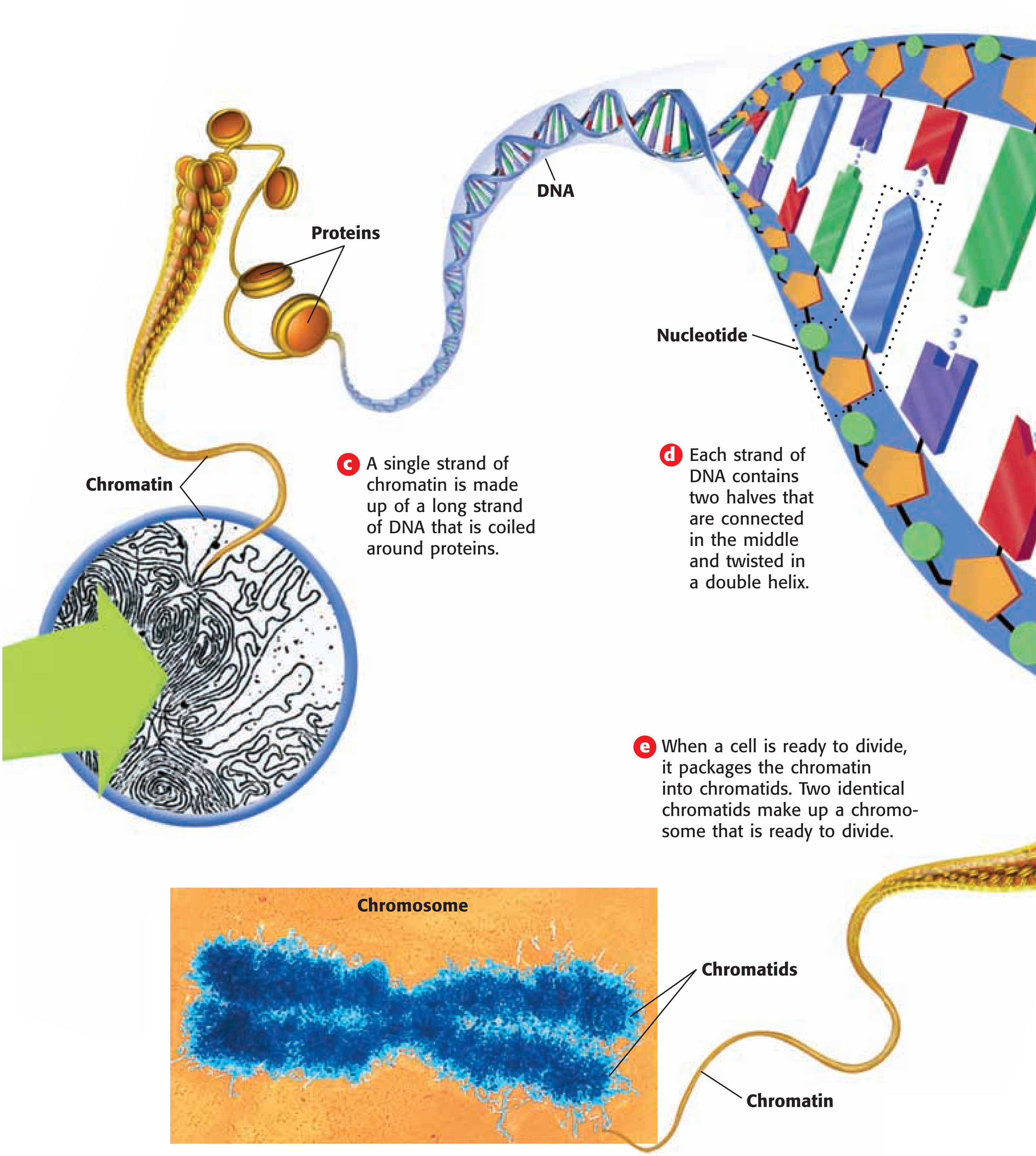
Reading Check **What makes up a gene?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 **Unraveling DNA**



a A typical skin cell has a diameter of about 0.0025 cm. The DNA in the nucleus of each cell codes for proteins that determine traits such as skin color.

b The DNA in the nucleus is part of a material called *chromatin*. Long strands of chromatin are usually bundled loosely within the nucleus.



c A single strand of chromatin is made up of a long strand of DNA that is coiled around proteins.

d Each strand of DNA contains two halves that are connected in the middle and twisted in a double helix.

e When a cell is ready to divide, it packages the chromatin into chromatids. Two identical chromatids make up a chromosome that is ready to divide.

f Just before division, each human cell contains 46 chromosomes. These chromosomes contain two identical copies of all of the cell's genetic material.

Genes and Proteins

The DNA code is read like a book—from one end to the other and in one direction. The bases form the alphabet of the code. Groups of three bases are the codes for specific amino acids. For example, the three bases CCA form the code for the amino acid proline. The bases AGC form the code for the amino acid serine. A long string of amino acids forms a protein. Thus, each gene is usually a set of instructions for making a protein.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5DNAW.**

Proteins and Traits

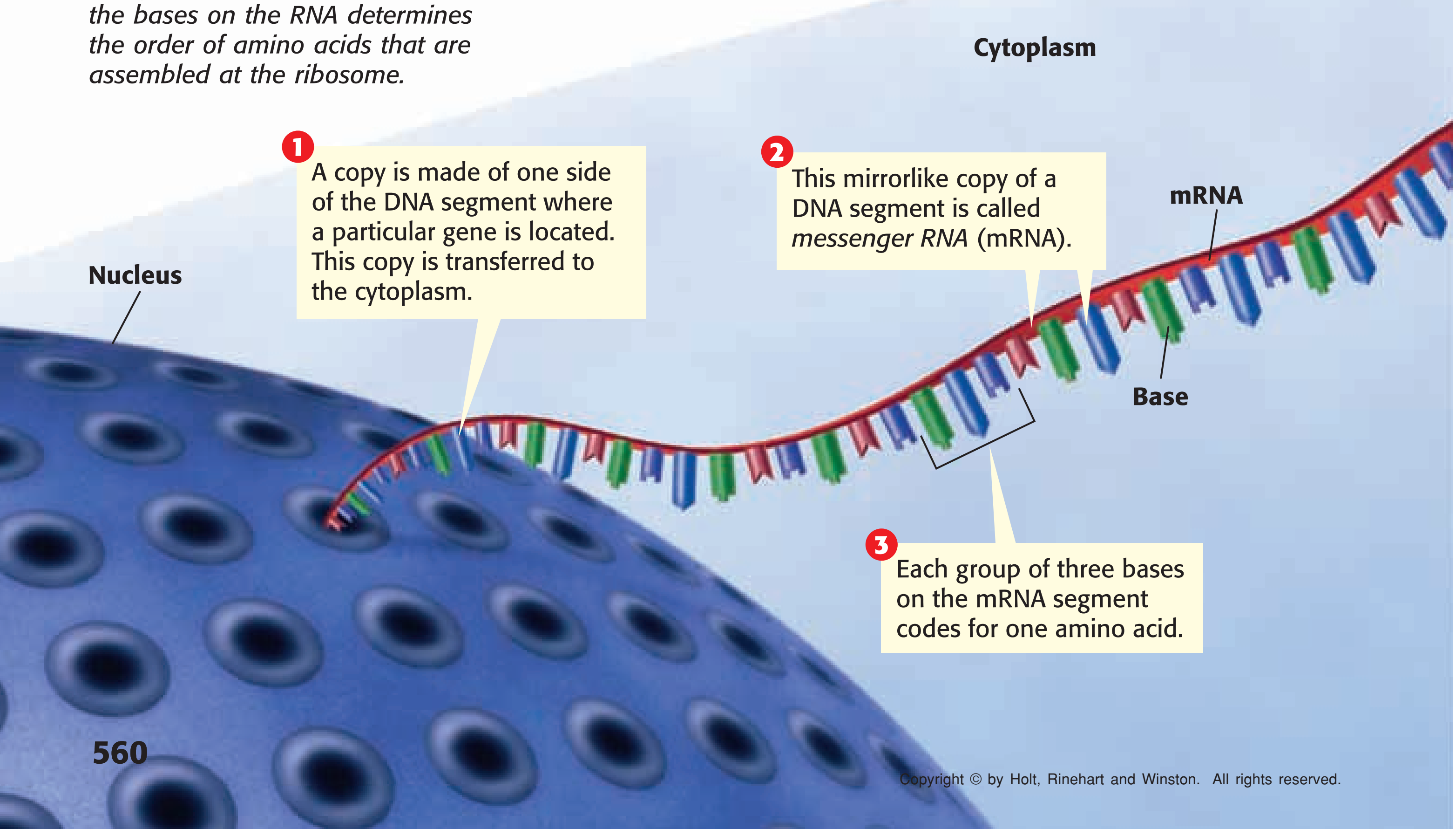
How are proteins related to traits? Proteins are found throughout cells and cause most of the differences that you can see among organisms. Proteins act as chemical triggers and messengers for many of the processes within cells. Proteins help determine how tall you grow, what colors you can see, and whether your hair is curly or straight. Proteins exist in an almost limitless variety. A single organism may have thousands of genes that code for thousands of proteins.

RNA **r**ibo**n**ucleic **a**cid, a molecule that is present in all living cells and that plays a role in protein production

Help from RNA

Another type of molecule that helps make proteins is called **RNA,** or *ribonucleic acid* (RIE boh noo KLEE ik AS id). RNA is so similar to DNA that RNA can serve as a temporary copy of a DNA sequence. Several forms of RNA help in the process of changing the DNA code into proteins, as shown in **Figure 2.**

Figure 2 *Proteins are built in the cytoplasm by using RNA copies of a segment of DNA. The order of the bases on the RNA determines the order of amino acids that are assembled at the ribosome.*



The Making of a Protein

The first step in making a protein is to copy one side of the segment of DNA containing a gene. A mirrorlike copy of the DNA segment is made out of RNA. This copy of the DNA segment is called *messenger RNA* (mRNA). It moves out of the nucleus and into the cytoplasm of the cell.

In the cytoplasm, the messenger RNA is fed through a protein assembly line. The "factory" that runs this assembly line is known as a ribosome. A **ribosome** is a cell organelle composed of RNA and protein. The messenger RNA is fed through the ribosome three bases at a time. Then, molecules of *transfer RNA* (tRNA) translate the RNA message. Each transfer RNA molecule picks up a specific amino acid from the cytoplasm. Inside the ribosome, bases on the transfer RNA match up with bases on the messenger RNA like pieces of a puzzle. The transfer RNA molecules then release their amino acids. The amino acids become linked in a growing chain. As the entire segment of messenger RNA passes through the ribosome, the growing chain of amino acids folds up into a new protein molecule.

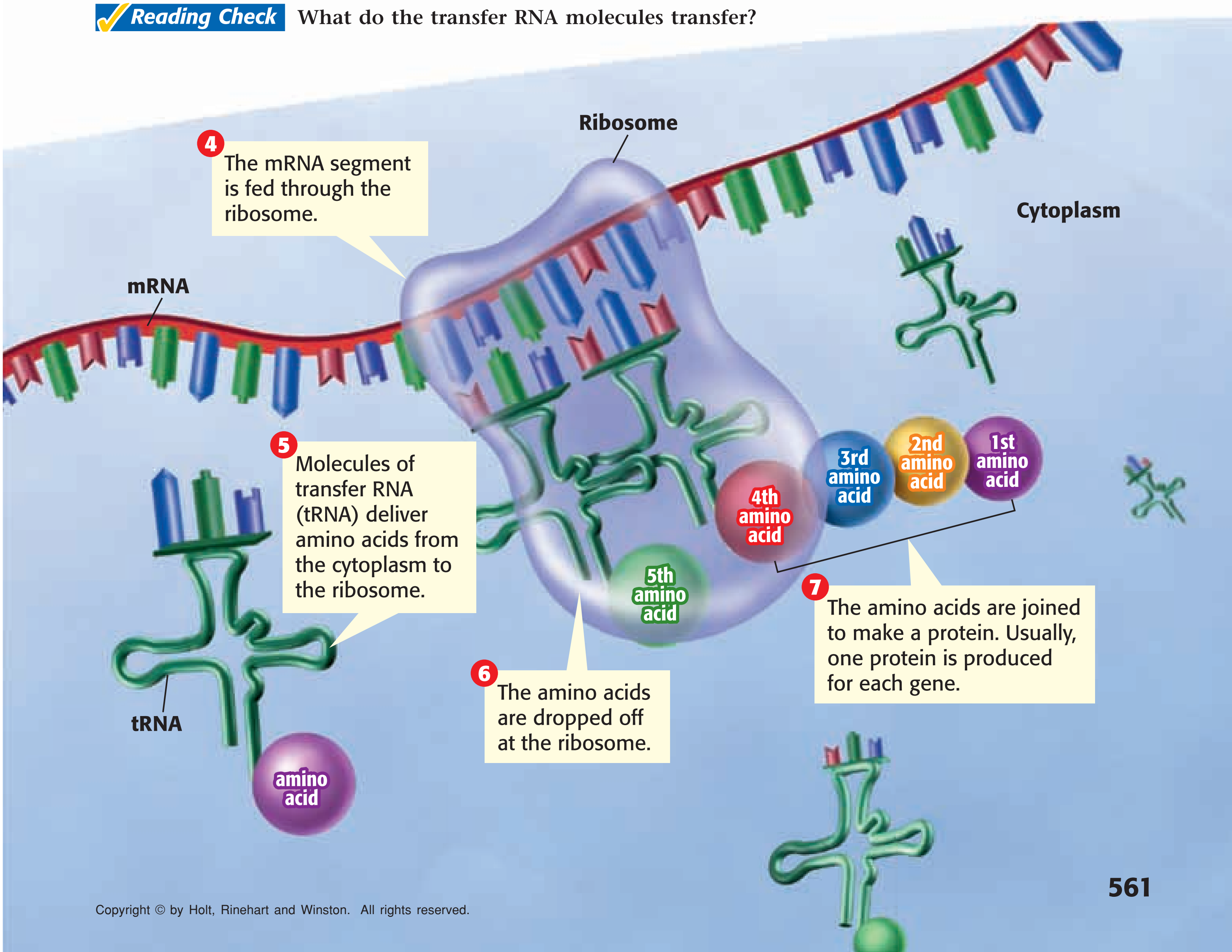
Reading Check What do the transfer RNA molecules transfer?

MATH PRACTICE

Code Combinations

A given sequence of three bases codes for one amino acid. For example, AGT is one possible sequence. How many different sequences of the four DNA base types are possible? (Hint: Make a list.)

ribosome a cell organelle composed of RNA and protein; the site of protein synthesis



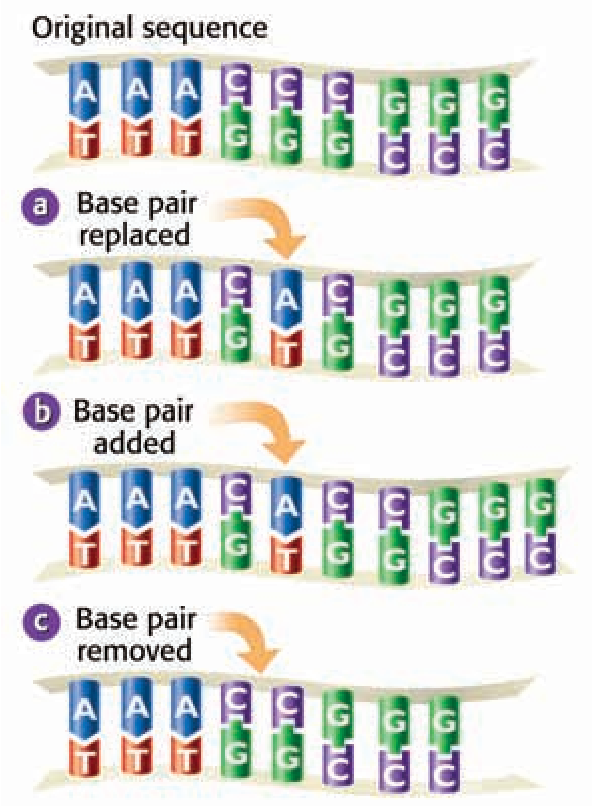


Figure 3 *The original base sequence on the top has been changed to illustrate (a) a substitution, (b) an insertion, and (c) a deletion.*

Changes in Genes

Imagine that you have been invited to ride on a new roller coaster at the state fair. Before you climb into the front car, you are told that some of the metal parts on the coaster have been replaced by parts made of a different substance. Would you still want to ride this roller coaster? Perhaps a strong metal was used as a substitute. Or perhaps a material that is not strong enough was used. Imagine what would happen if cardboard were used instead of metal!

Mutations

Substitutions like the ones in the roller coaster can accidentally happen in DNA. Changes in the number, type, or order of bases on a piece of DNA are known as **mutations.** Sometimes, a base is left out. This kind of change is known as a *deletion*. Or an extra base might be added. This kind of change is known as an *insertion*. The most common change happens when the wrong base is used. This kind of change is known as a *substitution*. **Figure 3** illustrates these three types of mutations.

Do Mutations Matter?

There are three possible consequences to changes in DNA: an improved trait, no change, or a harmful trait. Fortunately, cells make some proteins that can detect errors in DNA. When an error is found, it is usually fixed. But occasionally the repairs are not accurate, and the mistakes become part of the genetic message. If the mutation occurs in the sex cells, the changed gene can be passed from one generation to the next.

mutation a change in the nucleotide-base sequence of a gene or DNA molecule

How Do Mutations Happen?

Mutations happen regularly because of random errors when DNA is copied. In addition, damage to DNA can be caused by abnormal things that happen to cells. Any physical or chemical agent that can cause a mutation in DNA is called a *mutagen*. Examples of mutagens include high-energy radiation from X rays and ultraviolet radiation. Ultraviolet radiation is one type of energy in sunlight. It is responsible for suntans and sunburns. Other mutagens include asbestos and the chemicals in cigarette smoke.

Reading Check **What is a mutagen?**

An Example of a Substitution

A mutation, such as a substitution, can be harmful because it may cause a gene to produce the wrong protein. Consider the DNA sequence GAA. When copied as mRNA, this sequence gives the instructions to place the amino acid glutamic acid into the growing protein. If a mistake happens and the original DNA sequence is changed to GTA, the sequence will code for the amino acid valine instead.

This simple change in an amino acid can cause the disease *sickle cell disease*. Sickle cell disease affects red blood cells. When valine is substituted for glutamic acid in a blood protein, as shown in **Figure 4,** the red blood cells are changed into a sickle shape.

The sickle cells are not as good at carrying oxygen as normal red blood cells are. Sickle cells are also likely to get stuck in blood vessels and cause painful and dangerous clots.

Reading Check **What causes sickle cell disease?**

SCHOOL to HOME

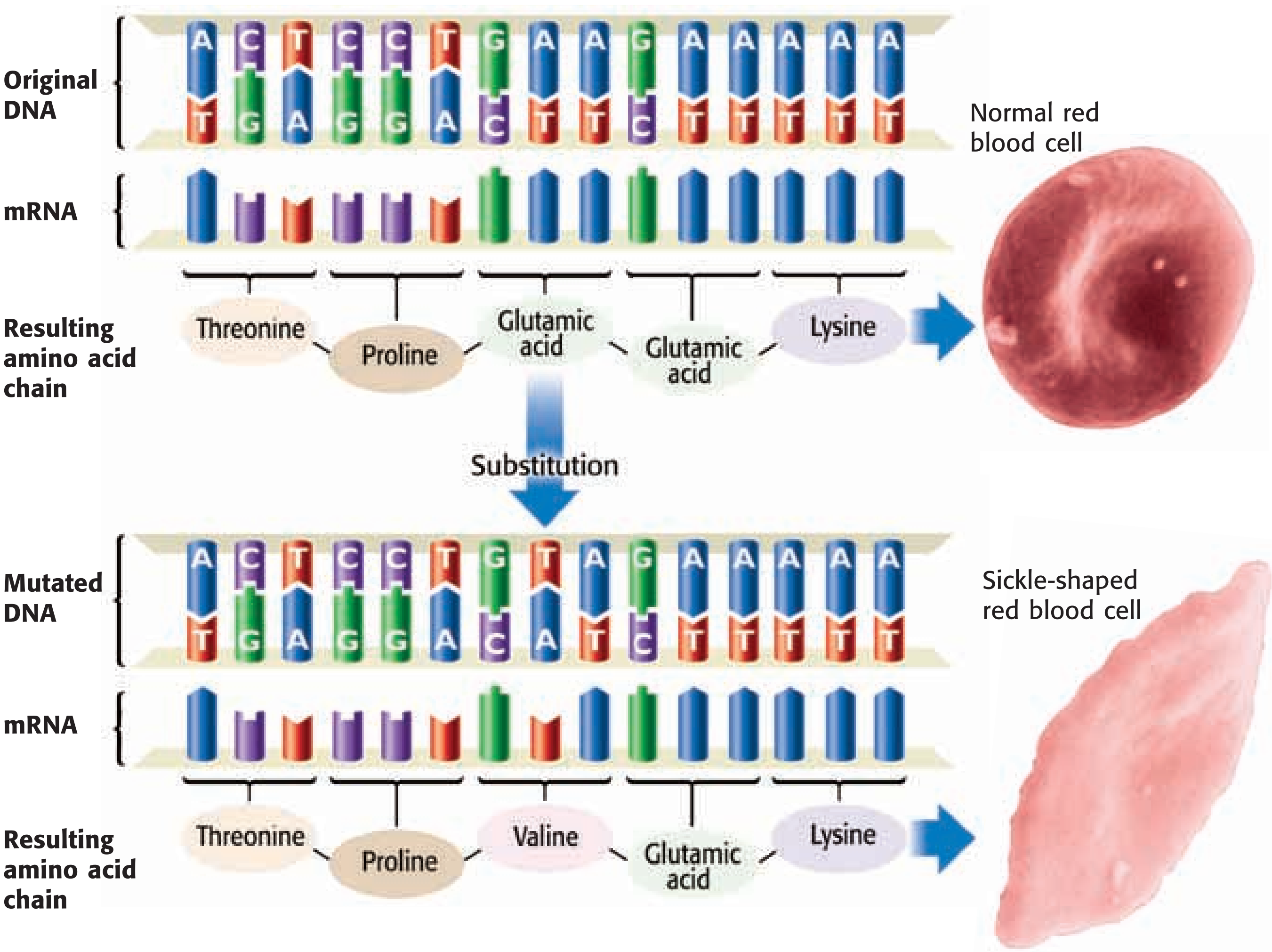
An Error in the Message

The sentence below is the result of an error similar to a DNA mutation. The original sentence was made up of three-letter words, but an error was made in this copy. Explain the idea of mutations to your parent. Then, work together to find the mutation, and write the sentence correctly.

THE IGB ADC ATA TET HEB IGR EDR AT.

ACTIVITY

Figure 4 **How Sickle Cell Disease Results from a Mutation**



Uses of Genetic Knowledge

In the years since Watson and Crick made their model, scientists have learned a lot about genetics. Using technology to study genes is called *biotechnology.* Biotechnology is often used in ways that benefit humans. But some uses of genetic knowledge also cause ethical and scientific debates.

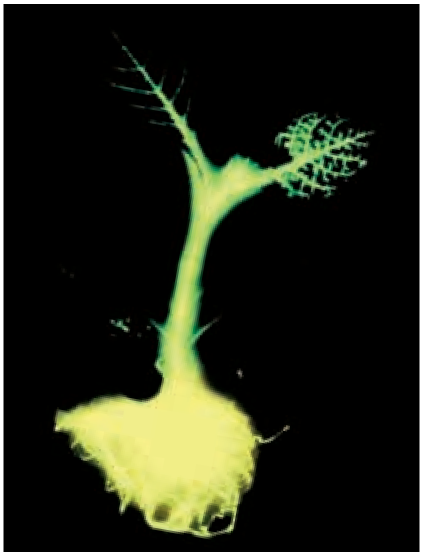


Figure 5 *This genetically engineered tobacco plant contains firefly genes.*

Genetic Engineering

Scientists can determine what individual genes within organisms encode. Manipulating genes based on this information is called *genetic engineering*. In some cases, genes may be transferred between two types of organisms. The genetically engineered plant in **Figure 5** has a gene from a firefly. The gene produces a protein that causes the plant to glow.

Scientists can use genetic engineering to create new products, such as drugs, foods, or fabrics. For example, people can engineer plants that do not spoil or bruise easily. Growing these plants could improve the quality and quantity of agricultural foods. But some scientists worry about the dangers of creating genetically engineered organisms. These organisms might change their environment in unexpected ways.

Genetic Identification

Your DNA is unique, so it can be used like a fingerprint to identify you. *DNA fingerprinting* identifies the unique patterns in an individual's DNA. DNA samples are now used as evidence in crimes, as **Figure 6** shows. Similarities between people's DNA can reveal other information, too. For example, DNA can be used to identify family relations or hereditary diseases.

Figure 6 *This scientist is gathering dead skin cells from a crime scene. DNA from the cells could be used as evidence of a criminal's identity.*

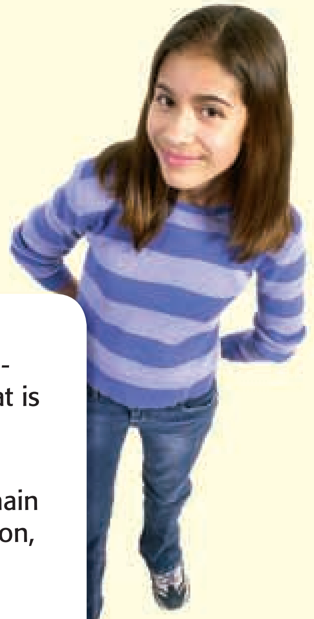
Identical twins have identical DNA. Scientists can now create a clone, which is something like a twin. A *clone* is a new organism that has an exact copy of another organism's genes. Clones of several types of organisms have been developed by scientists. However, ethical issues about cloning humans are debated among both scientists and politicians.

Reading Check **What is a clone?**

CONNECTION TO Social Studies

Economics Advances in biotechnology have led to new career opportunities in North Carolina, including teaching, research, medical, and public policy positions. Interest in university research, private companies, and educational groups has generated a large pool of jobs that bring economic support to communities throughout North Carolina. Interview a person whose biotechnology career interests you, and then tell your class about the career.

SECTION Review



Summary

- A gene is a set of instructions for assembling a protein. DNA is the molecular carrier of these genetic instructions.
- Every organism has DNA in its cells. Humans have about 2 m of DNA in each cell.
- Within a gene, each group of three bases codes for one amino acid. A sequence of amino acids is linked to make a protein.
- Proteins are fundamental to the function of cells and the expression of traits.
- Proteins are assembled within the cytoplasm through a multi-step process that is assisted by several forms of RNA.
- Genes can become mutated when the order of the bases is changed. Three main types of mutations are possible: insertion, deletion, and substitution.
- Genetic knowledge has many practical uses. Some applications of genetic knowledge are controversial.

Using Key Terms

1. Use each of the following terms in the same sentence: *ribosome* and *RNA*.

2. In your own words, write a definition for the term *mutation*.

Understanding Key Ideas

3. Explain the relationship between genes and proteins.

4. List three possible types of mutations.

5. Which type of mutation causes sickle cell anemia?

a. substitution　　**c.** deletion
b. insertion　　**d.** mutagen

Math Skills

6. A set of 23 chromosomes in a human cell contains 3.2 billion pairs of DNA bases in sequence. On average, about how many pairs of bases are in each chromosome?

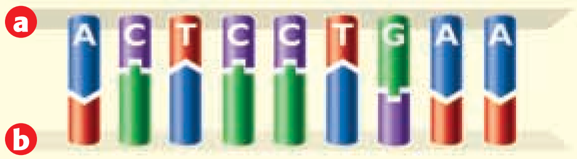
Critical Thinking

7. Applying Concepts In which cell type might a mutation be passed from generation to generation? Explain.

8. Making Comparisons How is genetic engineering different from natural reproduction?

Interpreting Graphics

The illustration below shows a sequence of bases on one strand of a DNA molecule. Use the illustration below to answer the questions that follow.



9. How many amino acids are coded for by the sequence on one side (a) of this DNA strand?

10. What is the order of bases on the complementary side of the strand (b), from left to right?

11. If a G were inserted as the first base on the top side (a), what would the order of bases be on the complementary side (b)?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Genetic Engineering
SciLinks code: HSM0654

Model-Making Lab

Base-Pair Basics

You have learned that DNA is shaped something like a twisted ladder. The side rails of the ladder are made of sugar parts and phosphate parts. The two side rails are connected to each other by parts called *bases*. The bases join in pairs to form the rungs of the ladder. Within DNA, each base can pair with only one other base. Each of these pairs is called a *base pair*. When DNA replicates, enzymes separate the base pairs, which breaks the rungs of the ladder in half. Then, each half of the DNA ladder can be used as a template for building a new half. In this activity, you will construct a paper model of DNA and use it to model the replication process.

OBJECTIVES

Construct a model of a DNA strand.

Model the process of DNA replication.

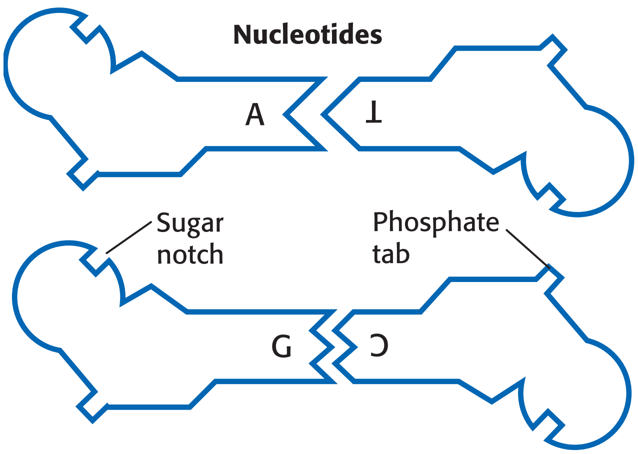
MATERIALS

- bag, large paper
- paper, colored (4 colors)
- paper, white
- scissors

SAFETY

Procedure

1. Trace the models of nucleotides below onto white paper. Label the pieces "A" (**a**denine), "T" (**t**hymine), "C" (**c**ytosine), and "G" (**g**uanine). Draw the pieces again on colored paper. Use a different color for each type of base. Draw the pieces as large as you want, and draw as many of the white pieces and as many of the colored pieces as time will allow.
2. Carefully cut out all of the pieces.
3. Put all of the colored pieces in the classroom into a large paper bag. Spread all of the white pieces in the classroom onto a large table.
4. Remove nine colored pieces from the bag. Arrange the colored pieces in any order in a straight column so that the letters *A, T, C,* and *G* are right side up. Be sure to fit the sugar notches to the phosphate tabs. Draw this arrangement.
5. Find the white bases that correctly pair with the nine colored bases. Remember the base-pairing rules, and pair the bases according to those rules.
6. Pair the pieces by fitting tabs to notches. The letters on the white pieces should be upside down. You now have a model of a double-stranded piece of DNA. The strand contains nine pairs of complementary nucleotides. Draw your model.



Analyze the Results

1. **Identifying Patterns** Now, separate the two halves of your DNA strand along the middle of the base pair rungs of the ladder. Keep the side rails together by keeping the sugar notches fitted to the phosphate tabs. Draw this arrangement.

2. **Recognizing Patterns** Look at the drawing made in the previous step. Along each strand in the drawing, write the letters of the bases that complement the bases in that strand.

3. **Examining Data** Find all of the bases that you need to complete replication. Find white pieces to pair with the bases on the left, and find colored pieces to pair with the bases on the right. Be sure that the tabs and notches fit and the sides are straight. You have now replicated your model of DNA. Are the two models identical? Draw your results.

Draw Conclusions

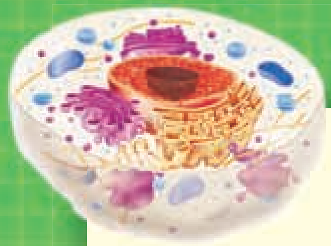
4. **Interpreting Information** State the correct base-pairing rules. How do these rules make DNA replication possible?

5. **Evaluating Models** What happens when you attempt to pair thymine with guanine? Do they fit together? Are the sides straight? Do all of the tabs and notches fit? Explain.

Applying Your Data

Construct a 3-D model of a DNA molecule that shows DNA's twisted-ladder structure. Use your imagination and creativity to select materials. You may want to use licorice, gum balls, and toothpicks or pipe cleaners and paper clips.

1. Display your model in your classroom.
2. Take a vote to decide which models are the most accurate and the most creative.



Chapter Review

USING KEY TERMS

1. Use the following terms in the same sentence: *mutation* and *mutagen*.

The statements below are false. For each statement, replace the underlined term to make a true statement.

2. The information in DNA is coded in the order of amino acids along one side of the DNA molecule.

3. The “factory” that assembles proteins based on the DNA code is called a gene.

UNDERSTANDING KEY IDEAS

Multiple Choice

4. James Watson and Francis Crick
   - **a.** took X-ray pictures of DNA.
   - **b.** discovered that genes are in chromosomes.
   - **c.** bred pea plants to study heredity.
   - **d.** made models to figure out DNA’s shape.

5. In a DNA molecule, which of the following bases pair together?
   - **a.** adenine and cytosine
   - **b.** thymine and adenine
   - **c.** thymine and guanine
   - **d.** cytosine and thymine

6. A gene can be all of the following EXCEPT
   - **a.** a set of instructions for a trait.
   - **b.** a complete chromosome.
   - **c.** instructions for making a protein.
   - **d.** a portion of a strand of DNA.

7. Which of the following statements about DNA is NOT true?
   - **a.** DNA is found in all organisms.
   - **b.** DNA is made up of five subunits.
   - **c.** DNA has a structure like a twisted ladder.
   - **d.** Mistakes can be made when DNA is copied.

8. Within the cell, where are proteins assembled?
   - **a.** the cytoplasm
   - **b.** the nucleus
   - **c.** the amino acids
   - **d.** the chromosomes

9. Changes in the type or order of the bases in DNA are called
   - **a.** nucleotides.
   - **b.** mutations.
   - **c.** RNA.
   - **d.** genes.

Short Answer

10. What would be the complementary strand of DNA for the following sequence of bases?

    C T T A G G C T T A C C A

11. If the DNA sequence TGAGCCATGA is changed to TGAGCACATGA, what kind of mutation has occurred?

12. Explain how the DNA in genes relates to the traits of an organism.

13. Why is DNA frequently found associated with proteins inside of cells?

14. What is the difference between DNA and RNA?

CRITICAL THINKING

15 **Concept Mapping** Use the following terms to create a concept map: *bases, adenine, thymine, nucleotides, guanine, DNA,* and *cytosine*.

16 **Analyzing Processes** Draw and label a picture that explains how DNA is copied.

17 **Analyzing Processes** Draw and label a picture that explains how proteins are made.

18 **Applying Concepts** The following DNA sequence codes for how many amino acids?

T C A G C C A C C T A T G G A

19 **Making Inferences** Why does the government make laws about the use of chemicals that are known to be mutagens?

INTERPRETING GRAPHICS

The illustration below shows the process of replication of a DNA strand. Use this illustration to answer the questions that follow.

20 Which strands are part of the original molecule?

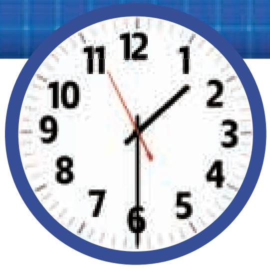
a. A and B
b. A and C
c. A and D
d. None of the above

21 Which strands are new?

a. A and B
b. B and C
c. C and D
d. None of the above

22 Which strands are complementary?

a. A and C
b. B and C
c. All of the strands
d. None of the strands



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The tension in the courtroom was so thick that you could cut it with a knife. The prosecuting attorney presented this evidence: "DNA analysis indicates that blood found on the defendant's shoes matches the blood of the victim. The odds of this match happening by chance are 1 in 20 million." The jury members were stunned by these figures. Can there be any doubt that the defendant is guilty?

DNA is increasingly used as evidence in court cases. Traditional fingerprinting has been used for more than 100 years, and it has been an extremely important identification tool. Recently, DNA fingerprinting, also called *DNA profiling,* has started to replace traditional techniques. DNA profiling has been used to clear thousands of wrongly accused or convicted individuals. However, there is some controversy over whether DNA evidence should be used to prove a suspect's guilt.

1. What does the first sentence in this passage describe?

A the air pollution in a particular place
B the feeling that a person might experience during an event
C the motion of an object
D the reason that a person was probably guilty of a crime

2. Which of the following best describes the main idea of the second paragraph of this passage?

F A defendant was proven guilty by DNA analysis.
G Court battles involving DNA fingerprinting are very exciting.
H The technique of DNA profiling is increasingly used in court cases.
I The technique of DNA profiling is controversial.

Passage 2 Most of the biochemicals found in living things are proteins. In fact, other than water, proteins are the most abundant molecules in your cells. Proteins have many functions, including regulating chemical activities, transporting and storing materials, and providing structural support.

Every protein is composed of small "building blocks" called *amino acids*. Amino acids are molecules that are composed of carbon, hydrogen, oxygen, and nitrogen atoms. Some amino acids also include sulfur atoms. Amino acids chemically bond to form proteins of many shapes and sizes.

The function of a protein depends on the shape of the bonded amino acids. If even a single amino acid is missing or out of place, the protein may not function correctly or may not function. Foods such as meat, fish, cheese, and beans contain proteins, which are broken down into amino acids as the foods are digested. Your body can then use these amino acids to make new proteins.

1. In the passage, what does *biochemical* mean?

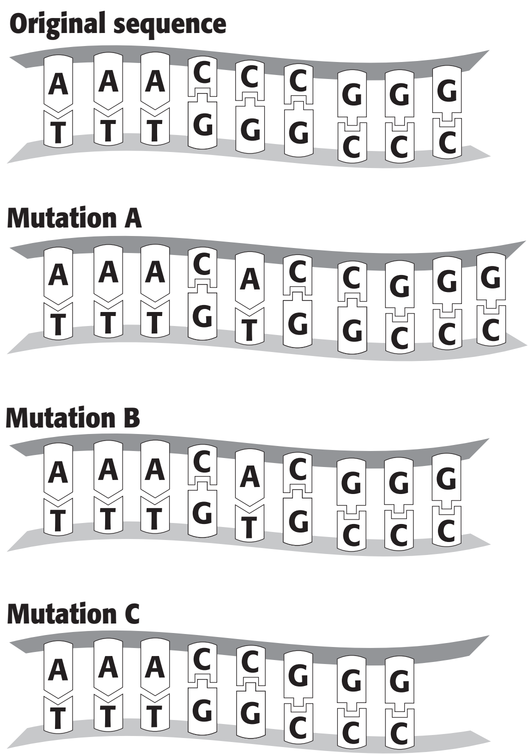
A a chemical found in nonliving things
B a chemical found in living things
C a pair of chemicals
D a protein

2. According to the passage, which of the following statements is true?

F Amino acids contain carbon dioxide.
G Amino acids contain proteins.
H Proteins are made of living things.
I Proteins are made of amino acids.

INTERPRETING GRAPHICS

The diagram below shows an original sequence of DNA and three possible mutations. Use the diagram to answer the questions that follow.



1. In which mutation was an original base pair replaced?

A Mutation A
B Mutation B
C Mutation C
D There is not enough information to determine the answer.

2. In which mutation was a new base pair added?

F Mutation A
G Mutation B
H Mutation C
I There is not enough information to determine the answer.

3. In which mutation was an original base pair removed?

A Mutation A
B Mutation B
C Mutation C
D There is not enough information to determine the answer.

MATH

Read each question below, and choose the best answer.

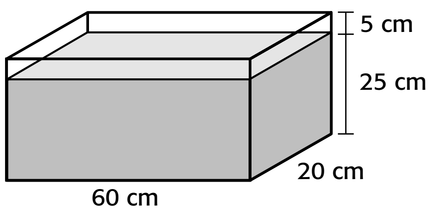
1. Mary was making a design on top of her desk with marbles. She put 3 marbles in the first row, 7 marbles in the second row, 15 marbles in the third row, and 31 marbles in the fourth row. If Mary continues this pattern, how many marbles will she put in the seventh row?

A 46
B 63
C 127
D 255

2. Bobby walked 3 1/2 km on Saturday, 2 1/3 km on Sunday, and 1 km on Monday. How many kilometers did Bobby walk on those 3 days?

F 5 1/6
G 5 5/6
H 6 1/6
I 6 5/6

3. Marie bought a new aquarium for her goldfish. The aquarium is 60 cm long, 20 cm wide, and 30 cm high. Which equation could be used to find the volume of water needed to fill the aquarium to 25 cm deep?



A $V = 30 \times 60 \times 20$
B $V = 25 \times 60 \times 20$
C $V = 30 \times 60 \times 20 - 5$
D $V = 30 \times 60 \times 25$

4. How is the product of $6 \times 6 \times 6 \times 4 \times 4 \times 4$ expressed in scientific notation?

F $6^4 \times 3^6$
G $6^3 \times 4^3$
H $3^6 \times 3^4$
I 24^6

Standardized Test Preparation

Science in Action

Scientific Debate

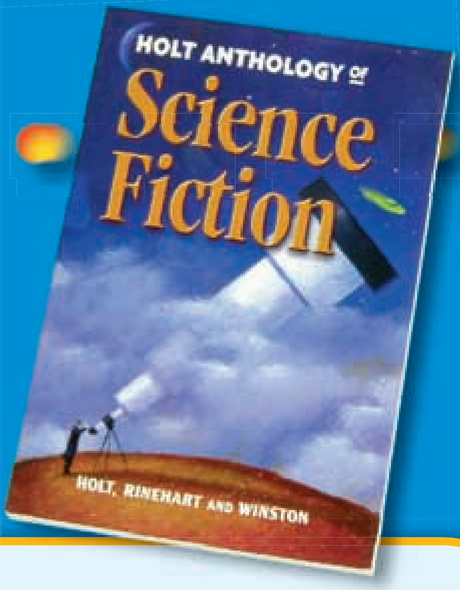
Supersquash or Frankenfruit?

Some food that you buy may have been developed in a new way. Food producers may use genetic engineering to make food crops easier to grow or sell, more nutritious, or resistant to pests and disease. More than half of the packaged foods sold in the United States are likely to contain ingredients from genetically modified organisms.

The U.S. government has stated that research shows that these foods are safe. But some scientists are concerned that genes introduced into crop plants could cause new environmental or health problems. For example, people who are allergic to peanuts might also be allergic to tomato plants that contain peanut genes.

Math ACTIVITY

Write a survey about genetically altered foods. Ask your teacher to approve your questions. Ask at least 15 people to answer your survey. Create graphs to summarize your results.



Science Fiction

"Moby James" by Patricia A. McKillip

Rob Trask and his family live on a space station. Rob thinks that his real brother was sent back to Earth. The person who claims to be his brother, James, is really either some sort of mutated plant or a mutant pair of dirty sweat socks.

Now, Rob has another problem—his class is reading Herman Melville's novel *Moby Dick*. As he reads the novel, Rob becomes convinced that his brother is a great white mutant whale—Moby James. To see how Rob solves his problems, read "Moby James" in the *Holt Anthology of Science Fiction*.

Language Arts ACTIVITY

WRITING SKILL Read "Moby James" by Patricia A. McKillip. Then, write your own short science-fiction story about a mutant organism. Be sure to incorporate some science into your science fiction.

People in Science

Lydia Villa-Komaroff

Genetic Researcher When Lydia Villa-Komaroff was young, science represented “a kind of refuge” for her. She grew up in a very large family that lived in a very small house. “I always wanted to find things out. I was one of those kids who took things apart.”

In college, Villa-Komaroff became very interested in the process of embryonic development—how a simple egg grows into a complex animal. This interest led her to study genes and the way that genes code for proteins. For example, insulin is a protein that is normally produced by the human body. Often, people who suffer from diabetes lack the insulin gene, so their bodies can’t make insulin. These people may need to inject insulin into their blood as a drug treatment.

Before the research by Villa-Komaroff’s team was done, insulin was difficult to produce. Villa-Komaroff’s team isolated the human gene that codes for insulin. Then, the scientists inserted the normal human insulin gene into the DNA of bacteria. This inserted gene caused the bacteria to produce insulin. This technique was a new and more efficient way to produce insulin. Now, most of the insulin used for diabetes treatment is made in this way. Many genetic researchers dream of making breakthroughs like the one that Villa-Komaroff made in her work with insulin.

Social Studies ACTIVITY

WRITING SKILL Do some research about several women, such as Marie Curie, Barbara McClintock, or Maxine Frank Singer, who have done important scientific research. Write a short biography about one of these women.

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HL5DNAF.

Current Science

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UNIT 7

TIMELINE

Simple Organisms

Gross, all you want to do is get rid of that mold on your sandwich bread. Don't eat it, but did you know that bread mold can be used to make penicillin? In fact, even some bacteria are used to make drugs to fight infection. In this unit, you will learn about simple organisms, such as bacteria, protists, and fungi. Some of these organisms cause disease, but others provide food and medicines. Read on, and be amazed!

Around 250

Mayan farmers build terraces to control the flow of water to crops.

1864

Louis Pasteur uses heat to eliminate microbes. This process is later called *pasteurization*.

1897

Beatrix Potter, the author of *The Tale of Peter Rabbit*, completes her collection of 270 watercolors of fungi. Today, she is considered an expert in mycology, the study of fungi.

1971

Ananda Chakrabarty uses genetics to design bacteria that can break down oil in oil spills.

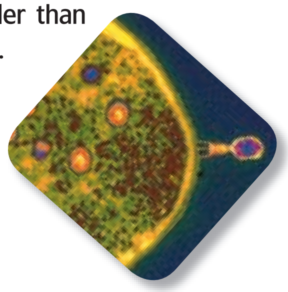
1580
Prospero Alpini discovers that plants have both male structures and female structures.

1683
Anton van Leeuwenhoek is the first person to describe bacteria.

E. coli under an electron microscope

1763
Joseph Kolreuter studies orchid pollination and discovers that both parent plants contribute traits to the offspring.

1898
Martinus Beijerinck gives the name *virus* to infectious material that is smaller than a bacterium.



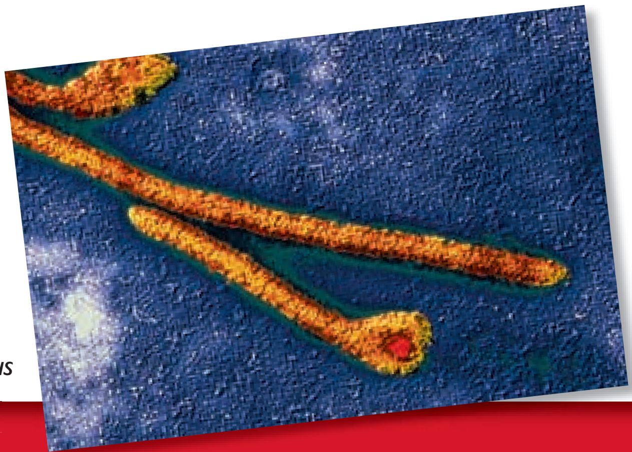
1928
Alexander Fleming observes that certain molds can eliminate bacterial growth, and he discovers penicillin.

1955


A vaccine for the polio virus developed by Dr. Jonas Salk becomes widely used.

1983
HIV, the virus responsible for AIDS, is isolated.

1995
An outbreak of the deadly Ebola virus occurs in Zaire.



Ebola virus

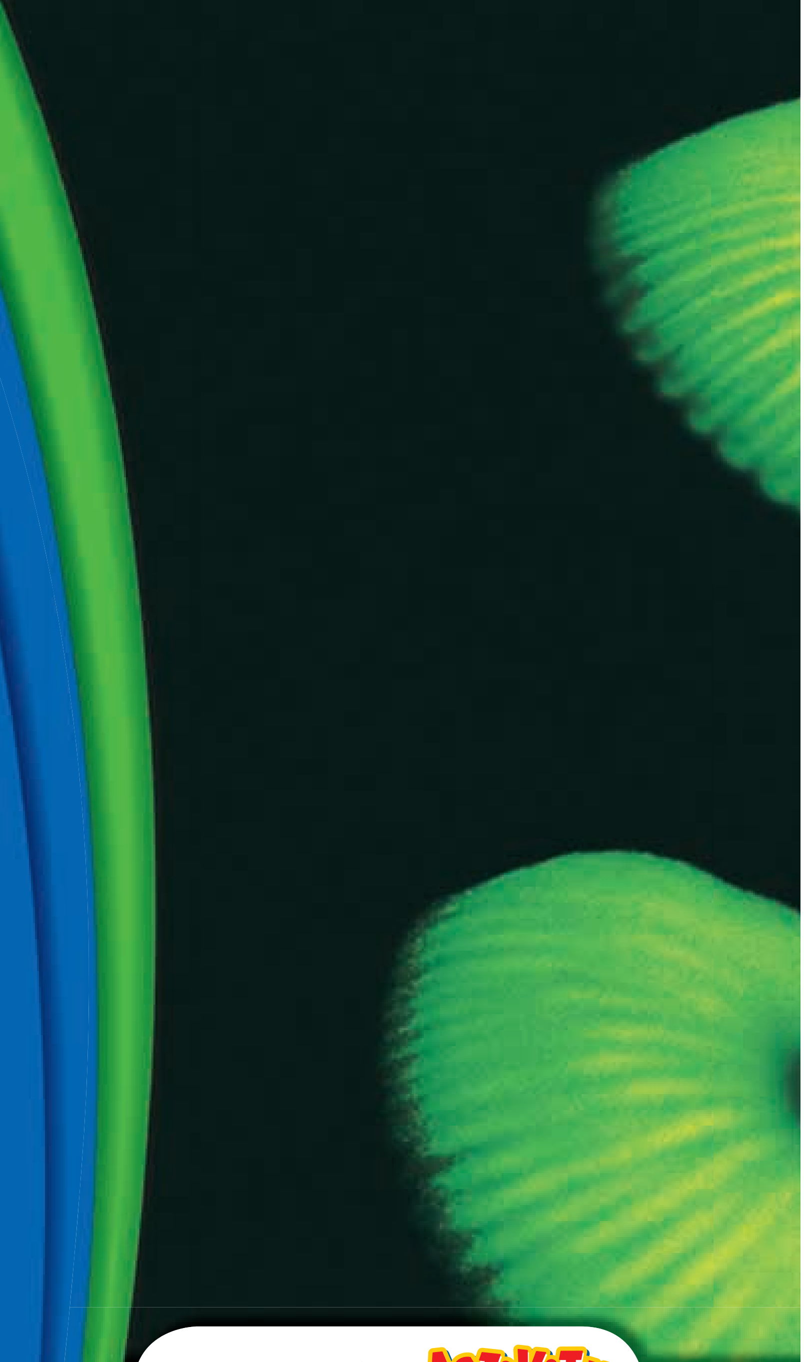
2002
An international team decodes the DNA sequences for both the protist that causes malaria and the mosquito that carries this protist. As a result, the door to more-effective antimalaria drugs is opened.

20

Protists and Fungi

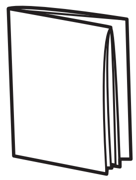
About the PHOTO

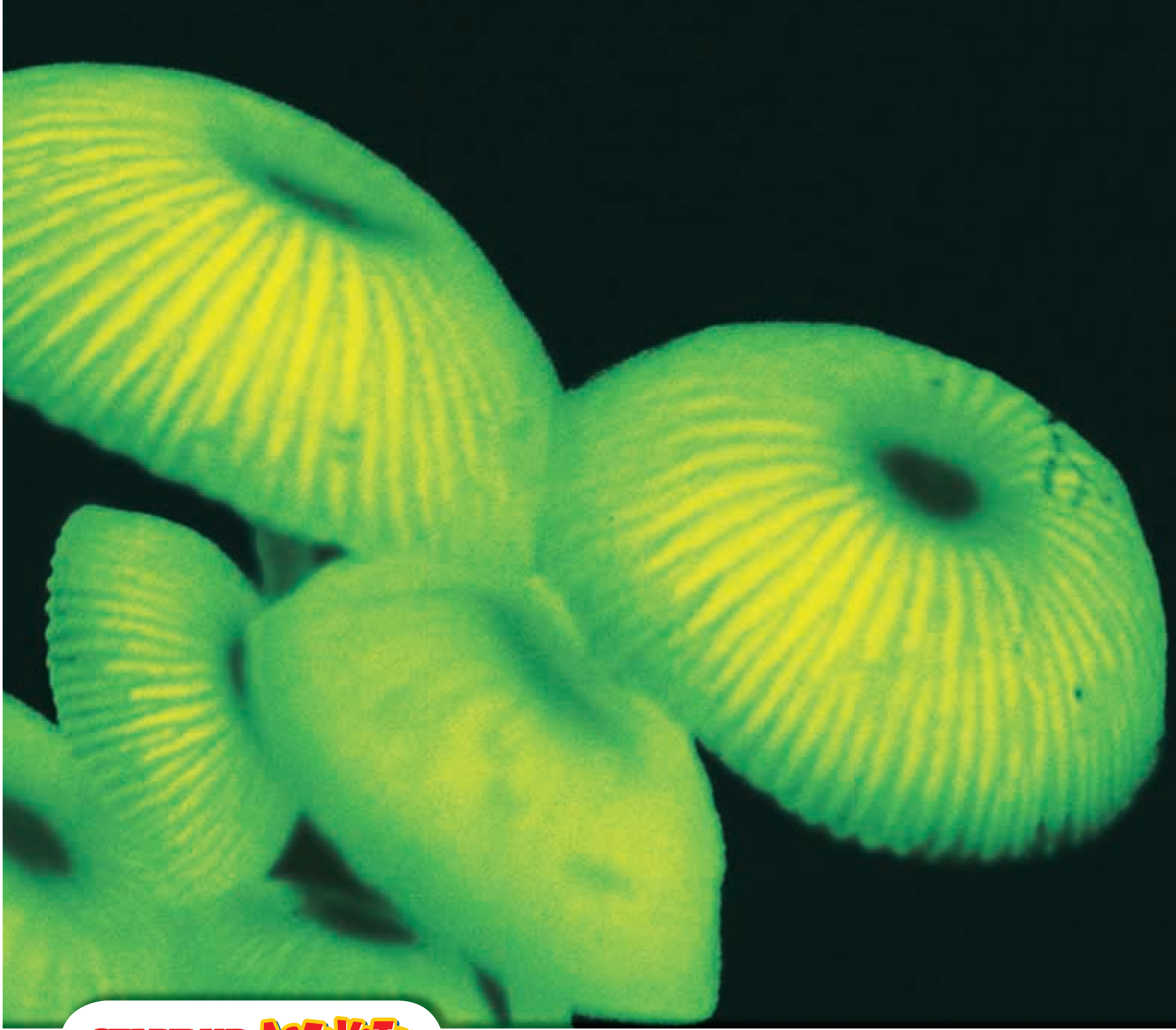
These glowing disks may look like spaceships, but they are mushrooms! Some fungi—and some protists—glow with bioluminescence (BIE oh LOO muh NES uhns), just as fireflies do. Bioluminescence is the production of light from chemical reactions in an organism. The function of bioluminescence in fungi is not known. Some scientists think that the glow attracts insects that help spread the fungi's spores. Other scientists think that the light is just a way to release energy.



PRE-READING ACTIVITY

FOLDNOTES **Booklet** Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.





START-UP ACTIVITY

A Microscopic World

In this activity, you will find some common protists in pond water or in a solution called a *hay infusion*.

Procedure

1. Use a **plastic eyedropper** to place **one drop of pond water or hay infusion** onto a **microscope slide.**
2. Add a **drop of ProtoSlo™** to the slide.
3. Add a **plastic coverslip** by putting one edge on the slide and then slowly lowering the coverslip over the drop to prevent air bubbles.
4. Observe the slide under low power of a **microscope.**
5. Find an organism in the liquid on the slide.
6. Observe the organism under high power to get a closer look.
7. Sketch the organism as you see it under high power. Then, return the microscope to low power, and find other organisms to sketch. Return the microscope to high power, and sketch the new organisms.

Analysis

1. How many kinds of organisms do you see?
2. Are the organisms alive? Support your answer with evidence.
3. How many cells does each organism appear to have?

SECTION 1

Protists

Some are so tiny that they cannot be seen without a microscope. Others grow many meters long. Some are poisonous. And some provide food for people.

What are they? The organisms described above are protists. A **protist** is a member of the kingdom Protista. Protists differ from other living things in many ways. Look at **Figure 1** to see a variety of protists.

General Characteristics

Protists are very diverse and have few traits in common. Most protists are single-celled organisms, but some are made of many cells, and others live in colonies. Some protists produce their own food, and some eat other organisms or decaying matter. Some protists can control their own movement, and others cannot. However, protists do share a few characteristics. For example, all protists are *eukaryotic* (yoo KAR ee AHT ik), which means that their cells each have a nucleus.

Members of the kingdom Protista are related more by how they differ from members of other kingdoms than by how they are similar to other protists. Protists are less complex than other eukaryotic organisms are. For example, protists do not have specialized tissues. Fungi, plants, and animals have specialized tissues that have specific functions. Most scientists agree that fungi, plants, and animals evolved from early protists.

READING WARM-UP

Objectives

- Describe the characteristics of protists.
- Describe four ways that protists get food.
- Describe three ways that protists reproduce.

Terms to Learn

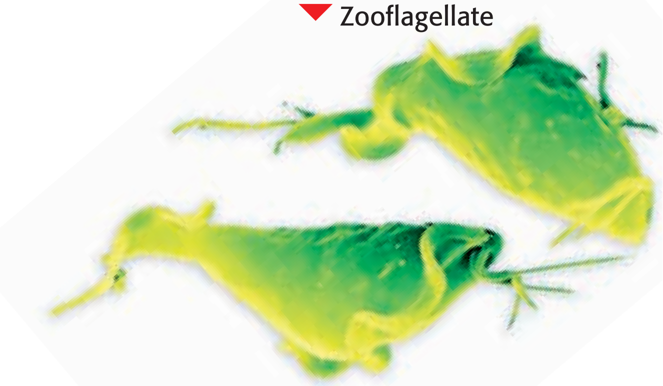
protist
heterotroph
parasite
host

READING STRATEGY

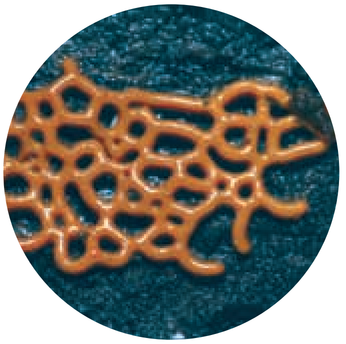
Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

protist an organism that belongs to the kingdom Protista

Zooflagellate



Pretzel slime mold



Ulva

Paramecium

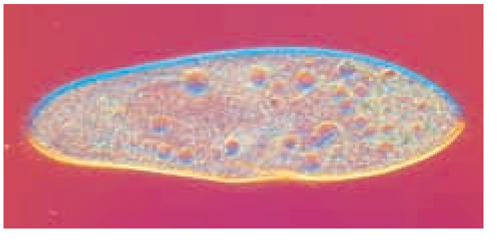


Figure 1 *Protists have many different shapes.*

Protists and Food

Protists get food in many ways. Some protists can make their own food. Other protists eat other organisms, parts or products of other organisms, or the remains of other organisms. Some protists use more than one method of getting food.

Producing Food

Some protists are *producers*. Like green plants, these protists make their own food. Protist producers have special structures called *chloroplasts* (KLAWR uh PLASTS) in their cells. These structures capture energy from the sun. Protists use this energy to produce food in a process called *photosynthesis* (FOHT oh SIN thuh sis). Plants use this same process to make their own food.

Reading Check **How do protist producers get their food?** (*See the Appendix for answers to Reading Checks.*)

SCHOOL to HOME

Food for Thought

With your family, review how producers, consumers, decomposers, and parasites get energy. Think of organisms that live near your home and that get their food in these different ways. Then, make a poster to display your examples. Be sure that the poster describes each way of getting food.

ACTIVITY

Finding Food

Some protists must get food from their environment. These protists are heterotrophs (HET uhr oh TROHFS). **Heterotrophs** are organisms that cannot make their own food. These organisms eat other organisms, parts or products of other organisms, or the remains of other organisms.

Many protist heterotrophs eat small living organisms, such as bacteria, yeast, or other protists. The way that these heterotrophs get food is similar to how many animals get food. Some protist heterotrophs are decomposers. *Decomposers* get energy by breaking down dead organic matter. Some protists get energy in more than one way. For example, slime molds, such as the one in **Figure 2,** get energy by engulfing both small organisms and particles of organic matter.

Some protist heterotrophs are parasites. A **parasite** invades another organism to get the nutrients that it needs. An organism that a parasite invades is called a **host.** Parasites cause harm to their host. Parasitic protists may invade fungi, plants, or animals. During the mid-1800s, a parasitic protist wiped out most of the potatoes in Ireland. Without potatoes to eat, many people died of starvation. Today, people know how to protect crops from many such protists.

heterotroph an organism that gets food by eating other organisms or their byproducts and that cannot make organic compounds from inorganic materials

parasite an organism that feeds on an organism of another species (the host) and that usually harms the host; the host never benefits from the presence of the parasite

host an organism from which a parasite takes food or shelter

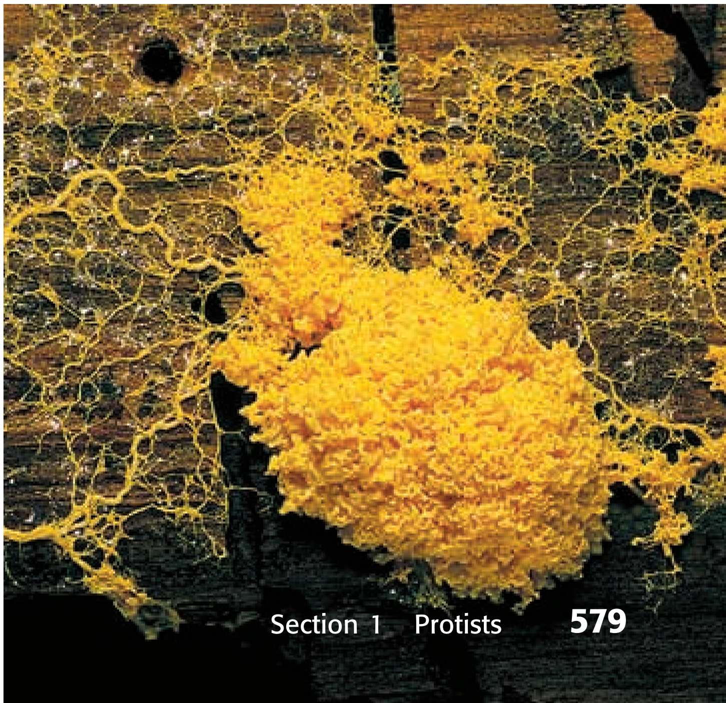


Figure 2 *Slime molds get energy from small organisms and particles of organic matter.*

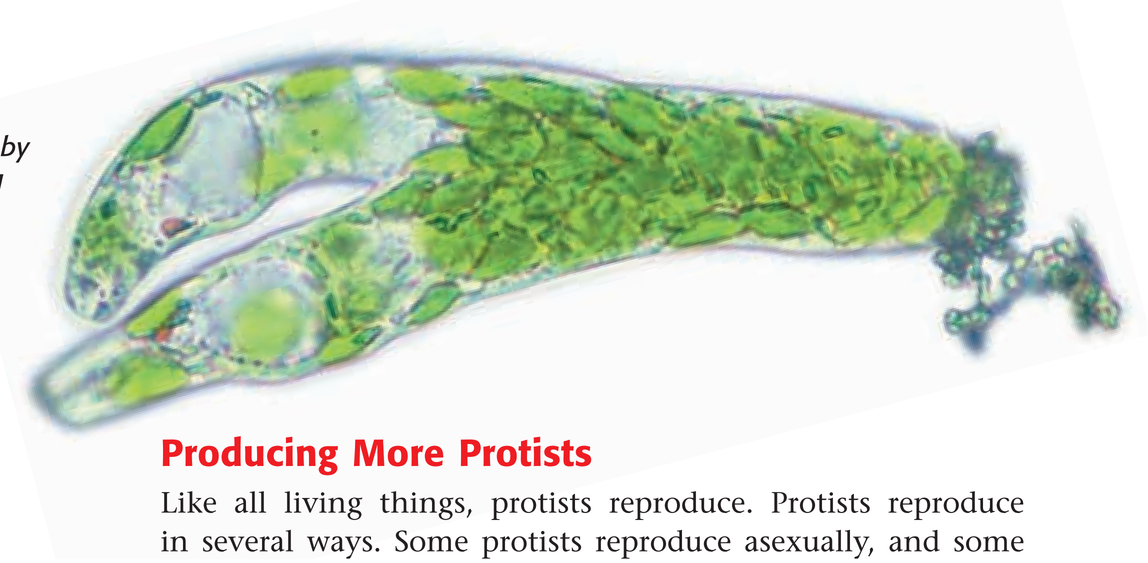


Figure 3 *Members of the genus* Euglena *reproduce by dividing lengthwise during fission.*

Producing More Protists

Like all living things, protists reproduce. Protists reproduce in several ways. Some protists reproduce asexually, and some reproduce sexually. Some protists even reproduce asexually at one stage in their life cycle and sexually at another stage.

MATH PRACTICE

Pairs of Paramecia

Suppose that three pairs of protists from the genus *Paramecium* are conjugating at one time. Each pair successfully results in four protists that have new combinations of genetic material. Then, the new individuals pair up for another successful round of conjugation. How many protists will there be after this round of conjugation?

Asexual Reproduction

Most protists reproduce asexually. In asexual reproduction, the offspring come from just one parent. These offspring are identical to the parent. **Figure 3** shows a member of the genus *Euglena* reproducing asexually by fission. In *binary fission,* a single-celled protist divides into two cells. In some cases, single-celled protists use *multiple fission* to make more than two offspring from one parent. Each new cell is a single-celled protist.

Reading Check **What are two ways that protists can reproduce asexually by fission?**

Sexual Reproduction

Some protists can reproduce sexually. Sexual reproduction requires two parents. Members of the genus *Paramecium* (PAR uh MEE see uhm) sometimes reproduce sexually by a process called *conjugation*. During conjugation, two individuals join together and exchange genetic material by using a small, second nucleus. Then, they divide to produce four protists that have new combinations of genetic material. **Figure 4** shows two paramecia in the process of conjugation.

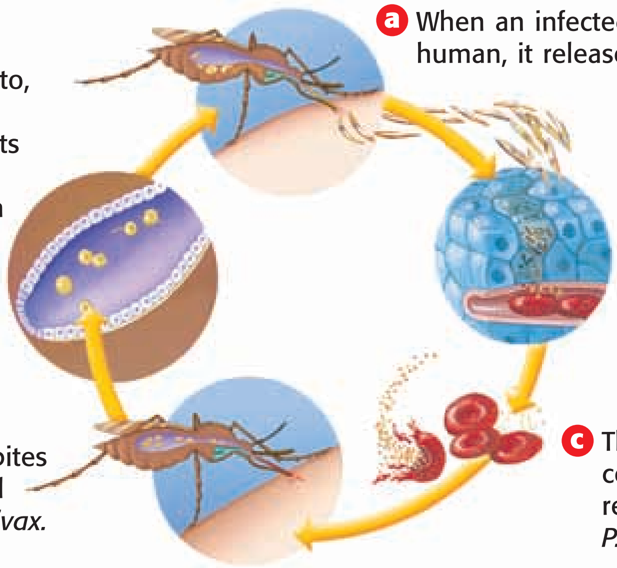
Figure 4 *Members of the genus* Paramecium *can reproduce by conjugation, a type of sexual reproduction.*

Many protists can reproduce asexually and sexually. In some protist producers, the kind of reproduction alternates by generation. For example, a parent will reproduce asexually, and its offspring will reproduce sexually. Other protists reproduce asexually until environmental conditions become stressful, such as when there is little food or water. When conditions are stressful, these protists will use sexual reproduction until conditions improve.

Reproductive Cycles

Some protists have complex reproductive cycles. These protists may change forms many times. **Figure 5** shows the life cycle of *Plasmodium vivax* (plaz MOH dee uhm VIE vaks), the protist that causes the disease malaria. *P. vivax* depends on both humans and mosquitoes to reproduce.

Figure 5 P. vivax *infects both humans and mosquitoes as it reproduces.*



SECTION Review

Summary

- Protists are a diverse group of single-celled and many-celled organisms.
- Protists are grouped in their own kingdom because they differ from other organisms in many ways.
- Protists get food by producing it or by getting it from their environment.
- Some protists reproduce asexually, some reproduce sexually, and some reproduce both asexually and sexually.

Using Key Terms

1. Use the following terms in the same sentence: *parasite* and *host.*
2. In your own words, write a definition for each of the following terms: *protist* and *heterotroph.*

Understanding Key Ideas

3. What is one way that protists differ from plants and animals?
   a. Protists are eukaryotic.
   b. All protists have many cells.
   c. Protists do not have specialized tissues.
   d. Protists are not eukaryotic.
4. Name a characteristic shared by all protists.
5. Name three ways that protists can differ from each other.
6. Describe four ways that protists get food.
7. Describe three ways that protists reproduce.

Math Skills

8. If seven individuals of the genus *Euglena* reproduce at one time, how many individuals result?

Critical Thinking

9. **Identifying Relationships** How is conjugation similar to fission?
10. **Applying Concepts** The spread of malaria depends on both human and mosquito hosts. Use this fact to think of a way to stop the spread of malaria.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Protists
SciLinks code: HSM1245

SECTION 2

Kinds of Protists

Would you believe that there is an organism that lives in the forest and looks like a pile of scrambled eggs? This organism exists, and it's a protist.

READING WARM-UP

Objectives

- Describe how protists can be organized into three groups based on their shared traits.
- List an example for each group of protists.

Terms to Learn

algae
phytoplankton

READING STRATEGY

Reading Organizer As you read this section, make a table comparing protist producers, heterotrophs that can move, and heterotrophs that can't move.

Slimy masses of protists can look like spilled food. Smears of protists on the walls of a fish tank may look like dirt. Few of the many kinds of protists look alike.

These unique organisms are hard to classify. Scientists are always learning more about protist relationships. So, organizing protists into groups is not easy. One way that protists are grouped is based on shared traits. Using this method, scientists can place protists into three groups: producers, heterotrophs that can move, and heterotrophs that can't move. These groups do not show how protists are related to each other. But these groups do help us understand how protists can differ.

Protist Producers

Many protists are producers. Like plants, protist producers use the sun's energy to make food through photosynthesis. These protist producers are known as **algae** (AL JEE). All algae (singular, *alga*) have the green pigment chlorophyll, which is used for making food. But most algae also have other pigments that give them a color. Almost all algae live in water.

Some algae are made of many cells, as shown in **Figure 1.** Many-celled algae generally live in shallow water along the shore. You may know these algae as *seaweeds*. Some of these algae can grow to many meters in length.

Free-floating single-celled algae are called **phytoplankton** (FIET oh PLANGK tuhn). These algae cannot be seen without a microscope. They usually float near the water's surface. Phytoplankton provide food for most other organisms in the water. They also produce much of the world's oxygen.

algae eukaryotic organisms that convert the sun's energy into food through photosynthesis but that do not have roots, stems, or leaves (singular, *alga*)

phytoplankton the microscopic, photosynthetic organisms that float near the surface of marine or fresh water

Figure 1 *Some kinds of algae, such as this giant kelp, can grow to be many meters in length.*

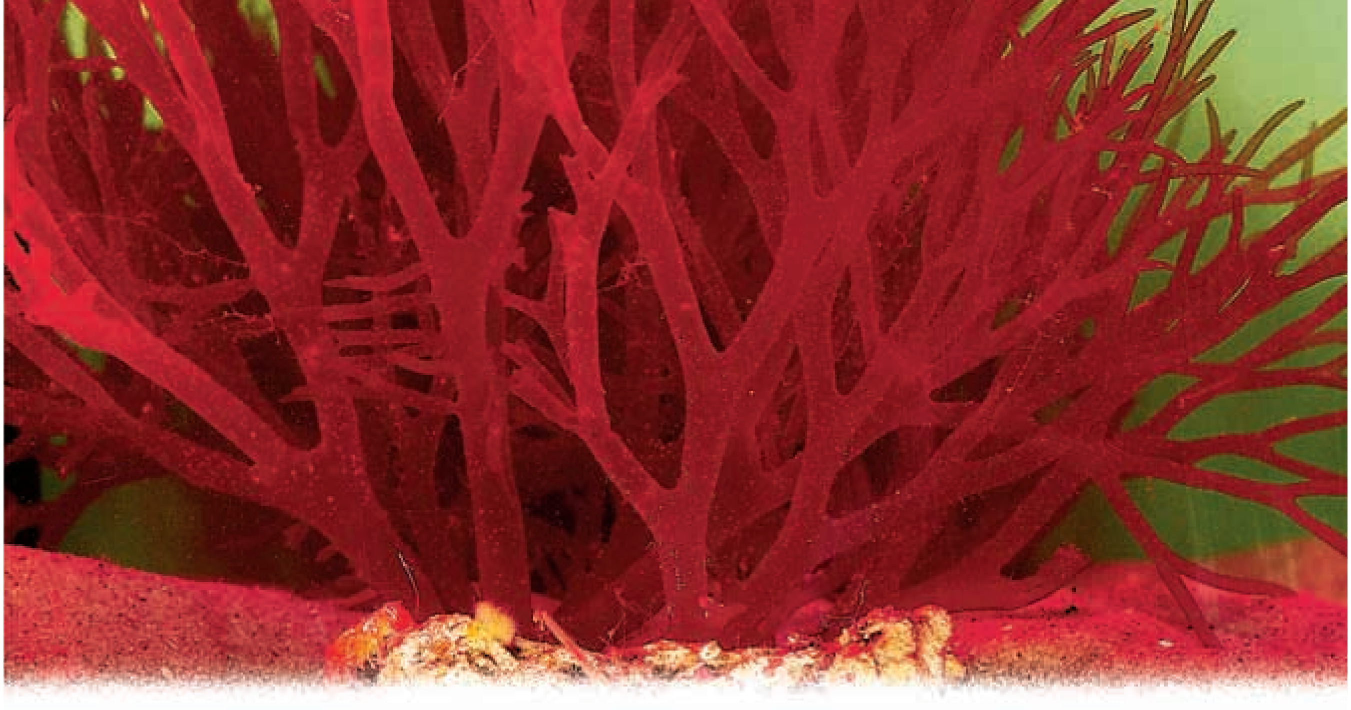


Figure 2 *This* Sebdenia *(seb DEE nee uh) is a red alga.*

Red Algae

Most of the world's seaweeds are red algae. Most red algae live in tropical oceans, attached to rocks or to other algae. Red algae are usually less than 1 m in length. Their cells contain chlorophyll, but a red pigment gives them their color. Their red pigment allows them to absorb the light that filters deep into the clear water of the Tropics. Red algae can grow as deep as 260 m below the surface of the water. An example of a red alga can be seen in **Figure 2.**

Reading Check **If red algae have chlorophyll in their cells, why aren't they green?** (*See the Appendix for answers to Reading Checks.*)

Green Algae

The green algae are the most diverse group of protist producers. They are green because chlorophyll is the main pigment in their cells. Most live in water or moist soil. But others live in melting snow, on tree trunks, and inside other organisms.

Many green algae are single-celled organisms. Others are made of many cells. These many-celled species may grow to be 8 m long. Individual cells of some species of green algae live in groups called *colonies*. **Figure 3** shows colonies of *Volvox*.

Figure 3 Volvox *is a green alga that grows in round colonies.*

Brown Algae

Most of the seaweeds found in cool climates are brown algae. They attach to rocks or form large floating beds in ocean waters. Brown algae have chlorophyll and a yellow-brown pigment. Many are very large. Some grow 60 m—as long as about 20 cars—in just one season! Only the tops of these gigantic algae are exposed to sunlight. These parts of the algae make food through photosynthesis. This food is transported to parts of the algae that are too deep in the water to receive sunlight.

Diatoms

Diatoms (DIE e TAHMZ) are single celled. They are found in both salt water and fresh water. Diatoms get their energy from photosynthesis. They make up a large percentage of phytoplankton. **Figure 4** shows some diatoms' many unusual shapes. The cell walls of diatoms contain a glasslike substance called *silica*. The cells of diatoms are enclosed in a two-part shell.

Figure 4 *Although most diatoms are free floating, some cling to plants, shellfish, sea turtles, and whales.*

Dinoflagellates

Most dinoflagellates (DIE noh FLAJ uh lits) are single celled. Most live in salt water, but a few species live in fresh water. Some dinoflagellates even live in snow. Dinoflagellates have two whiplike strands called *flagella* (singular, *flagellum*). The beating of these flagella causes the cells to spin through the water. Most dinoflagellates get their energy from photosynthesis, but a few are consumers, decomposers, or parasites.

Reading Check **Name three places where dinoflagellates live.**

Euglenoids

Euglenoids (yoo GLEE NOYDZ) are single-celled protists. Most euglenoids live in fresh water. They use their flagella to move through the water. Many euglenoids are producers and so make their own food. But when there is not enough light to make food, these euglenoids can get food as heterotrophs. Other euglenoids do not contain chlorophyll and cannot make food. These euglenoids are full-time consumers or decomposers. Because euglenoids can get food in several ways, they do not fit well into any one protist group. **Figure 5** shows the structure of a euglenoid.

Figure 5 The Structure of Euglenoids

Photosynthesis takes place in **chloroplasts.** These structures contain the green pigment chlorophyll.

Most euglenoids have two **flagella,** one long and one short. Euglenoids use flagella to move through water.

Euglenoids can't see, but they have **eyespots** that sense light.

A special structure called a **contractile vacuole** holds excess water and removes it from the cell.

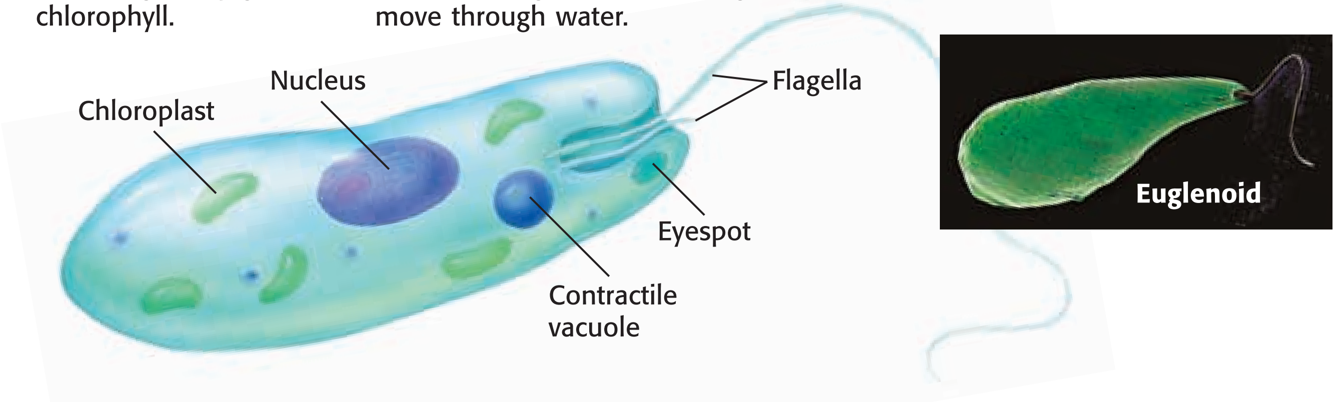
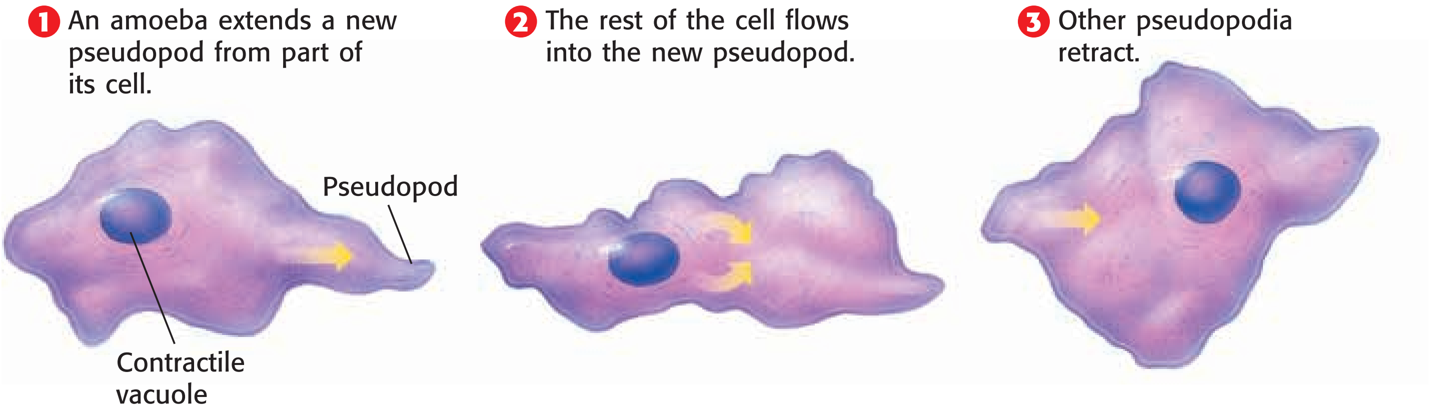


Figure 6 **Amoebic Movement**



Heterotrophs That Can Move

Some heterotrophic protists have special traits that allow them to move. Other heterotrophic protists cannot move on their own. Those that can move are usually single-celled consumers or parasites. These mobile protists are sometimes called *protozoans* (PROHT oh ZOH uhnz).

Amoebas

Amoebas (uh MEE buhs) and similar amoeba-like protists are soft, jellylike protozoans. They are found in both fresh and salt water, in soil, and as parasites in animals. Although amoebas look shapeless, they are highly structured cells. Amoebas have contractile vacuoles to get rid of excess water. Many amoebas eat bacteria and small protists. But some amoebas are parasites that get food by invading other organisms. Certain parasitic amoebas live in human intestines and cause amoebic dysentery (uh MEE bik DIS uhn TER ee). This painful disease causes internal bleeding.

Amoebic Movement

Amoebas and amoeba-like protists move with pseudopodia (SOO doh POH dee uh). *Pseudopodia* means "false feet." To move, an amoeba stretches a pseudopod out from the cell. The cell then flows into the pseudopod. **Figure 6** shows how an amoeba uses pseudopodia to move.

Amoebas and amoeba-like protists use pseudopodia to catch food, too. When an amoeba senses a food source, it moves toward the food. The amoeba surrounds the food with its pseudopodia. This action forms a *food vacuole*. Enzymes move into the vacuole to digest the food, and the digested food passes into the amoeba. **Figure 7** shows an amoeba catching food. To get rid of wastes, an amoeba reverses the process. A waste-filled vacuole is moved to the edge of the cell and is released.

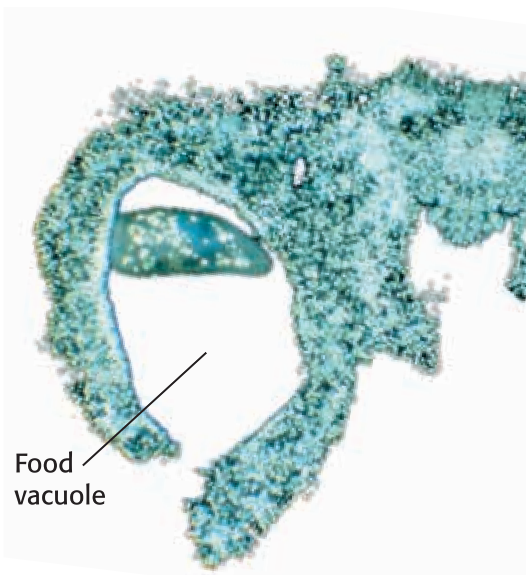


Figure 7 *An amoeba engulfs its prey with its pseudopodia.*

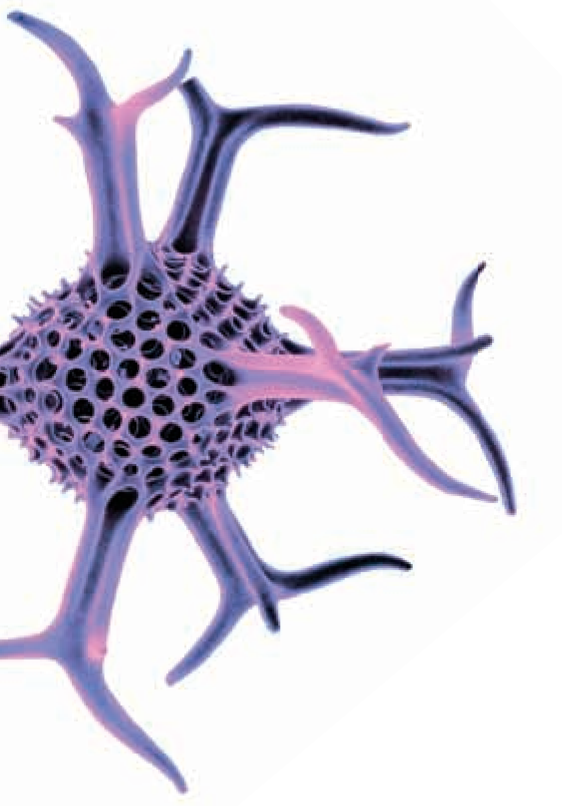


Figure 8 *Radiolarians are amoeba-like protists that have shells.*

Shelled Amoeba-Like Protists

Not all amoeba-like protists look shapeless. Some have an outer shell. *Radiolarian* (RAY dee oh LER ee uhn) shells look like glass ornaments, as shown in **Figure 8.** *Foraminiferans* (fuh RAM uh NIF uhr uhnz) have snail-like shells. These protists move by poking pseudopodia out of pores in the shells.

Reading Check **Name two shelled, amoeba-like protists.**

Zooflagellates

Zooflagellates (ZOH uh FLAJ uh LAYTS) are protists that wave flagella back and forth to move. Some zooflagellates live in water. Others live in the bodies of other organisms.

Some zooflagellates are parasites that cause disease. The parasite *Giardia lamblia* (jee AWR dee uh LAM blee uh) can live in the digestive tract of many vertebrates. One form of *G. lamblia* lives part of its life in water. People who drink water infected with *G. lamblia* can get severe stomach cramps.

Some zooflagellates live in mutualism with other organisms. In *mutualism,* one organism lives closely with another organism. Each organism helps the other live. The zooflagellate in **Figure 9** lives in the gut of termites. This zooflagellate digests the cell walls of the wood that the termites eat. Both organisms benefit from the arrangement. The protist helps the termite digest wood. The termite gives the protist food and a place to live.

CONNECTION TO Geology

Shell Deposits Foraminiferans have existed for more than 600 million years. During this time, shells of dead foraminiferans have been sinking to the bottom of the ocean. Millions of years ago, foraminiferan shells formed a thick layer of sediment of limestone and chalk deposits. The chalk deposits in England that are known as the White Cliffs of Dover formed in this way. Use geology books to find examples of sedimentary rocks formed from protist shells. Make a poster that explains the process by which shells become sedimentary rock.

ACTIVITY

Figure 9 **The Structure of Flagellates**

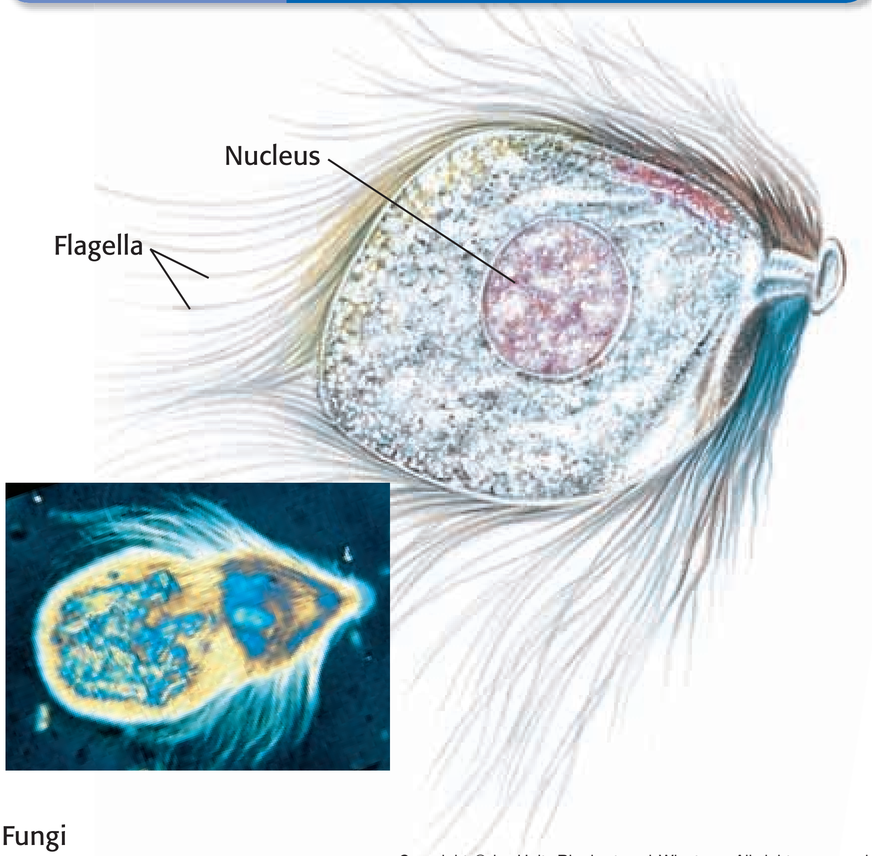


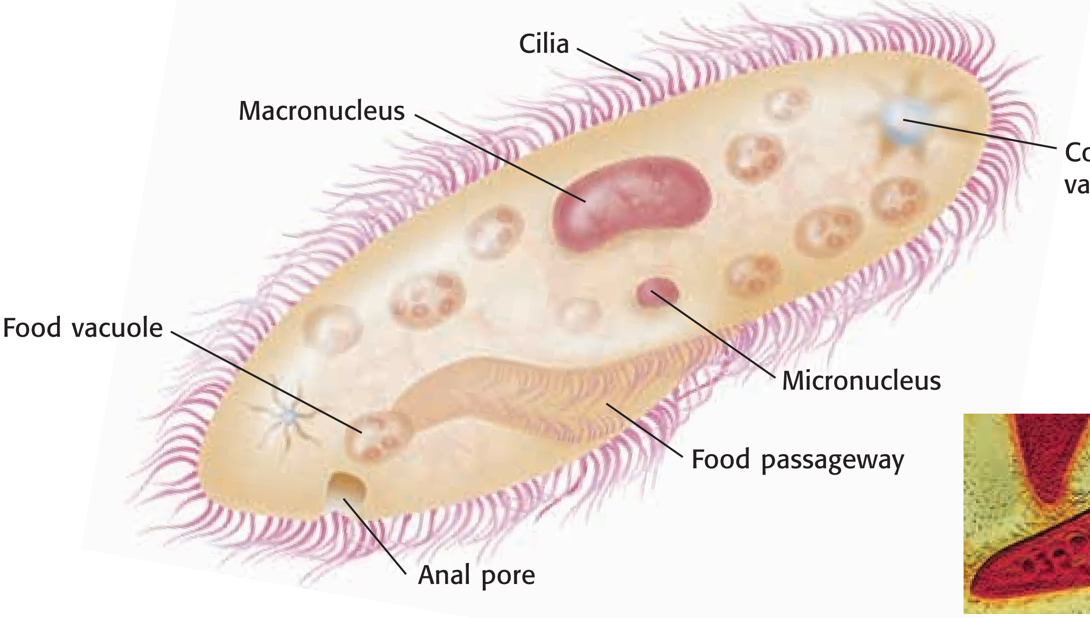
Figure 10 **The Structure of a Paramecium**

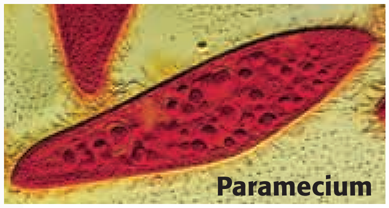
Members of the genus *Paramecium* eat by using cilia to sweep food into a **food passageway.**

Food enters a **food vacuole,** where enzymes digest the food.

Food waste is removed from the cell through the **anal pore.**

A **contractile vacuole** pumps out excess water.





Ciliates

Ciliates (SIL ee its) are complex protists. They have hundreds of tiny, hairlike structures known as *cilia*. The cilia move a protist forward by beating back and forth. Cilia can beat up to 60 times a second! Ciliates also use their cilia for feeding. The cilia sweep food toward the protist's food passageway. The best-known genus of ciliates is *Paramecium*, shown in **Figure 10.**

The cell of a paramecium has two kinds of nuclei. A large nucleus called a *macronucleus* controls the functions of the cell. A smaller nucleus, the *micronucleus,* passes genes to another paramecium during sexual reproduction.

Heterotrophs That Can't Move

Not all protist heterotrophs have features that help them move. Some of these protists are parasites that do not move about. Others can move only at certain phases in their life cycle.

Spore-Forming Protists

Many spore-forming protists are parasites. They absorb nutrients from their hosts. They have no cilia or flagella, and they cannot move on their own. Spore-forming protists have complicated life cycles that usually include two or more hosts. For example, the spore-forming protist that causes malaria uses both mosquitoes and humans as hosts.

CONNECTION TO Social Studies

Malaria *Plasmodium vivax* is a spore-forming protist that causes malaria. People get malaria in tropical areas when they are bitten by mosquitoes carrying *P. vivax*. Malaria can be treated with drugs, but many people do not have access to these drugs. Millions of people die from malaria each year. Research malaria rates in different parts of the world, and give a presentation of your findings to the class.

ACTIVITY

Figure 11 *Parasitic water molds attack various organisms, including fish.*

Water Molds

Water molds are also heterotrophic protists that can't move. Most water molds are small, single-celled organisms. Water molds live in water, moist soil, or other organisms. Some of them are decomposers and thus eat dead matter. But many are parasites. Their hosts can be living plants, animals, algae, or fungi. A parasitic water mold is shown in **Figure 11.**

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5PROW.**

Reading Check **Name two ways that water molds get food.**

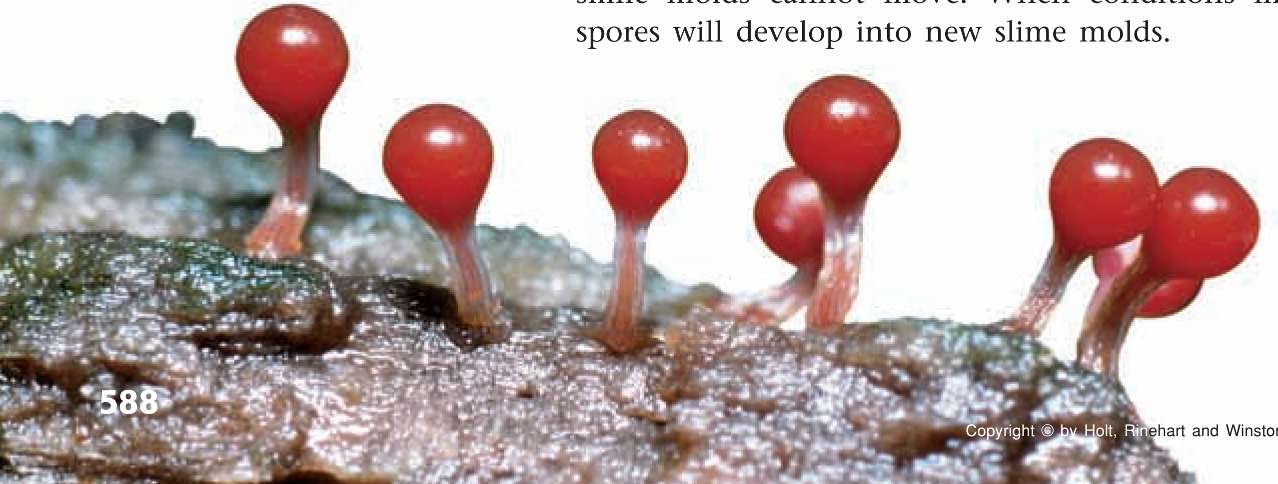
Slime Molds

Slime molds are heterotrophic protists that can move only at certain phases of their life cycle. They look like thin, colorful, shapeless globs of slime. Slime molds live in cool, moist places in the woods. They use pseudopodia to move and to eat bacteria and yeast. They also decompose small bits of rotting organic matter by surrounding small pieces of the matter and then digesting them.

Some slime molds live as a giant cell that has many nuclei and a single cytoplasm at one stage of life. As long as food and water are available, the cell will continue to grow. One cell may be more than 1 m across! Other slime molds live as single-celled individuals that can come together as a group when food or water is hard to find.

When environmental conditions are stressful, slime molds grow stalklike structures with rounded knobs at the top, as shown in **Figure 12.** The knobs contain spores. *Spores* are small reproductive cells covered by a thick cell wall. The spores can survive for a long time without water or nutrients. As spores, slime molds cannot move. When conditions improve, the spores will develop into new slime molds.

Figure 12 *The spore-containing knobs of a slime mold are called* sporangia *(spoh RAN jee uh).*



SECTION Review

Summary

- Protists can be organized into the following groups: producers, heterotrophs that can move, and heterotrophs that cannot move.
- Protist producers make their own food through photosynthesis. They are known as *algae,* and most live in water. Free-floating single-celled algae are phytoplankton.
- Red algae, green algae, brown algae, diatoms, dinoflagellates, and some euglenoids are producers.
- Heterotrophic protists cannot make their own food. They are consumers, decomposers, or parasites. Those that can move are sometimes called *protozoans*.
- Amoeba-like protists, shelled amoeba-like protists, flagellates, and ciliates are heterotrophs that can move.
- Spore-forming protists, water molds, and slime molds are protists that cannot move or can move only in certain phases of their life cycle.

Using Key Terms

1. Use the following terms in the same sentence: *phytoplankton* and *algae*.

Understanding Key Ideas

2. Which of the following kinds of protists are producers?
   - **a.** diatoms
   - **b.** amoebas
   - **c.** slime molds
   - **d.** ciliates
3. How do many amoeba-like protists eat?
   - **a.** They secrete digestive juices onto food.
   - **b.** They produce food from sunlight.
   - **c.** They engulf food with pseudopodia.
   - **d.** They use cilia to sweep food toward them.
4. Give an example of one protist from each of the three groups of protists.
5. Explain why it makes sense to group protists based on shared traits rather than by how they are related to each other.

Critical Thinking

6. **Making Comparisons** How do protist producers, heterotrophs that can move, and heterotrophs that can't move differ?
7. **Making Inferences** You learned how shelled amoeba-like protists move. How do you think they get food into their shells in order to eat?

Interpreting Graphics

Use the photo below to answer the questions that follow.

8. How does this protist move?
9. Identify what kind of protist is shown. To do so, first make a list of the kinds of protists that this organism could not be.

SECTION 3

Fungi

How are cheese, bread, and soy sauce related to fungi? A fungus can help make each of these foods.

READING WARM-UP

Objectives

- Describe the characteristics of fungi.
- Distinguish between the four main groups of fungi.
- Explain how lichens affect their environment.

Terms to Learn

fungus	spore
hypha	mold
mycelium	lichen

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Fungi (singular, *fungus*) are everywhere. The mushrooms on pizza are a type of fungus. The yeast used to make bread is a fungus. And if you've ever had athlete's foot, you can thank a fungus for that, too.

Characteristics of Fungi

Fungi are eukaryotic heterotrophs that have rigid cell walls and no chlorophyll. They are so different from other organisms that they are placed in their own kingdom. As you can see in **Figure 1,** fungi come in a variety of shapes, sizes, and colors.

fungus an organism whose cells have nuclei, rigid cell walls, and no chlorophyll and that belongs to the kingdom Fungi

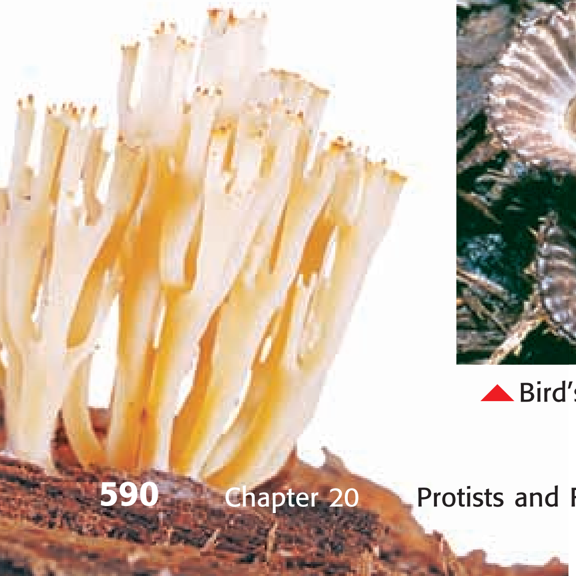
Food for Fungi

Fungi are heterotrophs, but they cannot catch or surround food. Fungi must live on or near their food supply. Most fungi are consumers. These fungi get nutrients by secreting digestive juices onto a food source and then absorbing the dissolved food. Many fungi are decomposers, which feed on dead plant or animal matter. Other fungi are parasites.

Some fungi live in mutualism with other organisms. For example, many types of fungi grow on or in the roots of a plant. The plant provides nutrients to the fungus. The fungus helps the root absorb minerals and protects the plant from some disease-causing organisms. This relationship between a plant and a fungus is called a *mycorrhiza* (MIE koh RIE zuh).

Figure 1 *Fungi vary greatly in their appearance.*

Straight coral fungus



Bird's nest fungus

Witch's hat fungus

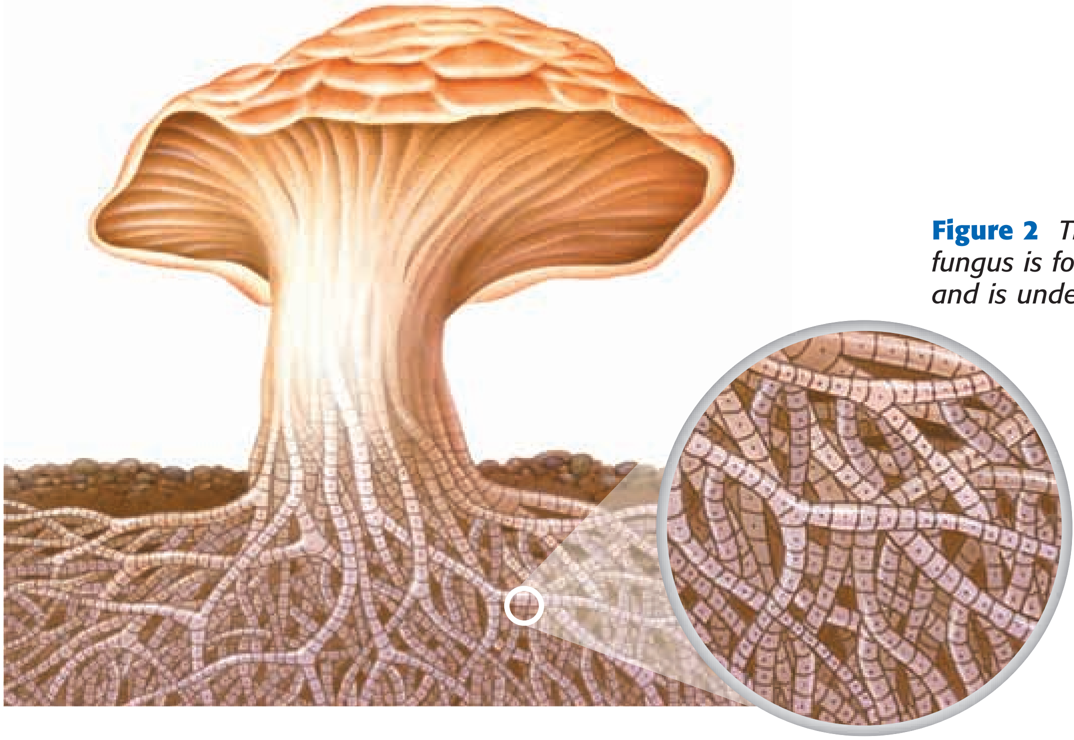


Figure 2 *The mycelium of a fungus is formed by hyphae and is underground.*

Hidden from View

All fungi are made of eukaryotic cells, which have nuclei. Some fungi are single celled, but most fungi are made of many cells. These many-celled fungi are made up of chains of cells called hyphae (HIE fee). **Hyphae** (singular, *hypha*) are threadlike fungal filaments. These filaments are made of cells that have openings in their cell walls. These openings allow cytoplasm to move freely between the cells.

Most of the hyphae that make up a fungus grow together to form a twisted mass called the **mycelium** (mie SEE lee uhm). The mycelium makes up the major part of the fungus. However, this mass is hidden from view underneath the ground. **Figure 2** shows the hyphae of a fungus.

hypha a nonreproductive filament of a fungus

mycelium the mass of fungal filaments, or hyphae, that forms the body of a fungus

spore a reproductive cell or multicellular structure that is resistant to stressful environmental conditions and that can develop into an adult without fusing with another cell

Making More Fungi

Reproduction in fungi may be either asexual or sexual. Asexual reproduction in fungi occurs in two ways. In one type of asexual reproduction, the hyphae break apart, and each new piece becomes a new fungus. Asexual reproduction can also take place by the production of spores. **Spores** are small reproductive cells that are protected by a thick cell wall. Spores are light and easily spread by wind. When the growing conditions where a spore lands are right, the spore will grow into a new fungus.

Sexual reproduction in fungi happens when special structures form to make sex cells. The sex cells join to produce sexual spores that grow into a new fungus. **Figure 3** shows a fungus releasing sexual spores into the air.

Reading Check **What are two ways that fungi can reproduce asexually?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 *This puffball is releasing sexual spores that can produce new fungi.*

Figure 4 *Black bread mold is a soft, cottony mass that grows on bread and fruit.*

Kinds of Fungi

Fungi are classified based on their shape and the way that they reproduce. There are four main groups of fungi. Most species of fungi fit into one of these groups. These groups are threadlike fungi, sac fungi, club fungi, and imperfect fungi.

Threadlike Fungi

Have you ever seen fuzzy mold growing on bread? A **mold** is a shapeless, fuzzy fungus. **Figure 4** shows a black bread mold. This particular mold belongs to a group of fungi called *threadlike fungi*. Most of the fungi in this group live in the soil and are decomposers. However, some threadlike fungi are parasites.

Threadlike fungi can reproduce asexually. Parts of the hyphae grow into the air and form round spore cases at the tips. These spore cases are called *sporangia* (spoh RAN jee uh). **Figure 5** shows some magnified sporangia. When the sporangia break open, many tiny spores are released into the air. New fungi will develop from these spores if they land in an area with good growing conditions.

mold a fungus that looks like wool or cotton

Threadlike fungi can also reproduce sexually. Threadlike fungi reproduce sexually when a hypha from one individual joins with a hypha from another individual. The hyphae grow into specialized sporangia that can survive times of cold or little water. When conditions improve, these specialized sporangia release spores that can grow into new fungi.

Reading Check **Describe two ways that threadlike fungi can reproduce.**

Quick Lab

Moldy Bread

1. Dampen a **slice of bread** with a **few drops of water,** and then seal it in a **plastic bag** for 1 week.
2. Draw a picture of the bread in the plastic bag.
3. Predict what you think will happen during the week. Will the bread get moldy?
4. After the week has passed, check on the bread in the plastic bag. Compare it with your original drawing. What happened? Were your predictions correct?
5. With a partner, discuss where you think mold spores come from and how they grow.

Figure 5 *Each of the round sporangia contains thousands of spores.*

Figure 6 *Morels are only part of a larger fungus. They are the sexual reproductive part of a fungus that lives under the soil.*

Sac Fungi

Sac fungi are the largest group of fungi. Sac fungi include yeasts, powdery mildews, truffles, and morels. Some morels are shown in **Figure 6.**

Sac fungi can reproduce both asexually and sexually during their life cycles. Most of the time, they use asexual reproduction. When they reproduce sexually, they form a sac called an *ascus*. This sac gives the sac fungi their name. Sexually produced spores develop within the ascus.

Figure 7 *Yeasts reproduce by budding. A round scar forms where a bud breaks off from a parent cell.*

Most sac fungi are made of many cells. However, *yeasts* are single-celled sac fungi. When yeasts reproduce asexually, they use a process called *budding*. In budding, a new cell pinches off from an existing cell. **Figure 7** shows a yeast that is budding. Yeasts are the only fungi that reproduce by budding.

Some sac fungi are very useful to humans. For example, yeasts are used in making bread and alcohol. Yeasts use sugar as food and produce carbon dioxide gas and alcohol as waste. Trapped bubbles of carbon dioxide cause bread dough to rise. This process is what makes bread light and fluffy. Other sac fungi are sources of antibiotics and vitamins. And some sac fungi, such as truffles and morels, are prized as human foods.

Not all sac fungi are helpful. In fact, many sac fungi are parasites. Some cause plant diseases, such as chestnut blight and Dutch elm disease. The effects of Dutch elm disease are shown in **Figure 8.**

Figure 8 *Dutch elm disease is a fungal disease that has killed millions of elm trees.*

Club Fungi

The umbrella-shaped mushrooms are the most familiar fungi. Mushrooms belong to a group of fungi called *club fungi*. This group gets its name from structures that the fungi grow during reproduction. Club fungi reproduce sexually. During reproduction, they grow special hyphae that form clublike structures. These structures are called *basidia* (buh SID ee uh), the Greek word for "clubs." Sexual spores develop on the basidia.

When you think of a mushroom, you probably picture only the spore-producing, above-ground part of the organism. But most of the organism is underground. The mass of hyphae from which mushrooms are produced may grow 35 m across. That's about as long as 18 adults lying head to toe! Mushrooms usually grow at the edges of the mass of hyphae. As a result, mushrooms often appear in circles, as shown in **Figure 9.**

Figure 9 *A ring of mushrooms can appear overnight. In European folk legends, these were known as "fairy rings."*

The most familiar mushrooms are known as *gill fungi*. The basidia of these mushrooms develop in structures called *gills,* under the mushroom cap. Some varieties are grown commercially and sold in supermarkets. However, not all gill fungi are edible. For example, the white destroying angel is a very poisonous fungus. Simply a taste of this mushroom can be fatal. See if you can pick out the poisonous fungus in **Figure 10.**

Reading Check **What part of a club fungus grows above the ground?**

Quick Lab

Observe a Mushroom

1. Identify the stalk, cap, and gills on a **mushroom** that your teacher has provided.
2. Carefully twist or cut off the cap, and cut it open with a **plastic knife.** Use a **magnifying lens** to observe the gills. Look for spores.
3. Use the magnifying lens to observe the other parts of the mushroom. The mycelium begins at the bottom of the stalk. Try to find individual hyphae.
4. Sketch the mushroom, and label the parts.

Figure 10 *Many poisonous mushrooms look just like edible ones. Never eat a mushroom from the wild unless a professional identifies it in person.*

Figure 11 *Bracket fungi look like shelves on trees. The underside of the bracket contains spores.*

Figure 12 *This corn is infected with a club fungus called* smut.

Nonmushroom Club Fungi

Mushrooms are not the only club fungi. Bracket fungi, puffballs, smuts, and rusts are also club fungi. Bracket fungi grow outward from wood and form small shelves or brackets, as shown in **Figure 11.** Smuts and rusts are common plant parasites. They often attack crops such as corn and wheat. The corn in **Figure 12** has been infected with a smut.

Imperfect Fungi

The *imperfect fungi* group includes all of the species of fungi that do not quite fit in the other groups. These fungi do not reproduce sexually. Most are parasites that cause diseases in plants and animals. One common human disease caused by these fungi is athlete's foot, a skin disease. Another fungus from this group produces a poison called *aflatoxin* (AF luh TAHKS in), which can cause cancer.

Some imperfect fungi are useful. *Penicillium,* shown in **Figure 13,** is the source of the antibiotic penicillin. Other imperfect fungi are also used to produce medicines. Some imperfect fungi are used to produce cheeses, soy sauce, and the citric acid used in cola drinks.

Figure 13 *The fungus* Penicillium *produces a substance that kills certain bacteria.*

CONNECTION TO Language Arts

Beatrix Potter Beatrix Potter (1866–1943) is best known for writing children's stories, such as *The Tale of Peter Rabbit* and *The Tale of Two Bad Mice*. Potter lived and worked in England and had a scholarly interest in fungi. She was a shy person, and she was not taken seriously by fungi scholars of her time. But today, she is widely respected as a mycologist (a scientist who studies fungi). She wrote many valuable papers about fungi and made detailed drawings of more than 270 fungi. Research Potter's life, and present a report to your class.

ACTIVITY

▲ Wolf lichen

British soldier lichen ▶

▼ Christmas lichen

Figure 14 *These are some of the many types of lichens.*

Lichens

A **lichen** (LIE kuhn) is a combination of a fungus and an alga that grow together. The alga actually lives inside the protective walls of the fungus. The resulting organism is different from either organism growing alone. The lichen is a result of a mutualistic relationship. But the merging of the two organisms to form a lichen is so complete that scientists give lichens their own scientific names. **Figure 14** shows some examples of lichens.

Unlike fungi, lichens are producers. The algae in the lichens produce food through photosynthesis. And unlike algae, lichens can keep from drying out. The protective walls of the fungi keep water inside the lichens. Lichens are found in almost every type of land environment. They can even grow in dry environments, such as deserts, and cold environments, such as the Arctic.

Because lichens need only air, light, and minerals to grow, they can grow on rocks. As lichens grow, the changes that they make to their surroundings allow other organisms to live there, too. For example, lichens make acids that break down rocks and cause cracks. When bits of rock and dead lichens fill the cracks, soil is made. Other organisms then grow in this soil.

Lichens absorb water and minerals from the air. As a result, lichens are easily affected by air pollution. So, the presence or absence of lichens can be a good measure of air quality in an area.

lichen a mass of fungal and algal cells that grow together in a symbiotic relationship and that are usually found on rocks or trees

Reading Check **How can lichens affect rocks?**

SECTION Review

Summary

- Fungi can be consumers, decomposers, or parasites, or they can live in mutualistic relationships with other organisms.
- Most fungi are made up of chains of cells called *hyphae*. Many hyphae join together to form a mycelium.
- The four main groups of fungi are threadlike fungi, sac fungi, club fungi, and imperfect fungi.
- Threadlike fungi are primarily decomposers that form sporangia containing spores.
- During sexual reproduction, sac fungi form little sacs in which sexual spores develop.
- Club fungi form structures called *basidia* during sexual reproduction.
- The imperfect fungi include all of the species that do not quite fit in the other groups. Many are parasites that reproduce only by asexual reproduction.
- A lichen is a combination of a specific fungus and a specific alga. The lichen is different from either organism growing alone.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *spore* and *mold*.

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

2. *fungus* and *lichen*

3. *hyphae* and *mycelium*

Understanding Key Ideas

4. Which of the following statements about fungi is true?

a. All fungi are eukaryotic.
b. All fungi are decomposers.
c. All fungi reproduce by sexual reproduction.
d. All fungi are producers.

5. What are the four main groups of fungi? Give a characteristic of each group.

6. How are fungi able to withstand periods of cold or drought?

Critical Thinking

7. Analyzing Processes Many fungi are decomposers. Imagine what would happen to the natural world if decomposers no longer existed. Write a description of how a lack of decomposers might affect the processes of nature.

8. Identifying Relationships Explain how two organisms make up a lichen.

Interpreting Graphics

Use the photo below to answer the questions that follow.

9. To which group of fungi does this organism belong? How can you be sure?

10. What part of the organism is shown in this photo? What part is not shown? Explain.

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For a variety of links related to this chapter, go to www.scilinks.org

Topics: Fungi; Lichens
SciLinks codes: HSM0628; HSM0871

Skills Practice Lab

There's a Fungus Among Us!

Fungi share many characteristics with plants. For example, most fungi live on land and cannot move from place to place. But fungi have several unique features that suggest that they are not closely related to any other kingdom of organisms. In this activity, you will observe some of the unique structures of a mushroom, a member of the kingdom Fungi.

OBJECTIVES

Examine the parts of a mushroom.

Describe your observations of the mushroom.

MATERIALS

- gloves, protective
- incubator
- microscope or magnifying lens
- mushroom
- paper, white (2 sheets)
- Petri dish with fruit-juice agar plate
- tape, masking
- tape, transparent
- tweezers

SAFETY

Procedure

1. Put on your safety goggles and gloves. Get a mushroom from your teacher. Carefully pull the cap of the mushroom from the stem.
2. Using tweezers, remove one of the gills from the underside of the cap. Place the gill on a sheet of white paper.
3. Place the mushroom cap gill-side down on the other sheet of paper. Use masking tape to keep the mushroom cap in place. Place the paper aside for at least 24 hours.
4. Use tweezers to take several 1 cm pieces from the stem, and place these pieces in your Petri dish. Record the appearance of the plate by drawing the plate in a notebook. Cover the Petri dish, and incubate it overnight.
5. Use tweezers to gently pull the remaining mushroom stem apart lengthwise. The individual fibers or strings that you see are the hyphae, which form the structure of the fungus. Place a thin strand on the same piece of paper on which you placed the gill that you removed from the cap.
6. Use a magnifying lens or microscope to observe the gill and the stem hyphae.
7. After at least 24 hours, record any changes that occurred in the Petri dish.
8. Carefully remove the mushroom cap from the paper. Place a piece of transparent tape over the print left behind on the paper. Record your observations.

Analyze the Results

1. **Describing Events** Describe the structures that you saw on the gill and hyphae.
2. **Explaining Events** What makes up the print that was left on the white paper?
3. **Examining Data** Describe the structures on the mushroom gill. Explain how these structures are connected to the print.
4. **Analyzing Data** Compare your original drawing of the Petri dish to your observations of the dish after leaving it for 24 hours.

Draw Conclusions

5. **Evaluating Results** Explain how the changes that occurred in your Petri dish are related to methods of fungal reproduction.

Applying Your Data

Fungi such as mushrooms and yeast are used in cooking and baking in many parts of the world. Bread is a staple food in many cultures. There are thousands of kinds of bread. Conduct library and Internet research on how yeast makes bread rise. Find a bread recipe, and show how the recipe involves the care and feeding of yeast. Ask an adult to help you bake a loaf of bread to share with your class during your presentation.

Chapter Review

USING KEY TERMS

1. In your own words, write a definition for each of the following terms: *mycelium, lichen,* and *heterotroph.*

2. Use the following terms in the same sentence: *protists, algae,* and *phytoplankton.*

3. Use the following terms in the same sentence: *spore* and *mold.*

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

4. *fungus* and *hypha*

5. *parasite* and *host*

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Protist producers include
   - **a.** euglenoids and ciliates.
   - **b.** lichens and zooflagellates.
   - **c.** spore-forming protists and smuts.
   - **d.** dinoflagellates and diatoms.

7. Protists can be
   - **a.** parasites or decomposers.
   - **b.** made of chains of cells called *hyphae.*
   - **c.** divided into four major groups.
   - **d.** only parasites.

8. A euglenoid has
   - **a.** a micronucleus.
   - **b.** pseudopodia.
   - **c.** two flagella.
   - **d.** cilia.

9. Which statement about fungi is true?
   - **a.** Fungi are producers.
   - **b.** Fungi cannot eat or engulf food.
   - **c.** Fungi are found only in the soil.
   - **d.** Fungi are primarily single celled.

10. A lichen is made up of
    - **a.** a fungus and a funguslike protist that live together.
    - **b.** an alga and a fungus that live together.
    - **c.** two kinds of fungi that live together.
    - **d.** an alga and a funguslike protist that live together.

11. Heterotrophic protists that can move
    - **a.** are also known as *protozoans.*
    - **b.** include amoebas and paramecia.
    - **c.** may be either free living or parasitic.
    - **d.** All of the above

Short Answer

12. How are fungi helpful to humans?

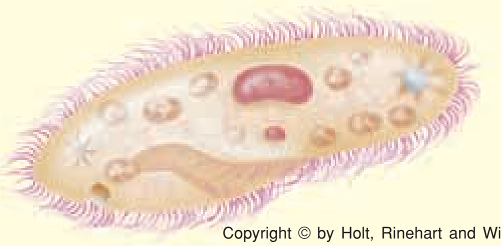
13. What is the function of cilia in a paramecium?

14. How are fungi different from protists that get food as decomposers?

15. How are slime molds and amoebas similar?

16. What is a contractile vacuole?

17. Compare how *Paramecium, Plasmodium vivax,* and *Euglena* reproduce.



18 Compare how phytoplankton, amoebas, and *Giardia lamblia* get food.

19 Explain how protists differ from other organisms.

20 Give an example of where you might find each of the following fungi: threadlike fungi, sac fungi, club fungi, and imperfect fungi.

CRITICAL THINKING

21 **Concept Mapping** Use the following terms to create a concept map: *yeast, basidia, threadlike fungi, mushrooms, fungi, bread mold, ascus,* and *club fungi*.

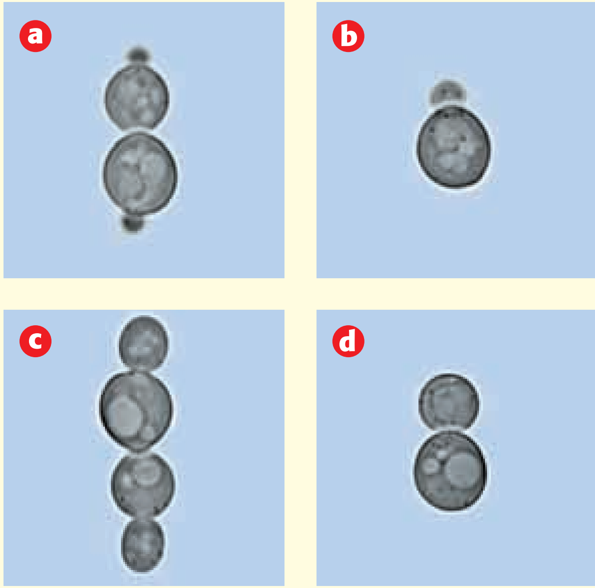
22 **Applying Concepts** Why do you think bread turns moldy less quickly when it is kept in a refrigerator than when it is kept at room temperature?

23 **Making Inferences** Some protozoans, such as radiolarians and foraminiferans, have shells around their bodies. How might these shells be helpful to the protists that live in them?

24 **Predicting Consequences** Suppose a forest where many threadlike fungi live goes through a very dry summer and fall and then a very cold winter. How could this extreme weather affect the reproductive patterns of these fungi?

INTERPRETING GRAPHICS

Use the pictures of fungi below to answer the questions that follow.



25 What kind of fungus is shown here?

26 What cellular process is shown in these pictures?

27 Which picture was taken first? Which was taken last? Arrange the pictures in order.

28 Which is the original parent cell? How do you know?

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 For centuries, people living near Cueva de Villa Luz (the Cave of the Lighted House) in Mexico have walked past slimy globs that drip from the cave's ceiling without thinking much about them. When scientists decided to analyze these slime balls, they discovered that the formations are home to billions of microscopic organisms! Scientists nicknamed these colonies "snot-tites" because the colonies <u>resemble</u> mucus. Actually, the "snot-tites" are a mixture of fungi and bacteria.

1. In the passage, what does *resemble* mean?

A to look like
B to feel like
C to smell like
D to sound like

2. Which of the following statements is a fact according to the passage?

F Many kinds of organisms live in Cueva de Villa Luz.
G The people of Mexico ignore the snot-tites.
H Scientists found no explanation for the slime balls that are in Cueva de Villa Luz.
I Cueva de Villa Luz's ceiling is dripping with microscopic organisms.

3. The microscopic organisms discovered by scientists

A are fungi.
B are bacteria.
C are a mixture of fungi and bacteria.
D are a mixture of protists and fungi.

Passage 2 Between 1845 and 1852, Ireland lost one-third of its population. In 1846, a disease swept through the potato fields of Ireland. In just a few weeks, it destroyed almost the entire crop of potatoes. Because the Irish depended on potatoes for food, people were dying of starvation each day. About 2 million people fled the country to find a place to live where they could find enough food. The cause of all of these deaths and this devastation was a simple organism. The disease was caused by a water mold, which is a kind of protist.

1. What caused the population of Ireland to decline between 1845 and 1852?

A a fungus
B a water mold
C a potato
D poisonous potatoes

2. According to the passage, why did the population of Ireland decline?

F A disease swept through the people of Ireland.
G Some people died of starvation, and others fled the country.
H A simple organism infected the people of Ireland.
I When people ate potatoes, they became sick.

3. Which of the following statements is a fact according to the passage?

A People in Ireland have always depended on potatoes for food.
B Protists are parasitic and cause disease.
C About 2 million people fled Ireland between 1845 and 1852.
D Food is more readily available in the United States than it is in Ireland.

INTERPRETING GRAPHICS

The table below shows the number of species in different phyla of protists. Use this table to answer the questions that follow.

Protist Phyla

Phylum	Number of Species
Rhizopoda	300
Foraminifera	300
Chlorophyta	7,000
Rhodophyta	4,000
Phaeophyta	1,500
Bacillariophyta	11,500
Dinoflagellata	2,100
Euglenophyta	1,000
Kinetoplastida	3,000
Ciliophora	8,000
Acrasiomycota	70
Myxomycota	800
Oomycota	580
Apicomplexa	3,900

1. Which phylum has the largest number of species?

A Rhizopoda
B Bacillariophyta
C Ciliophora
D Euglenophyta

2. Which phylum has the smallest number of species?

F Acrasiomycota
G Rhizopoda
H Chlorophyta
I Bacillariophyta

3. If the total number of species of protists is 43,000, what percentage of species are in the phylum Bacillariophyta?

A 0.27%
B 3.7%
C 27%
D 374%

4. If the total number of species of protists is 43,000, what percentage of species are in the phylum Rhizopoda?

F 0.7%
G 1.4%
H 7%
I 143%

MATH

Read each question below, and choose the best answer.

1. Beth had $300 in her savings account when she started her summer job as an assistant to a commercial mushroom grower. If she put $25 into her savings account each month, which equation could be used to find n, the number of months it took Beth to increase her savings to $1,000?

A $1{,}000 = 300 + n$
B $1{,}000 = 25n$
C $1{,}000 = 25n + 300$
D $1{,}000 = 300n + 25$

2. If you want to determine whether a polygon-shaped protist has the shape of a pentagon, which of the following pieces of information do you need to know?

F the area
G the length of the diagonal
H the number of sides
I the number of faces

3. Marcus had an average score of 90% on two biology tests about protists. If his first test score was 96%, which score did he receive on the second test?

A 45%
B 84%
C 90%
D 102%

Standardized Test Preparation

Science in Action

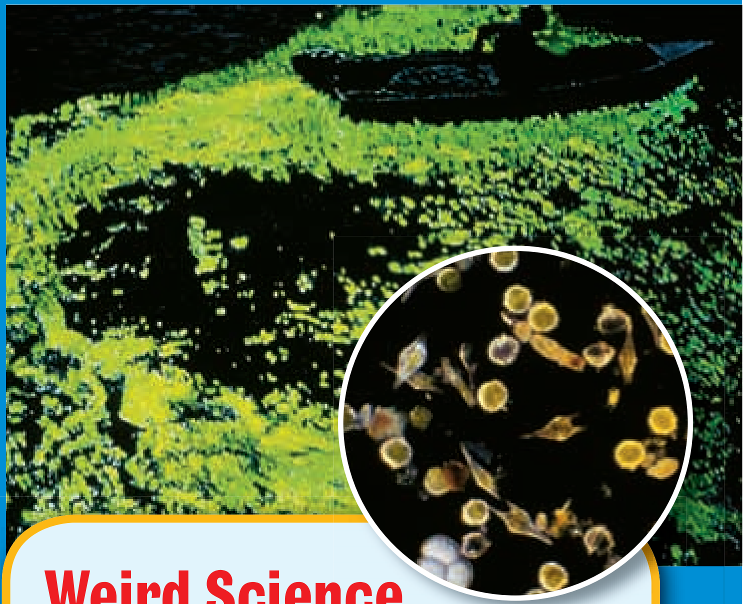
Science, Technology, and Society

Algae Ice Cream

If someone offered you a bowl of algae ice cream, would you eat it? Would you eat algae pudding? These foods may not sound appetizing, but algae are a central ingredient in these foods. You eat many kinds of algae every day. Parts of brown algae help thicken ice cream and other dairy products. Red algae help keep breads and pastries from drying out. They are also used in chocolate, milk, eggnog, ice cream, sherbet, instant pudding, and frosting. Green algae contain a pigment that is used as yellow and orange food coloring. Algae are all around you!

Social Studies ACTIVITY

Food products are not the only products that use protist producers. In groups, research how people take advantage of the shiny shells of diatoms. Then, present your findings to the class.



Weird Science

Glowing Protists

As your kayak drifts silently through the night, it leaves a trail of swirling green light in the water behind it. You jump in the water to swim, and your hands turn into glowing underwater comets, which leave sparkling trails that slowly fade away. This may sound like a dream, but it happens every night for swimmers at Mosquito Bay on the island of Vieques in Puerto Rico. The source of this green glow is a protist. The waters of this bay contain millions of dinoflagellates that glow when the water around them is disturbed.

The species of dinoflagellates in Mosquito Bay is *Pyrodinium bahamense,* which means "whirling fire." These spherical single-celled protists are covered by armored plates. Each individual has two flagella that spin it through the water. The light is produced by a chemical reaction that is similar to the reaction in fireflies.

Math ACTIVITY

Living in every gallon of water in Mosquito Bay are 750,000 dinoflagellates. Suppose you took a gallon of water from this bay and dumped it into a bathtub full of 6 gal of fresh water that didn't contain any dinoflagellates. Then, you mixed up the water and turned out the lights to see if the bathtub would glow in the dark. How many dinoflagellates would be in each gallon of water in the bathtub after you mixed up the water?

People in Science

Terrie Taylor

Fighting Malaria Malaria claims about 2 million victims each year. A person gets malaria when the blood is infected by protists from the genus *Plasmodium*. Dr. Terrie Taylor of Michigan State University's College of Osteopathic Medicine has devoted her life to malaria research. Since 1987, Dr. Taylor has spent six months of every year in Malawi, a small African country in which malaria is widespread.

When Dr. Taylor first traveled to Malawi, she did not have a particular interest in malaria. However, she quickly started to realize that the majority of her patients were infected with the deadly disease. The patients who were suffering the most were children. For every 100 children infected with malaria and treated by Dr. Taylor, between 20 and 25 would die from a malaria-induced coma. When a malaria coma starts, the patient becomes confused and sleepy. The patient then falls into a coma, which may lead to death. Dr. Taylor worked with other doctors at the hospital to develop a coma scale so that doctors could have a standardized way to assess patients moving toward coma. This scale is now used around the world.

Dr. Taylor wanted to find out why malaria victims fell into a coma. She took blood samples from malaria patients. She realized that severe malaria often led to a rapid fall in the patient's blood-sugar level. Dr. Taylor hypothesizes that the drop in blood sugar is related to the fact that the protists that cause malaria primarily infect a person's liver. The liver is the organ responsible for releasing sugar into the blood. Dr. Taylor has used this information to create a new treatment. Whenever she treats children who have a severe case of malaria, she gives them glucose, the type of sugar that is found in the bloodstream. This simple treatment has already saved hundreds of lives!

Language Arts ACTiViTy

The word *malaria* is a combination of two words. *Mala* means "bad," and *aria* means "air." Why do you think that people would use these words to describe the disease? Note that people did not realize that malaria was transmitted to people by mosquitoes until about 1899.

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Current Science

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21

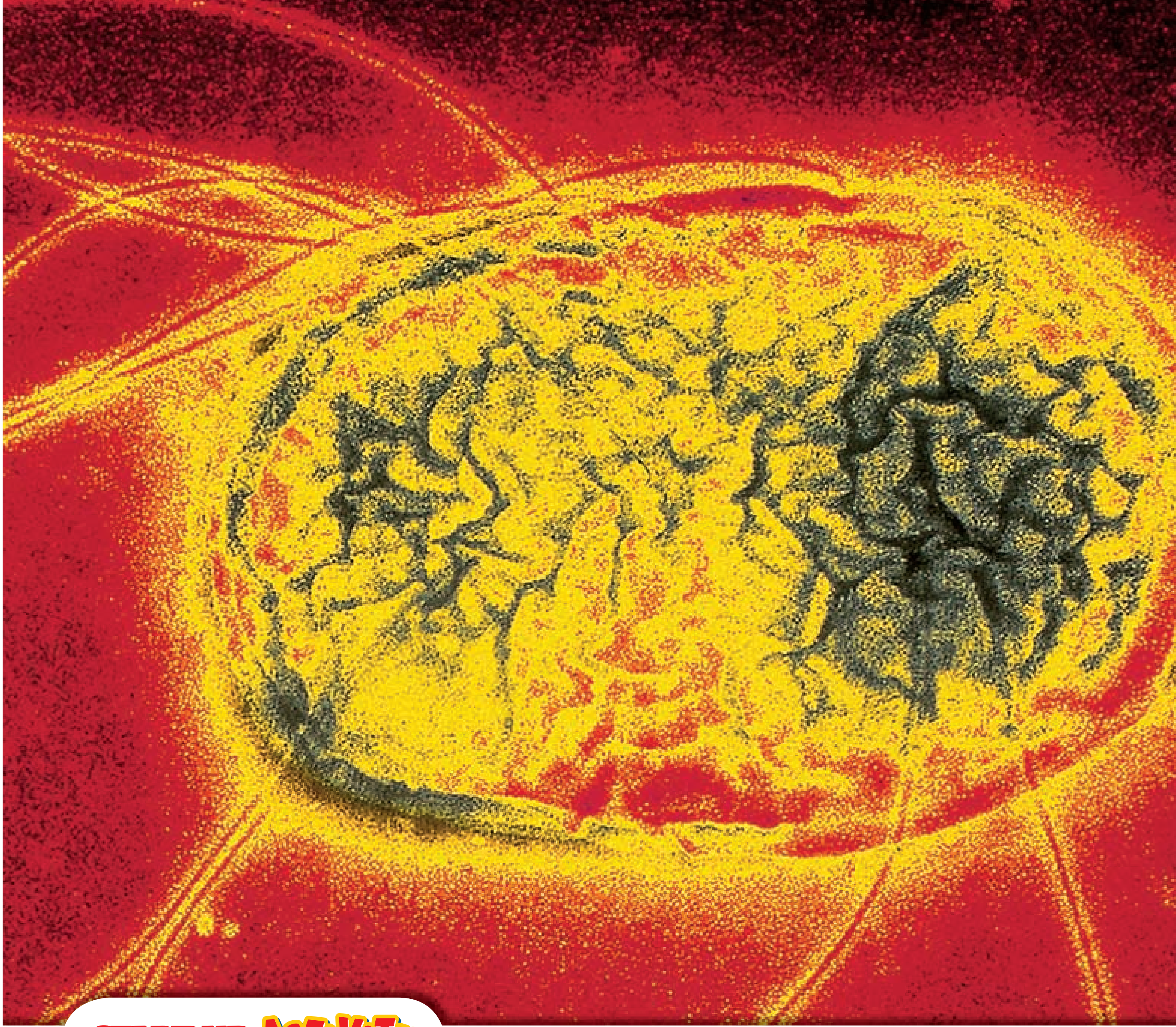
Bacteria, Viruses, and Disease

About the PHOTO

Bacteria are everywhere. Some provide us with medicines, and some make foods we eat. Others, such as the one pictured here, can cause illness. This bacterium is a kind of *Salmonella,* and it can cause food poisoning. *Salmonella* can live inside chickens and other birds. Cooking eggs and chicken properly helps make sure that you don't get sick from *Salmonella*.

PRE-READING ACTIVITY

FOLDNOTES **Double Door** Before you read the chapter, create the FoldNote entitled "Double Door" described in the **Study Skills** section of the Appendix. Write "Bacteria" on one flap of the double door and "Viruses" on the other flap. As you read the chapter, compare the two topics, and write characteristics of each on the inside of the appropriate flap.



START-UP ACTIVITY

Our Constant Companions

Bacteria are in the soil, in the air, and even inside your body. When grown in a laboratory, microscopic bacteria form colonies that you can see. In this activity, you will observe some of the bacteria that share your world.

Procedure

1. Get **three plastic Petri dishes containing nutrient agar** from your teacher. Label one dish "Hand," another "Breath," and another "Soil."
2. Wipe your finger across the agar in the dish labeled "Hand." Breathe into the dish labeled "Breath." Place a **small amount of soil** in the dish labeled "Soil."
3. Secure the Petri dish lids with **transparent tape.** Wash your hands. Keep the dishes upside down in a warm, dark place for about one week. **Caution:** Do not open the Petri dishes after they are sealed.
4. Observe the Petri dishes each day. What do you see? Record your observations.

Analysis

1. How does the appearance of the colonies growing on the agar in each dish differ? What do bacterial colonies look like?
2. Which source caused the most bacterial growth—your hand, your breath, or the soil? Why do you think this source caused the most growth?

SECTION 1

Bacteria

How many bacteria are in a handful of soil? Would you believe that a single gram of soil—which is about the mass of a pencil eraser—may have more than 2.5 billion bacteria? A handful of soil may contain trillions of bacteria!

READING WARM-UP

Objectives

- Describe the characteristics of bacteria.
- Explain how bacteria reproduce.
- Compare and contrast eubacteria and archaebacteria.

Terms to Learn

prokaryote
binary fission
endospore

READING STRATEGY

Prediction Guide Before reading this section, predict whether each of the following statements is true or false:
- There are only a few kinds of bacteria.
- Most bacteria are too small to see.

There are more types of bacteria on Earth than all other living things combined. Most bacteria are too small to be seen without a microscope. But not all bacteria are the same size. In fact, the largest known bacteria are 1,000 times larger than the average bacterium. One of these giant bacteria was first found inside a surgeonfish and is shown in **Figure 1.**

Characteristics of Bacteria

All living things fit into one of six kingdoms: Protista, Plantae, Fungi, Animalia, Eubacteria, or Archaebacteria. Bacteria make up the kingdoms Eubacteria (YOO bak TIR ee uh) and Archaebacteria (AHR kee bak TIR ee uh). These two kingdoms contain the oldest forms of life on Earth. All bacteria are single-celled organisms. Bacteria are usually one of three main shapes: bacilli, cocci, or spirilla.

Reading Check **What two kingdoms are made up of bacteria?** (*See the Appendix for answers to Reading Checks.*)

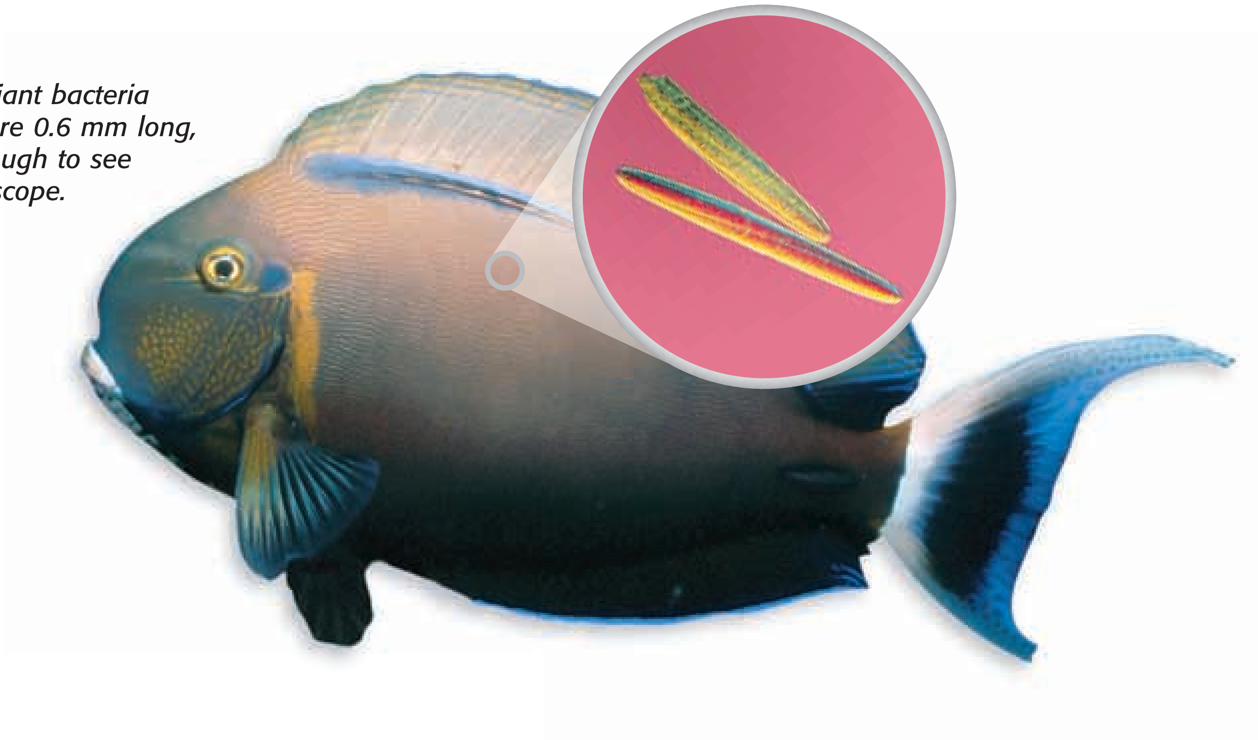
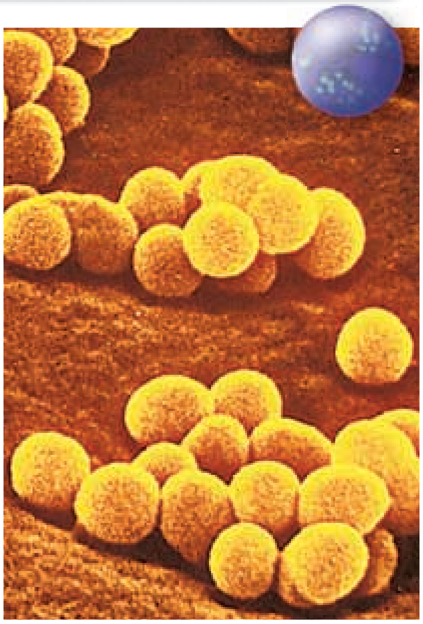


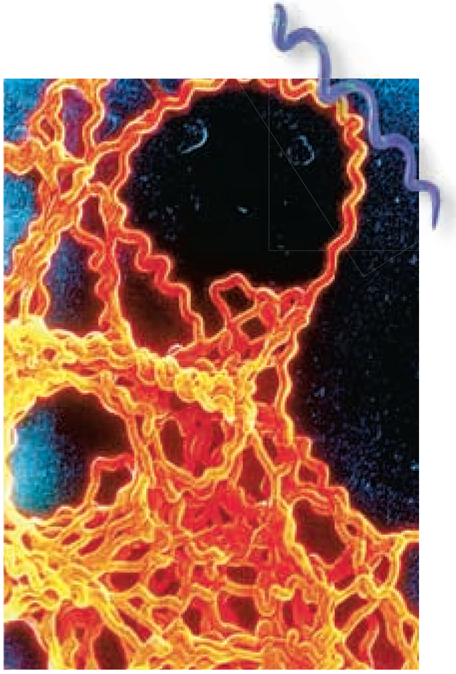
Figure 1 *The giant bacteria inside this fish are 0.6 mm long, which is big enough to see without a microscope.*

Figure 2 **The Most Common Shapes of Bacteria**

Bacilli (buh SIL IE) are rod shaped. They have a large surface area, which helps them take in nutrients. But a large surface area can cause them to dry out easily.



Cocci (KAHK SIE) are spherical. They do not dry out as quickly as rod-shaped bacteria.



Spirilla (spie RIL uh) are long and spiral shaped. They use flagella at both ends to move like a corkscrew.

The Shape of Bacteria

Most bacteria have a rigid cell wall that gives them their shape. **Figure 2** shows the three most common shapes of bacteria. Bacilli (buh SIL IE) are rod shaped. Cocci (KAHK SIE) are spherical. Spirilla (spie RIL uh) are long and spiral shaped. Each shape helps bacteria in a different way.

Some bacteria have hairlike parts called *flagella* (fluh JEL uh) that help them move around. Flagella spin to push a bacterium through water or other liquids.

prokaryote an organism that consists of a single cell that does not have a nucleus

No Nucleus!

All bacteria are single-celled organisms that do not have a nucleus. An organism that does not have a nucleus is called a **prokaryote** (proh KAR ee OHT). A prokaryote is able to move, get energy, and reproduce like cells that have a nucleus, which are called *eukaryotes* (yoo KAR ee OHTZ).

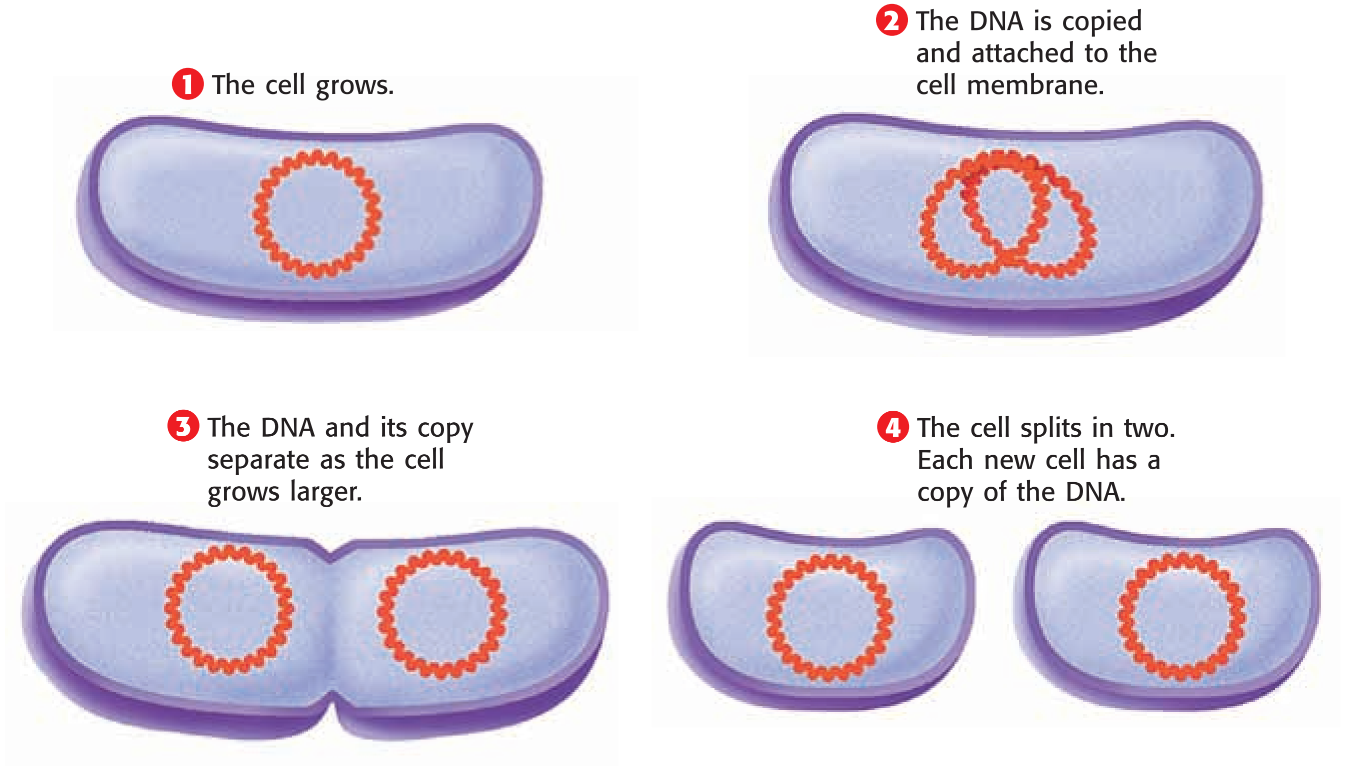
Prokaryotes function as independent organisms. Some bacteria stick together to form strands or films, but each bacterium is still functioning as a single organism. Most prokaryotes are much simpler and smaller than eukaryotes. Prokaryotes also reproduce differently than eukaryotes do.

Quick Lab

Spying on Spirilla

1. Using a **microscope,** observe prepared **slides of bacteria.** Draw each type of bacteria you see.
2. What different shapes do you see? What are these shapes called?

Figure 3 **Binary Fission**



Bacterial Reproduction

binary fission a form of asexual reproduction in single-celled organisms by which one cell divides into two cells of the same size

Bacteria reproduce by the process shown in **Figure 3.** This process is called binary fission (BIE nuh ree FISH uhn). **Binary fission** is reproduction in which one single-celled organism splits into two single-celled organisms.

Prokaryotes have no nucleus, so their DNA is not surrounded by a membrane. The DNA of bacteria is in circular loops. In the first step of binary fission, the cell's DNA is copied. The DNA and its copy then bind to different places on the inside of the cell membrane. As the cell and its membrane grow bigger, the loops of DNA separate. Finally, when the cell is about double its original size, the membrane pinches inward as shown in **Figure 4.** A new cell wall forms and separates the two new cells. Each new cell has one exact copy of the parent cell's DNA.

Reading Check **What is binary fission?**

Figure 4 *This bacterium is about to complete binary fission.*

Endospores

Most species of bacteria do well in warm, moist places. In dry or cold surroundings, some species of bacteria will die. In these conditions, other bacteria become inactive and form endospores (EN doh SPAWRZ). An **endospore** contains genetic material and proteins and is covered by a thick, protective coat. Many endospores can survive in hot, cold, and very dry places. When conditions improve, the endospores break open, and the bacteria become active again. Scientists found endospores inside an insect that was preserved in amber for 30 million years. When the endospores were moistened in a laboratory, bacteria began to grow! A similar piece of amber can be seen in **Figure 5.**

Figure 5 *Endospores found in a preserved insect like this one showed scientists that bacteria can survive for millions of years.*

Kingdom Eubacteria

Most bacteria are eubacteria. The kingdom Eubacteria has more individuals than all of the other five kingdoms combined. Scientists think that eubacteria have lived on Earth for more than 3.5 billion years.

endospore a thick-walled protective spore that forms inside a bacterial cell and resists harsh conditions

Eubacteria Classification

Eubacteria are classified by the way they get food. Most eubacteria, such as those breaking down the leaf in **Figure 6,** are consumers. Consumers get their food by eating other organisms. Many bacteria are decomposers, which feed on dead organisms. Other consumer bacteria live in or on the body of another organism. Eubacteria that make their own food are called *producers*. Like plants, producer bacteria use the energy from sunlight to make food. These bacteria are often green.

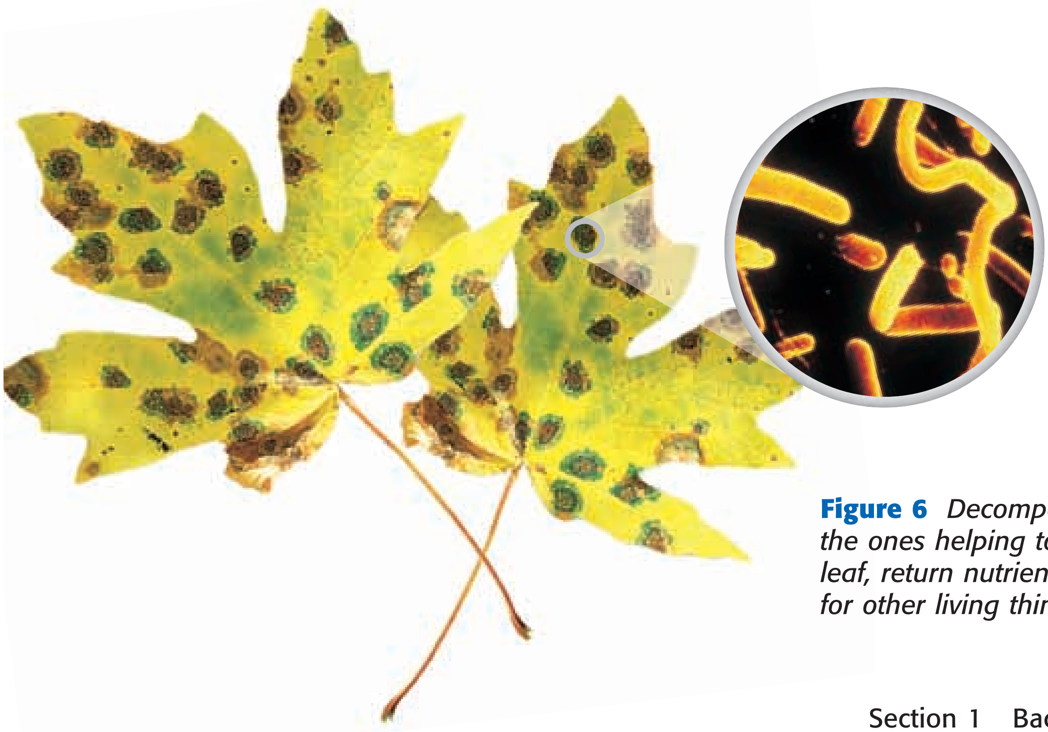


Figure 6 *Decomposers, such as the ones helping to decay this leaf, return nutrients to the soil for other living things to use.*

Cyanobacteria

Cyanobacteria (SIE uh noh bak TIR ee uh) are producers. Cyanobacteria usually live in water. These bacteria contain the green pigment chlorophyll. Chlorophyll is important to photosynthesis (the process of making food from the energy in sunlight). Many cyanobacteria have other pigments as well. Some have a blue pigment that helps in photosynthesis. This pigment gives those cyanobacteria a blue tint. Other cyanobacteria have red pigment. Flamingos get their pink color from eating red cyanobacteria.

Some scientists think that billions of years ago, bacteria similar to cyanobacteria began to live inside larger cells. According to this theory, the bacteria made food, and the cells provided protection. This combination may have given rise to the first plants on Earth.

CONNECTION TO Language Arts

Colorful Names *Cyanobacteria* means "blue bacteria." Many other names also refer to colors. You might not recognize these colors because the words for the colors are in another language. Look at the list of Greek color words below. Write down two English words that have one of the color roots in them. (Hint: Many words have the color as the first part of the word.)

melano = black

chloro = green

erythro = red

leuko = white

Kingdom Archaebacteria

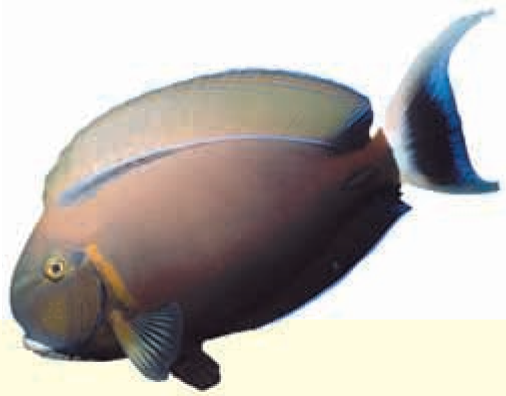
The three main types of archaebacteria are *heat lovers, salt lovers,* and *methane makers*. Heat lovers live in ocean vents and hot springs. They live in very hot water, usually from 60°C to 80°C, but they can survive temperatures of more than 250°C. Salt lovers live in environments that have high levels of salt, such as the Dead Sea and Great Salt Lake. Methane makers give off methane gas and live in swamps and animal intestines. **Figure 7** shows one type of methane maker found in the mud of swamps.

Figure 7 *These bacteria are methane makers. This micrograph shows two bacteria sliced across their narrow side and a dividing bacterium sliced lengthwise.*

Harsh Environments

Archaebacteria often live where nothing else can. Most archaebacteria prefer environments where there is little or no oxygen. Scientists have found them in the hot springs at Yellowstone National Park and beneath 430 m of ice in Antarctica. Archaebacteria have even been found living 8 km below the Earth's surface! Even though they are often found in these harsh environments, many archaebacteria can also be found in moderate environments in Earth's oceans.

Archaebacteria are very different from eubacteria. Not all archaebacteria have cell walls. When they do have them, the cell walls are chemically different from those of eubacteria.



SECTION Review

Summary

- Bacteria are single-celled organisms that are the smallest and simplest living things on Earth.
- Most bacteria have a rigid cell wall that gives them their shape. The main shapes of bacteria are rod shaped (bacilli), spherical (cocci), and spiral shaped (spirilla).
- Bacteria reproduce by binary fission. In binary fission, one cell divides into two cells.
- Eubacteria have cell walls and are either producers (bacteria that make their own food) or consumers (bacteria that get food from other organisms).
- Archaebacteria often live in harsh environments.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. Bacteria are eukaryotes.
2. Bacteria reproduce by primary fission.

Understanding Key Ideas

3. The structure that helps some bacteria survive harsh conditions is called a(n)
   a. endospore.
   b. shell.
   c. exospore.
   d. exoskeleton.
4. How are eubacteria and archaebacteria different?
5. Draw and label the four stages of binary fission.
6. Describe one advantage of each shape of bacteria.
7. What two things do producer bacteria and plants have in common?

Math Skills

8. An ounce (oz) is equal to about 28 g. If 1 g of soil contains 2.5 billion bacteria, how many bacteria are in 1 oz of soil?

Critical Thinking

9. **Applying Concepts** Many bacteria cannot reproduce in cooler temperatures and are destroyed at high temperatures. How do humans take advantage of this fact when preparing and storing food?
10. **Making Comparisons** Scientists are studying cold and dry environments on Earth that are like the environment on Mars. What kind of bacteria do you think they might find in these environments on Earth? Explain.
11. **Forming Hypotheses** You are studying a lake and the bacteria that live in it. What conditions of the lake would you measure to form a hypothesis about what kind of bacteria may live there?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Bacteria; Archaebacteria
SciLinks code: HSM0133; HSM0091

SECTION 2

Bacteria's Role in the World

Have you ever had strep throat or a cavity in your tooth? Did you know that both are caused by bacteria?

READING WARM-UP

Objectives

- Explain how life on Earth depends on bacteria.
- List three ways bacteria are useful to people.
- Describe two ways in which bacteria can be harmful to people.

Terms to Learn

bioremediation
antibiotic
pathogenic bacteria

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Bacteria live in our water, our food, and our bodies. Much of what we know about bacteria was learned by scientists fighting bacterial diseases. But of the thousands of types of bacteria, only a few hundred cause disease. Many bacteria do things that are important and even helpful to us.

Good for the Environment

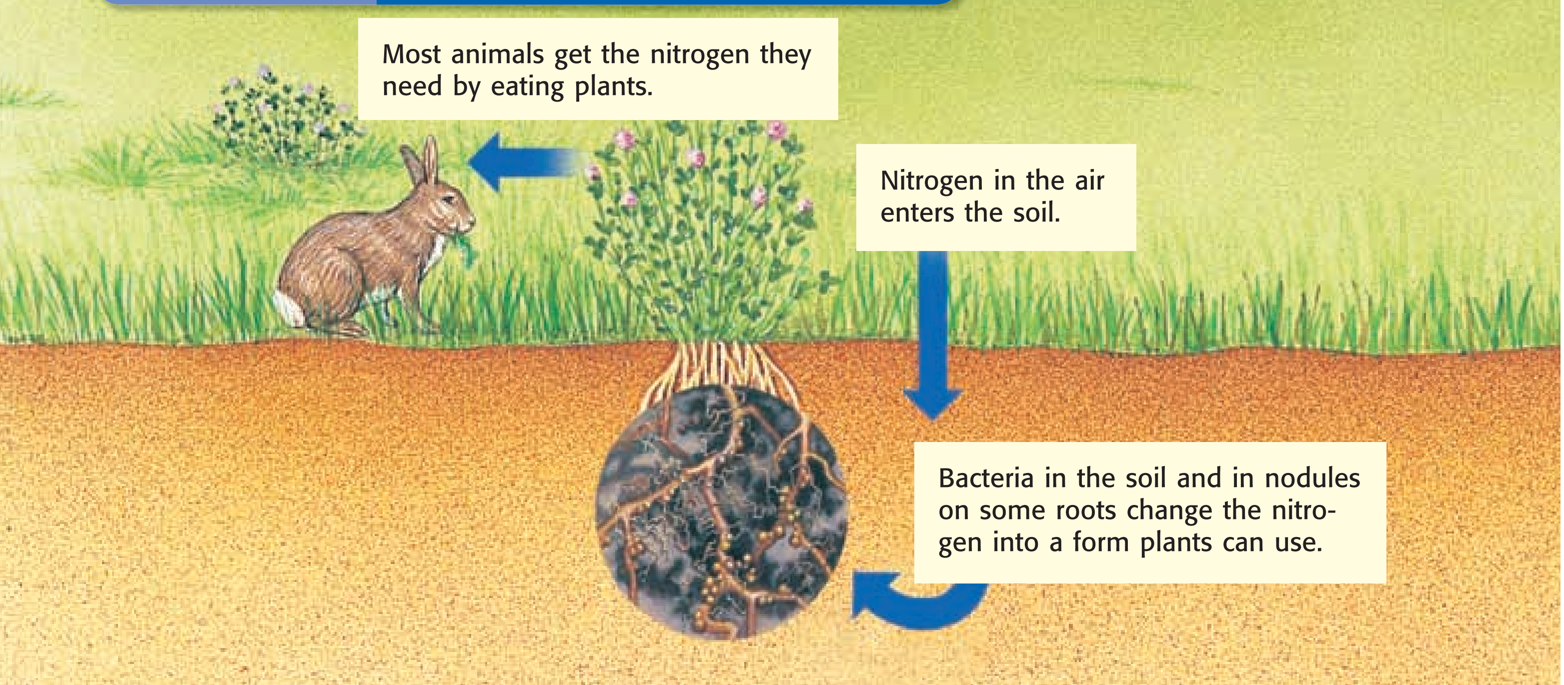
Life as we know it could not exist without bacteria. Bacteria are very important to the health of Earth. They help recycle dead animals and plants. Bacteria also play an important role in the nitrogen cycle.

Nitrogen Fixation

Most living things depend on plants. Plants need nitrogen to grow. Nitrogen gas makes up about 78% of the air, but most plants cannot use nitrogen directly from the air. They need to take in a different form of nitrogen. Nitrogen-fixing bacteria take in nitrogen from the air and change it to a form that plants can use. This process, called *nitrogen fixation,* is described in **Figure 1.**

Reading Check **What is nitrogen fixation?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 **Bacteria's Role in the Nitrogen Cycle**



Recycling

Have you ever seen dead leaves and twigs on a forest floor? These leaves and twigs are recycled over time with the help of bacteria. Decomposer bacteria break down dead plant and animal matter. Breaking down dead matter makes nutrients available to other living things.

Figure 2 *Bioremediating bacteria are added to soil to eat pollutants. The bacteria then release the pollutants as harmless waste.*

Cleaning Up

Bacteria and other microorganisms are also used to fight pollution. **Bioremediation** (BIE oh ri MEE dee AY shuhn) means using microorganisms to change harmful chemicals into harmless ones. Bioremediation is used to clean up hazardous waste from industries, farms, and cities. It is also used to clean up oil spills. The workers in **Figure 2** are using bacteria to remove pollutants from the soil.

Good for People

Bacteria do much more than help keep our environment clean. Bacteria also help produce many of the foods we eat every day. They even help make important medicines.

bioremediation the biological treatment of hazardous waste by living organisms

Bacteria in Your Food

Believe it or not, people raise bacteria for food! Every time you eat cheese, yogurt, buttermilk, or sour cream, you are also eating bacteria. Lactic acid-producing bacteria break down the sugar in milk, which is called *lactose*. In the process, the bacteria change lactose into lactic acid. Lactic acid preserves and adds flavor to the food. All of the foods shown in **Figure 3** were made with the help of bacteria.

SCHOOL to HOME

Make a Meal Plan

With a parent, create a week's meal plan without any foods made with bacteria. What would your diet be like without bacteria?

ACTIVITY

Figure 3 *Bacteria are used to make many kinds of foods.*

Figure 4 *Genes from the* Xenopus *frog were used to produce the first genetically engineered bacteria.*

Making Medicines

What's the best way to fight disease-causing bacteria? Would you believe that the answer is to use other bacteria? **Antibiotics** are medicines used to kill bacteria and other microorganisms. Many antibiotics are made by bacteria.

antibiotic medicine used to kill bacteria and other microorganisms

pathogenic bacteria bacteria that cause disease

Insulin

The human body needs insulin to break down and use sugar and carbohydrates. People who have diabetes do not make enough insulin. In the 1970s, scientists discovered how to put genes into bacteria so that the bacteria would make human insulin. The insulin can then be separated from the bacteria and given to people who have diabetes.

Genetic Engineering

When scientists change the genes of bacteria, or any other living thing, the process is called *genetic engineering*. Scientists have been genetically engineering bacteria since 1973. In that year, researchers put genes from a frog like the one in **Figure 4** into the bacterium *Escherichia coli* (ESH uh RIK ee uh KOH LIE). The bacterium then started making copies of the frog genes. Scientists can now engineer bacteria to make many products, such as insecticides, cleansers, and adhesives.

Reading Check **What is genetic engineering?**

Harmful Bacteria

Humans couldn't live without bacteria, but bacteria can also cause harm. Scientists learned in the 1800s that some bacteria are pathogenic (PATH uh JEN ik). **Pathogenic bacteria** are bacteria that cause disease. Pathogenic bacteria get inside a host organism and take nutrients from the host's cells. In the process, they harm the host. Today, we are protected from many bacterial diseases by vaccination, as shown in **Figure 5.** Many bacterial diseases can also be treated with antibiotics.

Figure 5 *Vaccines can protect you from bacterial diseases such as tetanus and diptheria.*

Diseases in Other Organisms

Bacteria cause diseases in other organisms as well as in people. Have you ever seen a plant with odd-colored spots or soft rot? If so, you've seen bacterial damage to plants. Pathogenic bacteria attack plants, animals, protists, fungi, and even other bacteria. They can cause damage to grain, fruit, and vegetable crops. The branch of the pear tree in **Figure 6** shows the effects of pathogenic bacteria. Plants are sometimes treated with antibiotics. Scientists have also genetically engineered certain plants to be resistant to disease-causing bacteria.

Figure 6 *This branch of a pear tree has a bacterial disease called* fire blight.

SECTION Review

Summary

- Bacteria are important to life on Earth because they fix nitrogen and decompose dead matter.
- Bacteria are useful to people because they help make foods and medicines.
- Scientists have genetically engineered bacteria to make medicines.
- Pathogenic bacteria are harmful to people. Bacteria can also harm the crops we grow for food.

Using Key Terms

1. In your own words, write a definition for the term *bioremediation.*
2. Use the following terms in the same sentence: *pathogenic bacteria* and *antibiotic.*

Understanding Key Ideas

3. What are two ways that bacteria affect plants?
4. How can bacteria both cause and cure diseases?
5. Explain two ways in which bacteria are crucial to life on Earth.
6. Describe two ways your life was affected by bacteria today.

Math Skills

7. Nitrogen makes up about 78% of air. If you have 2 L of air, how many liters of nitrogen are in the air?

Critical Thinking

8. **Identifying Relationships** Legumes, which include peas and beans, are efficient nitrogen fixers. Legumes are also a good source of amino acids. What chemical element would you expect to find in amino acids?
9. **Applying Concepts** Design a bacterium that will be genetically engineered. What do you want it to do? How would it help people or the environment?

SECTION 3

Viruses

One day, you discover red spots on your skin. More and more spots appear, and they begin turning into itchy blisters. What do you have?

The spots could be chickenpox. Chickenpox is a disease caused by a virus. A **virus** is a microscopic particle that gets inside a cell and often destroys the cell. Many viruses cause diseases, such as the common cold, flu, and acquired immune deficiency syndrome (AIDS).

READING WARM-UP

Objectives

- Explain how viruses are similar to and different from living things.
- List the four major virus shapes.
- Describe the two kinds of viral reproduction.

Terms to Learn

virus
host

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

virus a microscopic particle that gets inside a cell and often destroys the cell

host an organism from which a parasite takes food or shelter

It's a Small World

Viruses are tiny. They are smaller than the smallest bacteria. About 5 billion virus particles could fit in a single drop of blood. Viruses can change rapidly. So, a virus's effect on living things can also change. Because viruses are so small and change so often, scientists don't know exactly how many types exist. These properties also make them difficult to fight.

Are Viruses Living?

Like living things, viruses contain protein and genetic material. But viruses, such as the ones shown in **Figure 1,** don't act like living things. They can't eat, grow, break down food, or use oxygen. In fact, a virus cannot function on its own. A virus can reproduce only inside a living cell that serves as a host. A **host** is a living thing that a virus or parasite lives on or in. Using a host's cell as a tiny factory, the virus forces the host to make viruses rather than healthy new cells.

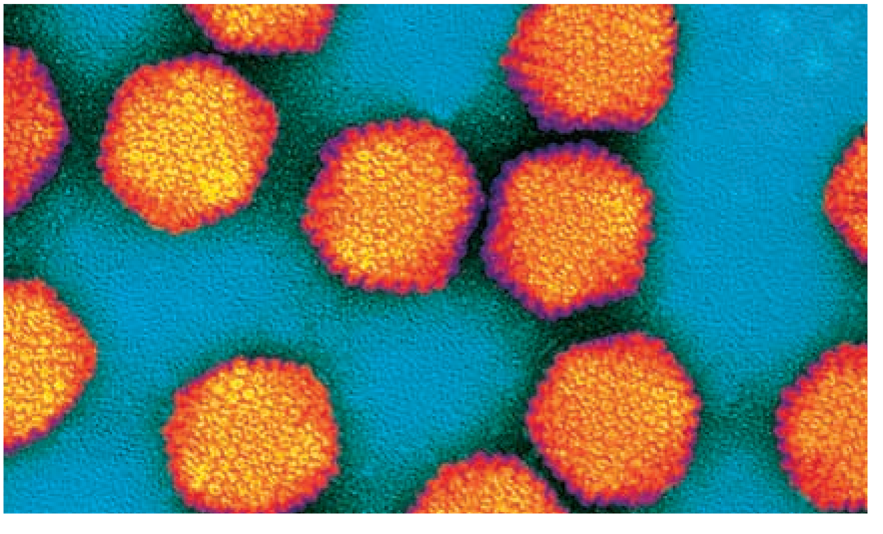
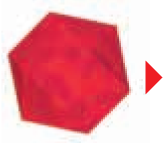
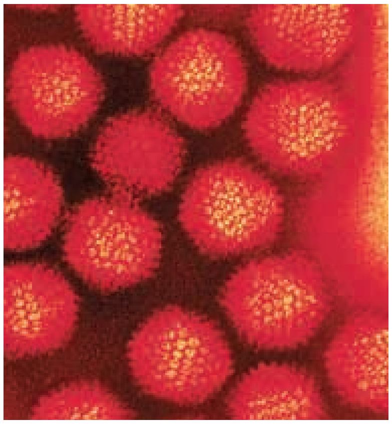


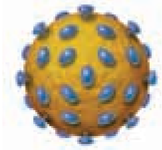
Figure 1 *Viruses are not cells. They do not have cytoplasm or organelles.*

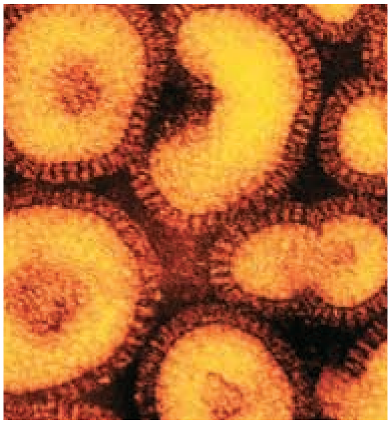
Figure 2 **The Basic Shapes of Viruses**





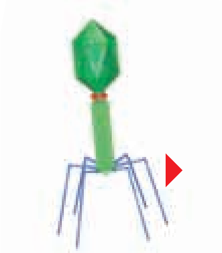
Crystals
The polio virus is shaped like the crystals shown here.

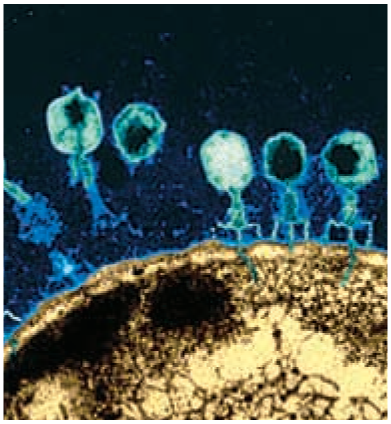




Spheres
Influenza viruses look like spheres. HIV is another virus that has this structure.

Cylinders
The tobacco mosaic virus is shaped like a cylinder and attacks tobacco plants.





Spacecraft
One group of viruses attacks only bacteria. Many of these look almost like spacecraft.

Classifying Viruses

Viruses can be grouped by their shape, the type of disease they cause, their life cycle, or the kind of genetic material they contain. The four main shapes of viruses are shown in **Figure 2.** Every virus is made up of genetic material inside a protein coat. The protein coat protects the genetic material and helps a virus enter a host cell. Many viruses have a protein coat that matches characteristics of their specific host.

The genetic material in viruses is either DNA or RNA. Most RNA is made up of one strand of nucleotides. Most DNA is made up of two strands of nucleotides. Both DNA and RNA contain information for making proteins. The viruses that cause warts and chickenpox contain DNA. The viruses that cause colds and the flu contain RNA. The virus that causes AIDS, which is called the *human immunodeficiency virus* (HIV), also contains RNA.

Reading Check **What are two ways in which viruses can be classified?** (*See the Appendix for answers to Reading Checks.*)

Math Practice

Sizing Up a Virus

If you enlarged an average virus 600,000 times, it would be about the size of a small pea. How tall would you be if you were enlarged 600,000 times?

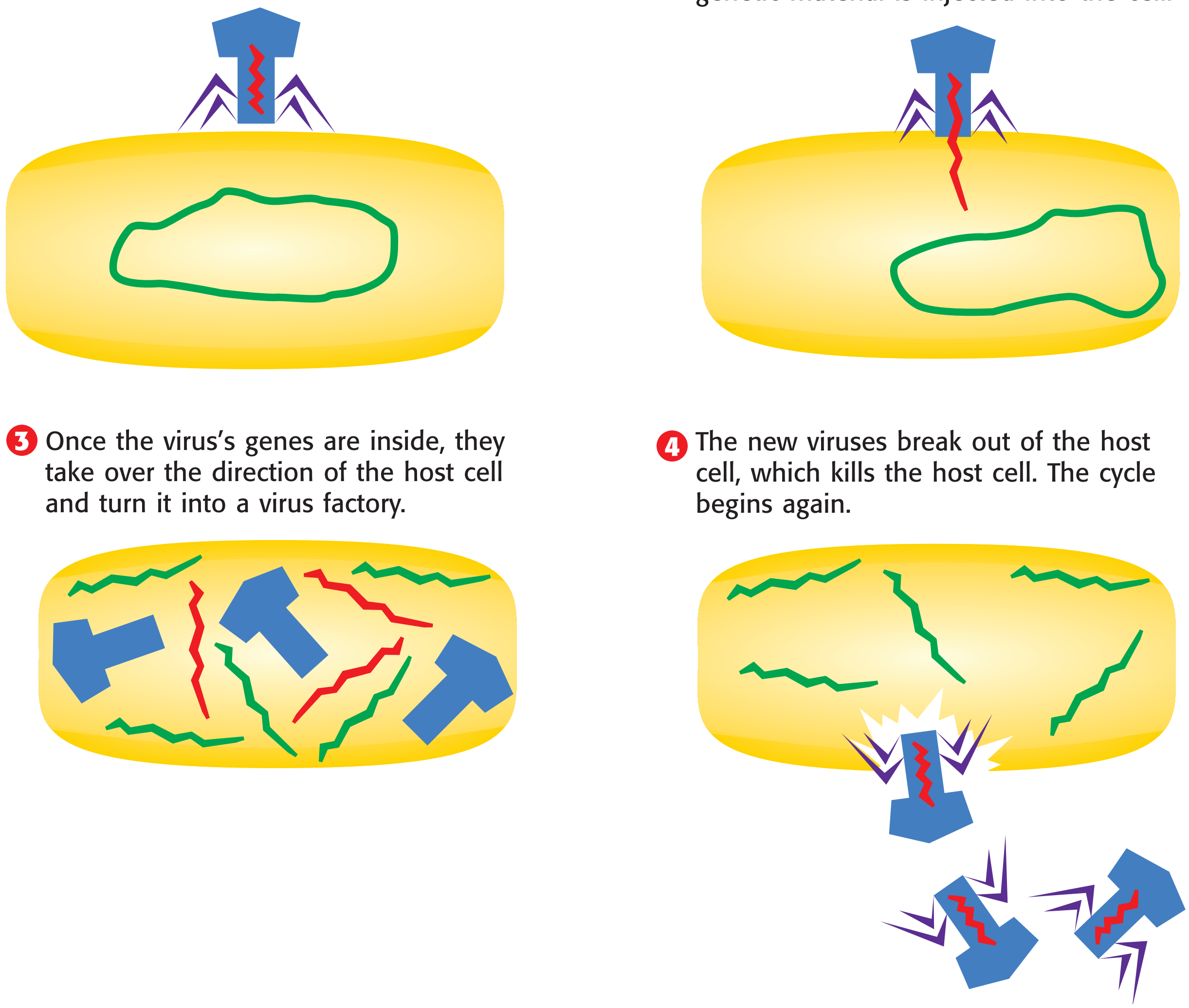


Figure 3 The Lytic Cycle

1. The virus finds and joins itself to a host cell.
2. The virus enters the cell, or the virus's genetic material is injected into the cell.
3. Once the virus's genes are inside, they take over the direction of the host cell and turn it into a virus factory.
4. The new viruses break out of the host cell, which kills the host cell. The cycle begins again.

A Destructive House Guest

The one thing that viruses do that living things also do is make more of themselves. Viruses attack living cells and turn them into virus factories. This cycle is called the *lytic cycle* (LIT ik SIE kuhl), and it is shown in **Figure 3.**

Reading Check **What is the lytic cycle?**

A Time Bomb

Some viruses don't go straight into the lytic cycle. These viruses also put their genetic material into the host cell. But new viruses are not made right away. In the lysogenic (LIE soh JEN ik) cycle, each new cell gets a copy of the virus's genes when the host cell divides. The genes can stay inactive for a long time. When the genes do become active, they begin the lytic cycle and make copies of the virus.

CONNECTION TO Chemistry

Viral Crystals Many viruses can form into crystals. Scientists can study X rays of these crystals to learn about the structure of viruses. Why do you think scientists want to learn more about viruses?

Treating a Virus

Antibiotics do not kill viruses. But scientists have recently developed antiviral (AN tie VIE ruhl) medications. Many of these medicines stop viruses from reproducing. Because many viral diseases do not have cures, it is best to prevent a viral infection from happening in the first place. Childhood vaccinations give your immune system a head start in fighting off viruses. Having current vaccinations can prevent you from getting a viral infection. It is also a good practice to wash your hands often and never to touch wild animals. If you do get sick from a virus, like the boy in **Figure 4,** it is often best to rest and drink extra fluids. As with any sickness, you should tell your parents or a doctor.

Figure 4 *The chickenpox virus resides inside your body even after the red spots are gone.*

SECTION Review

Summary

- Viruses have characteristics of living and nonliving things. They reproduce in living cells.
- Viruses may be classified by their shape, the kind of disease they cause, or their life cycle.
- To reproduce, a virus must enter a cell, reproduce itself, and then break open the cell. This is called the lytic cycle.
- In the lysogenic cycle, the genes of a virus are incorporated into the genes of the host cell.

Using Key Terms

1. Use the following terms in the same sentence: *virus* and *host*.

Understanding Key Ideas

2. One characteristic viruses have in common with living things is that they
   - **a.** eat.
   - **b.** reproduce.
   - **c.** sleep.
   - **d.** grow.
3. Describe the four steps in the lytic cycle.
4. Explain how the lytic cycle and the lysogenic cycle are different.

Math Skills

5. A bacterial cell infected by a virus divides every 20 min. After 10,000 divisions, the new viruses are released from their host cell. About how many weeks will this process take?

Critical Thinking

6. **Making Inferences** Do you think modern transportation has had an effect on the way viruses spread? Explain.
7. **Identifying Relationships** What characteristics of viruses do you think have made finding drugs to attack them difficult?
8. **Expressing Opinions** Do you think that vaccinations are important even in areas where a virus is not found?

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Viruses
SciLinks code: HSM1607

SECTION 4

Disease

You've probably heard it before: "Cover your mouth when you sneeze!" "Wash your hands!" "Don't put that in your mouth!"

What is all the fuss about? When people say these things to you, they are concerned about the spread of disease.

READING WARM-UP

Objectives

- Describe infectious diseases and noninfectious diseases.
- Identify five ways that you might come into contact with a pathogen.
- Describe four kinds of diseases.
- Discuss four methods that have helped reduce the spread of disease.

Terms to Learn

noninfectious disease
infectious disease
pathogen
immunity

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Causes of Disease

When you have a *disease,* your normal body functions are disrupted. Some diseases, such as most cancers and heart disease, are not spread from one person to another. They are called **noninfectious diseases.**

Noninfectious diseases can be caused by a variety of factors. For example, a genetic disorder causes the disease hemophilia (HEE moh FIL ee uh), in which a person's blood does not clot properly. Smoking, lack of physical activity, and a high-fat diet can greatly increase a person's chances of getting certain noninfectious diseases. Avoiding harmful habits may help you avoid noninfectious diseases.

A disease that can be passed from one living thing to another is an **infectious disease.** Infectious diseases are caused by agents called **pathogens.** Viruses and some bacteria, fungi, protists, and worms may all cause diseases. **Figure 1** shows some enlarged images of common pathogens.

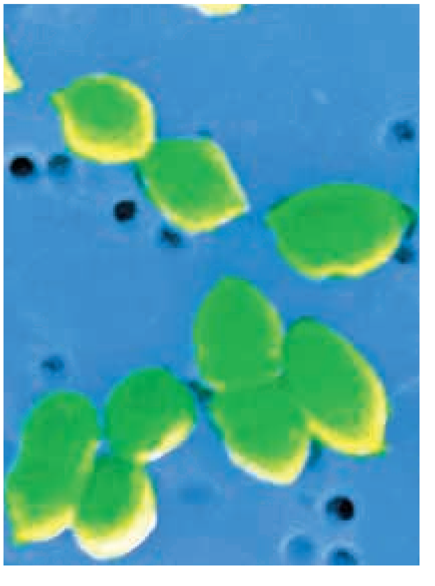
noninfectious disease a disease that cannot spread from one individual to another

infectious disease a disease that is caused by a pathogen and that can be spread from one individual to another

pathogen a virus, microorganism, or other organism that causes disease

Figure 1 **Pathogens**

This virus causes rabies.



Streptococcus bacteria can cause strep throat.

Pathways to Pathogens

There are many ways pathogens can be spread. Being aware of them can help you stay healthy.

Air

Some pathogens travel through the air. For example, a single sneeze, such as the one shown in **Figure 2,** releases thousands of tiny droplets of moisture that can carry pathogens.

Figure 2 *A sneeze can force thousands of pathogen-carrying droplets out of your body at up to 160 km/h.*

Contaminated Objects

If you drink from a glass that an infected person has just used, you could become infected with a pathogen. A person who is sick may leave bacteria or viruses on many other objects, too. For example, contaminated doorknobs, keyboards, combs, and towels can pass pathogens.

Person to Person

Some pathogens are spread by direct person-to-person contact. You can become infected with some illnesses by kissing, shaking hands, or touching the sores of an infected person. People who pass diseases to others are called *carriers*. Some carriers pass diseases to others without even feeling sick.

Animals

Some pathogens are spread by animals. Animals can be carriers, or they can be vectors. A *vector* transmits a pathogen from a host to a new organism. For example, if a mosquito bites an animal infected by malaria and then bites a person, the malaria pathogen infects the person. So, the mosquito is a vector.

Food and Water

Drinking water in the United States is generally safe. But water lines can break, or treatment plants can become flooded. These problems may allow microorganisms to enter the public water supply. Bacteria growing in foods and beverages can cause illness, too. For example, meat, fish, and eggs that are not cooked enough can still contain dangerous bacteria or parasites. Even leaving food out at room temperature can give bacteria such as salmonella the chance to grow and produce toxins in the food. Refrigerating foods can slow the growth of many of these pathogens. Because bacteria grow in food, washing all used cooking surfaces and tools is also important.

Reading Check **Why must you cook meat and eggs thoroughly?** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Social Studies

Disease and History Many diseases have shaped history. For example, yellow fever, which is caused by a virus that is spread by mosquitoes, was one of the obstacles in building the Panama Canal. Only after people learned how to prevent the spread of the yellow fever virus could the canal be completed.

Use information from Internet and library research to create a poster describing how one infectious disease affected history.

ACTIVITY

Figure 3 *A throat culture is a very simple and painless test that can show whether or not you have strep throat.*

Kinds of Diseases

Each pathogen causes a specific disease. But diseases caused by similar pathogens do share some similarities. For example, bacterial diseases are different from viral diseases. Knowing what kind of pathogen causes a disease helps doctors know how to treat the disease.

Bacterial Diseases

Many diseases caused by bacteria are contagious. Bacteria can spread between people easily. Some bacterial diseases cause serious problems if they are not treated. However, certain medicines can be used to kill bacteria quickly.

Sinus infections, tuberculosis, and strep throat are a few bacterial infections. **Figure 3** shows a girl being tested for strep throat, which is caused by a bacterium called *Streptococcus*. Strep throat causes people to feel pain when they swallow. The disease can also cause people to feel achy or to have a fever.

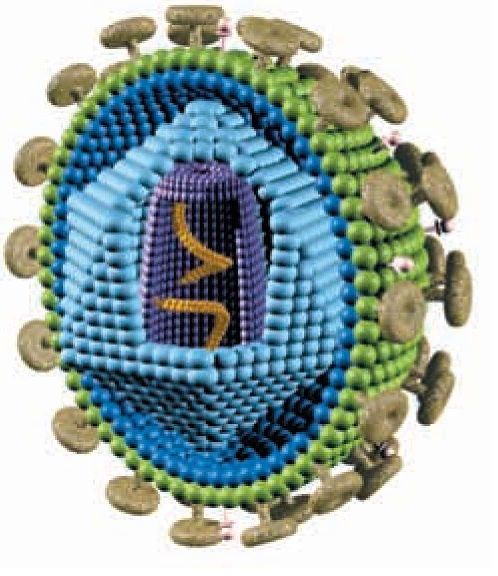


Figure 4 *This model shows what HIV looks like. HIV is the virus that causes AIDS, which destroys the body's immune system.*

Viral Diseases

Many viral diseases are also contagious. Some viral diseases, such as the common cold, can be spread through the air or by touch. Other viruses, such as HIV, a model of which is shown in **Figure 4,** are spread through body fluids.

Influenza, mononucleosis, and the common cold are common viral diseases. Most people catch about two colds a year. Colds usually cause a sore throat, sneezing, congestion, headaches, and a runny nose. The common cold is actually caused by many different viruses. Because colds are caused by different viruses, finding a medicine to treat the common cold is difficult.

Reading Check **Why is it difficult to treat the common cold?**

Parasites

Not all pathogens are bacteria or viruses. Some small organisms, such as protists, fungi, and even tiny invertebrates, cause parasitic diseases in people. A *parasite* is an organism that gets its food from another living organism, called the *host*.

Giardia (jee AHR dee uh) and malaria are common parasitic diseases caused by protists. Infections caused by parasites from the genus *Giardia* can cause nausea, stomach cramps, and diarrhea in humans. Malaria can cause high fever and even death. Malaria is not common in the United States. Athlete's foot is a common parasitic disease that is caused by a fungus. Athlete's foot causes skin to itch and flake. **Figure 5** shows a woman who is infected by a tiny parasitic worm that causes the disease *elephantiasis* (el uh fuhn TIE uh sis). Elephantiasis is not a threat in the United States.

Figure 5 *A parasitic worm caused fluid to build up in this woman's foot and ankle, which made the limb swell to many times its normal size.*

Other Causes of Disease

Chemicals and other nonliving things can also cause disease. Dangerous chemicals can act as a poison to the body. For example, lead that enters the body through water or the air can cause lead poisoning. This disease may damage the brain, kidneys, liver, and other organs. Lead poisoning can even cause behavioral changes and learning problems.

Some diseases are caused by mutagens. *Mutagens* are substances that cause a person's cells to *mutate,* or change form. X-rays, cigarette smoke, and even sunlight can cause human cells to change in harmful ways. For example, sunlight can change the skin and can cause skin cancer. The girl in **Figure 6** is using sunscreen to protect herself from the sun.

Figure 6 *Applying sunblock to skin that is exposed to sunlight can reduce your risk of skin cancer.*

SCHOOL to HOME

Label Check

At home or in a local store, find a product that has been pasteurized. In your **science journal,** write down other safety information you find on the label, including the product's refrigeration needs. Why do you think most products that require pasteurization also require refrigeration?

ACTIVITY

immunity the ability to resist or to recover from an infectious disease

Putting Pathogens in Their Place

Until the 20th century, surgery patients often died of bacterial infections. But doctors learned that simple cleanliness could help prevent the spread of some diseases. And over the years, researchers have produced a variety of ways to prevent the spread of pathogens. Now, ultraviolet radiation, new technologies, and new medicines are used to fight pathogens. Scientific research against pathogens continues today, as new medicines are tested and approved.

Pasteurization

During the mid-1800s, Louis Pasteur, a French scientist, discovered that microorganisms caused wine to spoil. The uninvited microorganisms were bacteria. Pasteur devised a method of using heat to kill most of the bacteria in the wine. This method is called *pasteurization* (PAS tuhr i ZAY shuhn), and it is still used today. The milk that the girl in **Figure 7** is drinking has been pasteurized.

Vaccines and Immunity

In the late 1700s, no one knew what a pathogen was. During this time, Edward Jenner studied a disease called *smallpox*. He observed that people who had been infected with cowpox seemed to have protection against smallpox. These people had a resistance to the disease. The ability to resist or recover from an infectious disease is called **immunity.** Jenner's work led to the first modern vaccine. A *vaccine* is a substance that helps your body develop immunity to a disease.

Today, vaccines are used all over the world to prevent many serious diseases. Modern vaccines contain pathogens that are killed or specially treated so that they can't make you very sick. The vaccine is enough like the pathogen to allow your body to develop a defense against the disease.

Figure 7 *Today, pasteurization is used to kill pathogens in many different types of food, including dairy products, shellfish, and juices.*

Antibiotics

Bacterial infections can be a serious threat to your health. Fortunately, doctors can usually treat these kinds of infections with antibiotics. An *antibiotic* is a substance that can kill bacteria or slow the growth of bacteria. Antibiotics may also be used to treat infections caused by other microorganisms, such as fungi. However, viruses are not affected by antibiotics. Antibiotics can kill only living things, and viruses are not alive. The only way to destroy viruses in your body is to locate and kill the cells they have invaded.

Reading Check **Why do you think a doctor would refuse to prescribe antibiotics for a cold?**

MATH PRACTICE

Epidemic!

You catch a cold. Your friends don't have immunity to your cold. On the first day back at school, you expose five friends to your cold. The next day, each of them passes the virus to five more people. If this pattern continues for 5 more days, how many people will be exposed to the virus?

SECTION Review

Summary

- Noninfectious diseases cannot be spread from one person to another.
- Infectious diseases are caused by pathogens that are passed from one living thing to another.
- Pathogens can travel through the air or can be spread by contact with other people, contaminated objects, animals, food, or water.
- Bacterial diseases, viral diseases, parasitic diseases, and diseases caused by changes to cell structure are some different kinds of diseases.
- Cleanliness, pasteurization, vaccines, and antibiotics help control the spread of pathogens.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *infectious disease*, *noninfectious disease*, and *immunity*.

Understanding Key Ideas

2. Vaccines contain
   a. treated pathogens.
   b. heat.
   c. antibiotics.
   d. pasteurization.
3. Give an example of a disease caused by a bacterium, a virus, a parasitic protist, and a chemical.
4. List five ways that you might come into contact with a pathogen.
5. Name four ways to help keep safe from pathogens.

Math Skills

6. If a certain kind of bacteria reproduces by binary fission and a bacterium takes 20 minutes to divide, how long would it take for 1 bacterium to produce 500,000 bacteria through binary fission?
7. If 10 people who have the virus each expose 25 more people to the virus, how many people will be exposed to the virus?

Critical Thinking

8. **Identifying Relationships** Why might the risk of infectious disease be high in a community that has no water treatment facility?
9. **Analyzing Methods** Explain what might happen if a doctor did not wear gloves when treating patients.
10. **Applying Concepts** Why do vaccines for diseases in animals help prevent some illnesses in people?

Using Scientific Methods

Inquiry Lab

Aunt Flossie and the Intruder

OBJECTIVES

Design an experiment that will answer a specific question.

Investigate what kind of organisms make food spoil.

MATERIALS

- gloves, protective
- items, such as sealable plastic bags, food samples, a scale, or a thermometer, to be determined by the students and approved by the teacher as needed for each experiment

SAFETY

Aunt Flossie is a really bad housekeeper! She never cleans the refrigerator, and things get really gross in there. Last week she pulled out a plastic bag that looked like it was going to explode! The bag was full of gas that she did not put there! Aunt Flossie remembered from her school days that gases are released from living things as waste products. Something had to be alive in the bag!

Aunt Flossie became very upset that there was an intruder in her refrigerator. She refuses to bake another cookie until you determine the nature of the intruder.

Ask a Question

1. How did gas get into Aunt Flossie's bag?

Form a Hypothesis

2. Write a hypothesis which answers the question above. Explain your reasoning.

Test the Hypothesis

3. Design an experiment that will determine how gas got into Aunt Flossie's bag. Make a list of the materials you will need, and prepare all the data tables you will need for recording your observations.
4. Get your teacher's approval of your experimental design and your list of materials before you begin.
5. Dispose of your materials according to your teacher's instructions at the end of your experiment. **Caution:** Do not open any bags of spoiled food or allow any of the contents to escape.

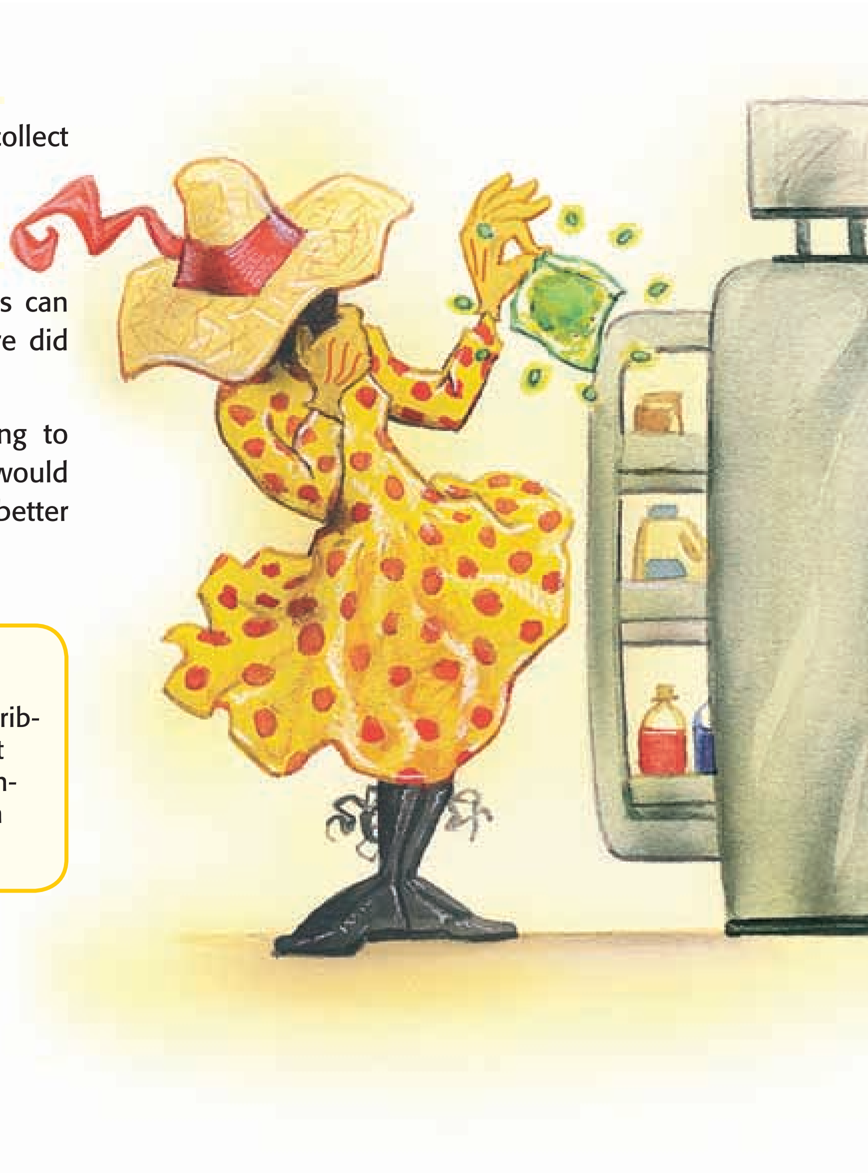
Analyze the Results

1. **Organizing Data** What data did you collect from your experiment?

Draw Conclusions

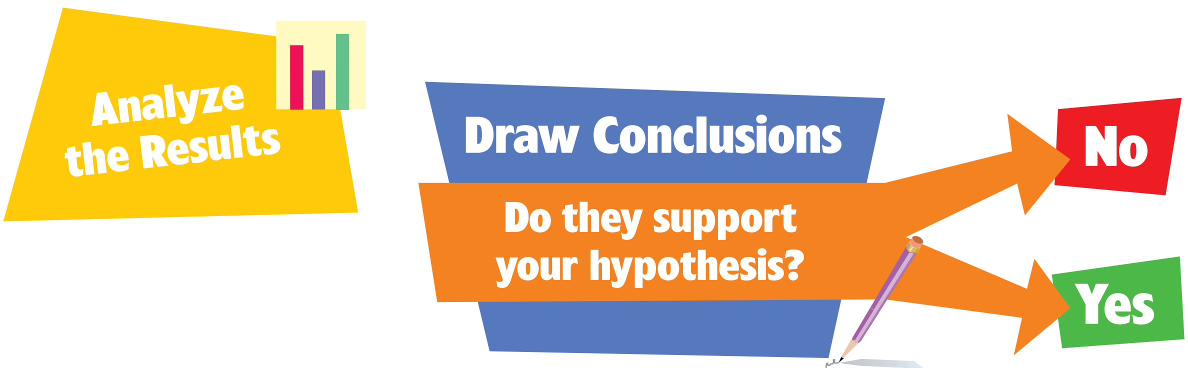
2. **Drawing Conclusions** What conclusions can you draw from your investigation? Where did the gas come from?

3. **Evaluating Methods** If you were going to perform another investigation, what would you change in the experiment to give better results? Explain your answer.



Communicating Your Data

WRITING SKILL Write a letter to Aunt Flossie describing your experiment. Explain what produced the gas in the bag and your recommendations for preventing these intruders in her refrigerator in the future.



Chapter Review

USING KEY TERMS

1. In your own words, write a definition for the term *pathogen*.

Complete each of the following sentences by choosing the correct term from the word bank.

binary fission	endospore
antibiotic	bioremediation
virus	bacteria

2. Most bacteria reproduce by ___.

3. Bacterial infections can be treated with ___.

4. A(n) ___ needs a host to reproduce.

UNDERSTANDING KEY IDEAS

Multiple Choice

5. Bacteria are used for all of the following EXCEPT
   - **a.** making certain foods.
   - **b.** making antibiotics.
   - **c.** cleaning up oil spills.
   - **d.** preserving fruit.

6. In the lytic cycle, the host cell
   - **a.** is destroyed.
   - **b.** destroys the virus.
   - **c.** becomes a virus.
   - **d.** undergoes cell division.

7. A bacterial cell
   - **a.** is an endospore.
   - **b.** has a loop of DNA.
   - **c.** has a distinct nucleus.
   - **d.** is a eukaryote.

8. Eubacteria
   - **a.** include methane makers.
   - **b.** include decomposers.
   - **c.** all have chlorophyll.
   - **d.** are rod-shaped.

9. Cyanobacteria
   - **a.** are consumers.
   - **b.** are parasites.
   - **c.** contain chlorophyll.
   - **d.** are decomposers.

10. Archaebacteria
    - **a.** are a special type of eubacteria.
    - **b.** live only in places without oxygen.
    - **c.** are lactic acid-producing bacteria.
    - **d.** can live in hostile environments.

11. Viruses
    - **a.** are about the same size as bacteria.
    - **b.** have nuclei.
    - **c.** can reproduce only within a host cell.
    - **d.** do not infect plants.

12. Bacteria are important to the planet as
    - **a.** decomposers of dead organic matter.
    - **b.** processors of nitrogen.
    - **c.** makers of medicine.
    - **d.** All of the above

13. Pathogens can be spread by food and water when
    - **a.** water lines break.
    - **b.** meat is not cooked well enough.
    - **c.** water treatment plants are flooded.
    - **d.** All of the above

Short Answer

14 How are the functions of nitrogen-fixing bacteria and decomposers similar?

15 Which cycle takes more time, the lytic cycle or the lysogenic cycle?

16 Describe two ways in which viruses do not act like living things.

17 What is pasteurization?

18 Describe how doctors can treat a viral infection.

CRITICAL THINKING

19 **Concept Mapping** Use the following terms to create a concept map: *eubacteria, bacilli, cocci, spirilla, consumers, producers,* and *cyanobacteria*.

20 **Predicting Consequences** Describe some of the problems you think bacteria might face if there were no humans.

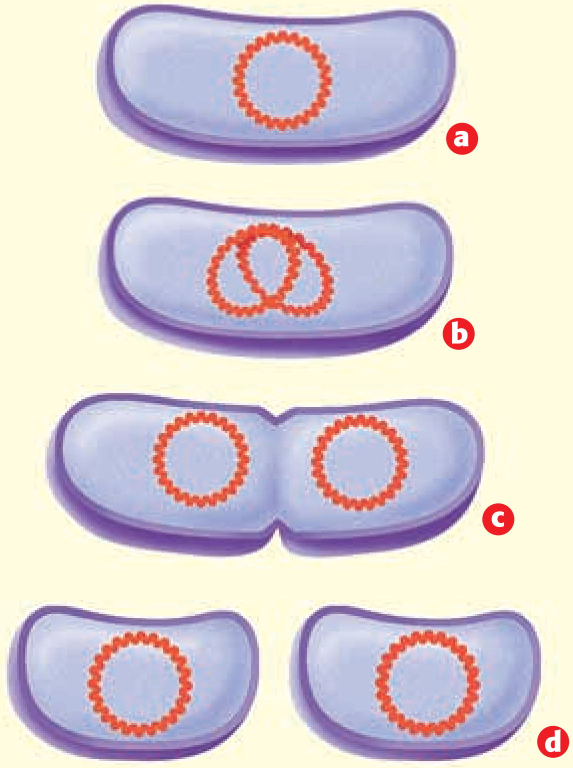
21 **Applying Concepts** Many modern soaps contain chemicals that kill bacteria. Describe one good outcome and one bad outcome of the use of antibacterial soaps.

22 **Identifying Relationships** Some people have digestive problems after they take a course of antibiotics. Why do you think these problems happen?

23 **Predicting Consequences** What do you think would happen if a doctor prescribed an antibiotic for a patient suffering from influenza?

INTERPRETING GRAPHICS

The diagram below illustrates the stages of binary fission. Match each statement with the correct stage.

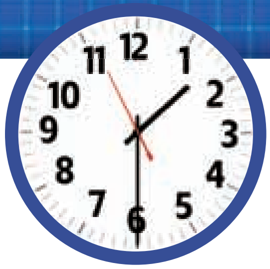


24 The DNA loops separate.

25 The DNA loop replicates.

26 The parent cell starts to expand.

27 The DNA attaches to the cell membrane.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Viruses that evolve in isolated areas and that can infect human beings are called emerging viruses. These new viruses are dangerous to public health. People become infected when they have contact with the normal hosts of these viruses. In the United States, the hantavirus is considered an emerging virus. First detected in the southwestern United States, the hantavirus occurs in wild rodents and can infect and kill humans. Roughly 40% to 50% of humans infected with the hantavirus die. Other emerging viruses include the Ebola (Africa), Lassa (Africa), and Machupo (South America) viruses.

1. In the passage, what does the word *emerging* mean?

A to become visible or known
B to fade away into the background
C to melt from two things into one
D to become urgent

2. Which of the following statements is a fact from the passage?

F Hantavirus causes death in more than 40% of its victims.
G Hantavirus causes death in more than 50% of its victims.
H Hantavirus causes death in fewer than 30% of its victims.
I Hantavirus causes death in fewer than 40% of its victims.

3. Which of the following is an emergent virus in South America?

A Ebola virus
B Lassa virus
C SARS virus
D Machupo virus

Passage 2 Less than 100 years ago, people had no way to treat bacterial infections. But in 1928, a Scottish scientist named Alexander Fleming discovered the first antibiotic, or bacteria-killing drug. This first antibiotic was called *penicillin*. The discovery of antibiotics improved healthcare dramatically. However, scientists are now realizing that many bacteria are becoming resistant to existing antibiotics. Scientists are hoping that a particular type of virus called a bacteriophage (bak TIR ee uh FAHJ) might hold the key to fighting bacteria in the future. Bacteriophages destroy bacteria cells. Each kind of bacteriophage can infect only a particular species of bacteria.

1. In what year was penicillin discovered?

A 1905
B 1928
C 1969
D 1974

2. According to the passage, what might be the key to fighting bacteria in the future?

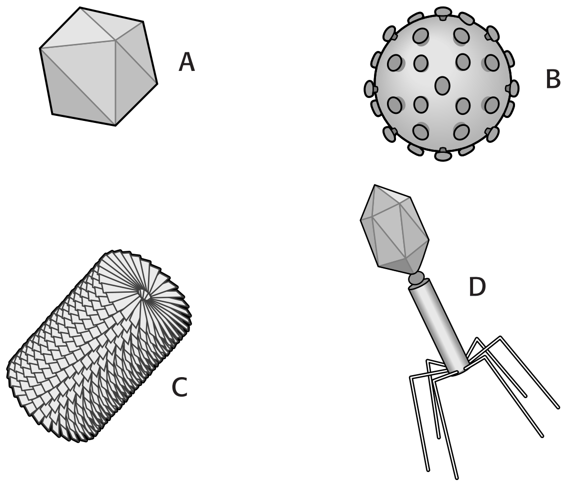
F antibiotics
G bacteriophages
H penicillin
I antibiotic-resistant bacteria

3. According to the passage, what can each kind of bacteriophage infect?

A viruses that cause disease
B only antibiotic-resistant bacteria
C all kinds of bacteria
D only a particular species of bacteria

INTERPRETING GRAPHICS

The images below show the four main shapes of viruses. Use these pictures to answer the questions that follow.



1. Which viral shape attacks only bacteria?

A virus A
B virus B
C virus C
D virus D

2. Which viral shape is the cylinder?

F virus A
G virus B
H virus C
I virus D

3. Which viral shape would you expect to have the largest surface area–to-volume ratio?

A virus A
B virus B
C virus C
D virus D

MATH

Read each question below, and choose the best answer.

1. Reagan spent $26 for four equally priced CDs. Which of the following equations could be used to find how much each CD costs?

A $4 \times \$26 = n$
B $n = \$26 - 4$
C $4 \times n = \$26$
D $n \times \$26 = 4$

2. What is $5 + (-8)$ equal to?

F -13
G -3
H 3
I 13

3. What is $-9 - 2$ equal to?

A -11
B -7
C -4
D 7

4. What is the solution to $45 \div 0.009$?

F 5,000
G 500
H 50
I 5

5. What is $-9 + 2$ equal to?

A -11
B -7
C -4
D 7

6. Jennifer, Beth, and Sienna live 8 km, 2.2 km, and 7.4 km from the school. Which of the following is a reasonable estimate of the average distance these friends live from the school?

F 6 km
G 7.4 km
H 9 km
I 18 km

Science in Action

Science, Technology, and Society

Edible Vaccines

Vaccines protect you from life-threatening diseases. But vaccinations are expensive, and the people who give them must go through extensive training. These and other factors often prevent people in developing countries from getting vaccinations. But help may be on the way. Scientists are developing edible vaccines. Imagine eating a banana and getting the same protection you would from several painful injections. These vaccines are made from DNA that encodes a protein in the disease-causing particles. This DNA can then be inserted into the banana's genes. Researchers are still working on safe and effective edible vaccines.

Language Arts ACTIVITY

WRITING SKILL Write an advertisement for an edible vaccine. Be sure to describe the benefits of vaccinations.

Scientific Discoveries

Spanish Flu and the Flu Cycle

In 1918, a version of the influenza (the flu) virus killed millions of people worldwide. This disease, mistakenly called the Spanish Flu (it probably started in China), was one of the worst epidemics in history. Doctors and scientists realized that the large movement of people during the First World War probably made it easier for the Spanish Flu to spread. But the question of how this common disease could become so deadly remained unknown. One important factor is that the influenza virus is constantly changing. Many scientists now think that the influenza virus mutates into a more deadly form about every 30 years. There were flu epidemics in 1918, 1957, and 1968, which leads some scientists to believe that we are overdue for another flu epidemic.

Social Studies ACTIVITY

WRITING SKILL Conduct an interview with an older member of your family. Ask them how the flu, smallpox, tuberculosis, or polio has affected their lives. Write a report that includes information on how doctors deal with the disease today.

People in Science

Laytonville Middle School

Composting Project In 1973, Mary Appelhof tried an experiment. She knew that bacteria can help break down dead organic matter. In her basement, she set up a bin with worms and dumped her food scraps in there. Her basement didn't smell like garbage because her worms were eating the food scraps! Composting uses heat, bacteria, and, sometimes, worms to break down food wastes. Composting turns these wastes into fertilizer.

Binet Payne, a teacher at the Laytonville Middle School in California, decided to try Appelhof's composting system. Ms. Payne asked her students to separate their school cafeteria's trash into different categories: veggie wastes (worm food), protein foods (meat, milk, and cheese), bottles, cans, bags (to be recycled), and "yucky trash" (napkins and other nonrecyclables). The veggie waste was placed into the worm bins, and the protein foods were used to feed a local farm's chickens and pigs. In the first year, the Garden Project saved the school \$6,000, which otherwise would have been used to dump the garbage into a landfill.

Math ACTIVITY

If the school saved \$6,000 the first year, how much money did the school save each day of the year?

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Current Science

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LabBook

Contents

Using Scientific Methods

Skills Practice Lab

Clean Up Your Act

When you wash dishes, the family car, the bathroom sink, or your clothes, you wash them with water. But have you ever wondered how water gets clean? Two major methods of purifying water are filtration and evaporation. In this activity, you will use both of these methods to test how well they remove pollutants from water. You will test detritus (decaying plant matter), soil, vinegar, and detergent. Your teacher may also ask you to test other pollutants.

MATERIALS

Part A

- charcoal, activated
- goggles
- gravel
- hammer and small nail
- sand
- scissors
- soda bottle, plastic, with cap, 2 L

Part B

- bag, plastic sandwich, sealable
- flask, Erlenmeyer
- gloves, heat-resistant
- hot plate
- ice
- stopper, rubber, one-hole, with a glass tube
- tubing, plastic, 1.5 m

Parts A and B

- beaker, 400 mL
- beaker, 1,000 mL (2)
- detergent, dishwashing
- detritus (grass and leaf clippings)
- hand lens
- pH test strips
- ring stand with ring
- soil
- spoons, plastic (2)
- vinegar, household
- water, 2,000 mL

SAFETY

Form a Hypothesis

1. Form a hypothesis about whether filtration and evaporation will clean each of the four pollutants from the water and how well they might do it. Then, use the procedures below to test your hypothesis.

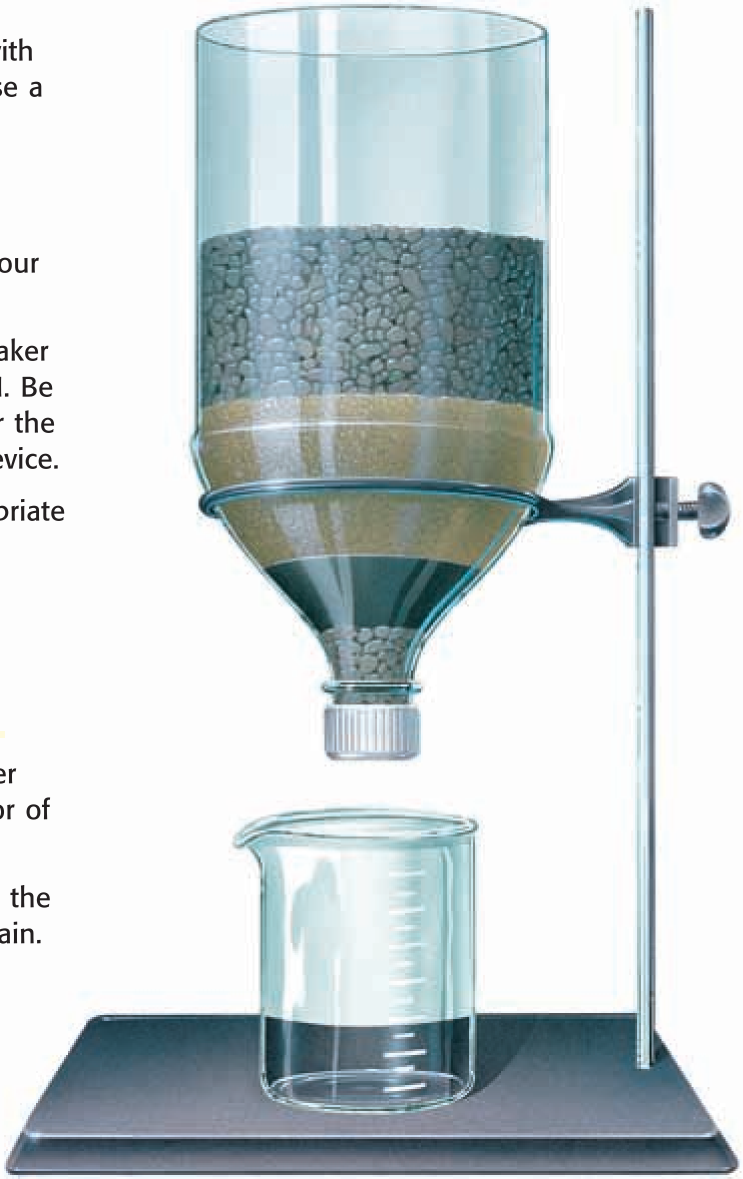
Part A: Filtration

Filtration is a common method of removing various pollutants from water. Filtration requires very little energy—gravity pulls water down through the layers of filter material. See how well this energy-efficient method works to clean your sample of polluted water.

Test the Hypothesis

2. Put on your gloves and goggles. Use scissors to carefully cut the bottom out of the empty soda bottle.
3. Using a small nail and hammer, carefully punch four or five small holes through the plastic cap of the bottle. Screw the plastic cap onto the bottle.
4. Turn the bottle upside down, and set its neck in a ring on a ring stand, as shown on the next page. Put a handful of gravel into the inverted bottle. Add a layer of activated charcoal, followed by thick layers of sand and gravel. Place a 400 mL beaker under the neck of the bottle.
5. Fill each of the large beakers with 1,000 mL of clean water. Set one beaker aside to serve as the control. Add three or four spoonfuls of each of the following pollutants to the other beaker: detritus, soil, household vinegar, and dishwashing detergent.
6. Copy the table on the next page, and record your observations for each beaker in the columns labeled "Before cleaning."
7. Observe the color of the water in each beaker.
8. Use a hand lens to examine the water for visible particles.

9. Smell the water, and note any unusual odors.
10. Stir the water in each beaker rapidly with a plastic spoon, and check for suds. Use a different spoon for each sample.
11. Use a pH test strip to find the pH of the water.
12. Gently stir the clean water, and then pour half of it through the filtration device.
13. Observe the water in the collection beaker for color, particles, odors, suds, and pH. Be patient. It may take several minutes for the water to travel through the filtration device.
14. Record your observations in the appropriate "After filtration" column in your table.
15. Repeat steps 12–14 using the polluted water.



Analyze the Results

1. How did the color of the polluted water change after the filtration? Did the color of the clean water change?
2. Did the filtration method remove all of the particles from the polluted water? Explain.
3. How much did the pH of the polluted water change? Did the pH of the clean water change? Was the final pH of the polluted water the same as the pH of the clean water before cleaning? Explain.

Results Table

	Before cleaning (clean water)	Before cleaning (polluted water)	After filtration (clean water)	After filtration (polluted water)	After evaporation (clean water)	After evaporation (polluted water)
Color						
Particles						
Odor						
Suds						
pH						

DO NOT WRITE IN BOOK

Part B: Evaporation

Cleaning water by evaporation is more expensive than cleaning water by filtration. Evaporation requires more energy, which can come from a variety of sources. In this activity, you will use an electric hot plate as the energy source. See how well this method works to clean your sample of polluted water.

Form a Hypothesis

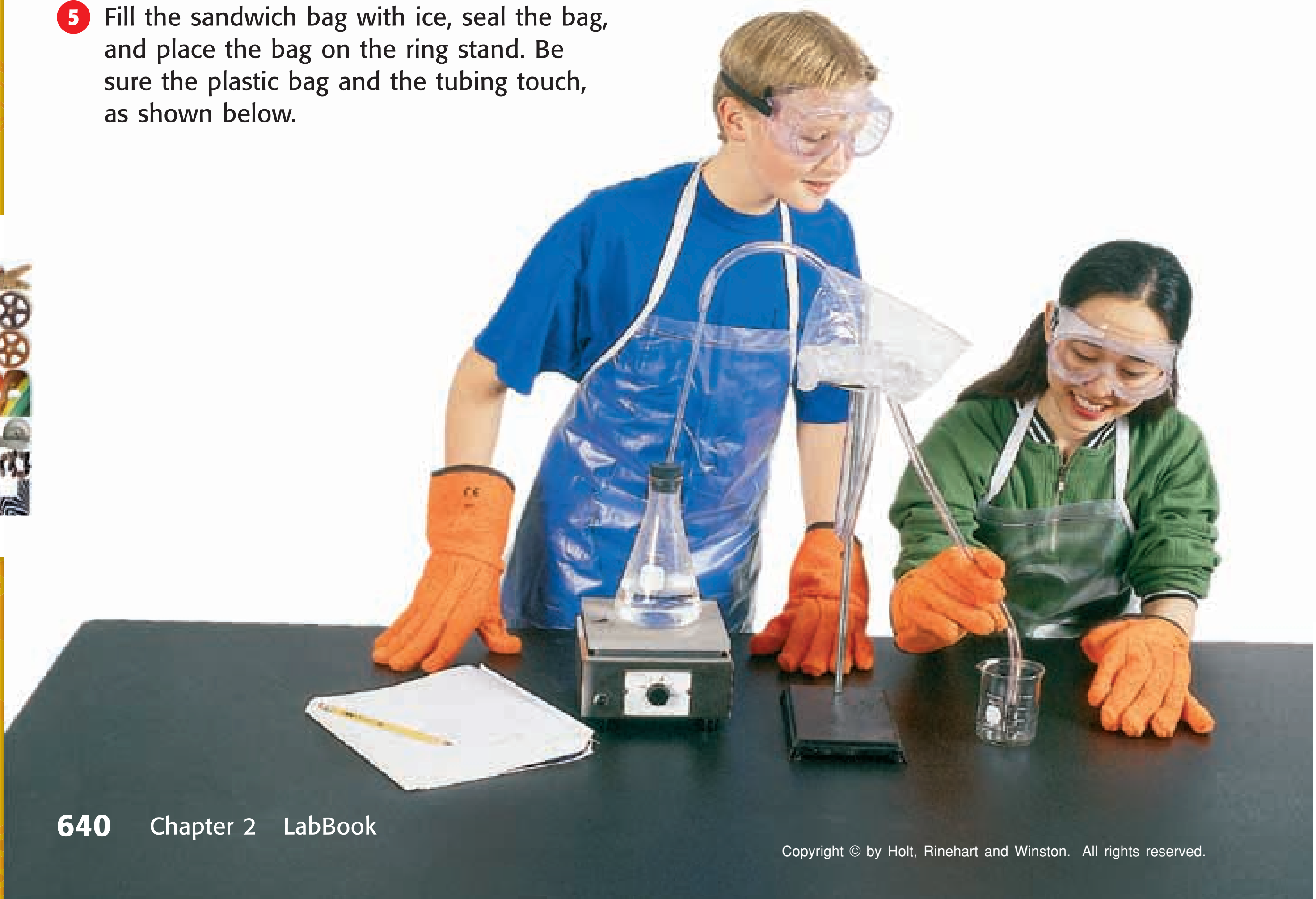
1. Write a hypothesis about which method you think will work better for water purification. Explain your reasoning.

Test the Hypothesis

2. Fill an Erlenmeyer flask with about 250 mL of the clean water, and insert the rubber stopper and glass tube into the flask.
3. Wearing goggles and gloves, connect about 1.5 m of plastic tubing to the glass tube.
4. Set the flask on the hot plate, and run the plastic tubing up and around the ring and down into a clean, empty 400 mL collection beaker.
5. Fill the sandwich bag with ice, seal the bag, and place the bag on the ring stand. Be sure the plastic bag and the tubing touch, as shown below.
6. Bring the water in the flask to a slow boil. As the water vapor passes by the bag of ice, the vapor will condense and drip into the collection beaker.
7. Observe the water in the collection beaker for color, particles, odor, suds, and pH. Record your observations in the "After evaporation" column in your data table.
8. Repeat steps 2–7 using the polluted water.

Analyze the Results

1. How did the color of the polluted water change after evaporation? Did the color of the clean water change after evaporation?
2. Did the evaporation method remove all of the particles from the polluted water? Explain.
3. How much did the pH of the polluted water change? Did the pH of the final clean water change? Was the final pH of the polluted water the same as the pH of the clean water before it was cleaned? Explain.



Draw Conclusions: Parts A and B

4. Which method—filtration or evaporation—removed the most pollutants from the water? Explain your reasoning.
5. Describe any changes that occurred in the clean water during this experiment.
6. What do you think are the advantages and disadvantages of each method?
7. Explain how you think each material (sand, gravel, and charcoal) used in the filtration system helped clean the water.
8. List areas of the country where you think each method of purification would be the most and the least beneficial. Explain your reasoning.

Applying Your Data

Do you think either purification method would remove oil from water? If time permits, repeat your experiment using several spoonfuls of cooking oil as the pollutant.

Filtration is only one step in the purification of water at water treatment plants. Research other methods used to purify public water supplies.

Using Scientific Methods

Skills Practice Lab

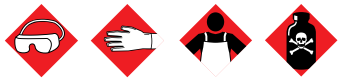
Investigating an Oil Spill

Have you ever wondered why it is important to recycle motor oil rather than pour it down the drain or sewer? Or have you ever wondered why a seemingly small oil spill can cause so much damage? The reason is that a little oil goes a long way.

MATERIALS

- calculator (optional)
- gloves, protective
- goggles
- graduated cylinder
- oil, light machine, 15 mL
- pan, large, at least 22 cm in diameter
- pipet
- ruler, metric
- water

SAFETY



Observing Oil and Water

Maybe you've heard the phrase "Oil and water don't mix." Oil dropped in water will spread out thinly over the surface of the water. In this activity, you'll learn how far a drop of oil can spread.

Ask a Question

1. How far will one drop of oil spread in a pan of water?

Form a Hypothesis

2. Write a hypothesis that could answer the question above.

Test the Hypothesis

3. Use a pipet to place one drop of oil into the middle of a pan of water. **Caution:** Machine oil is poisonous. Wear goggles and gloves. Keep materials that have contacted oil out of your mouth and eyes.
4. Observe what happens to the drop of oil for the next few seconds. Record your observations.
5. Using a metric ruler, measure the diameter of the oil slick to the nearest centimeter.
6. Determine the area of the oil slick in square centimeters. Use the formula below to find the area of a circle ($A = \pi r^2$). The radius (r) is equal to the diameter you measured in step 5 divided by 2. Multiply the radius by itself to get the square of the radius (r^2). Pi (π) is equal to 3.14. Record your answer.

Example

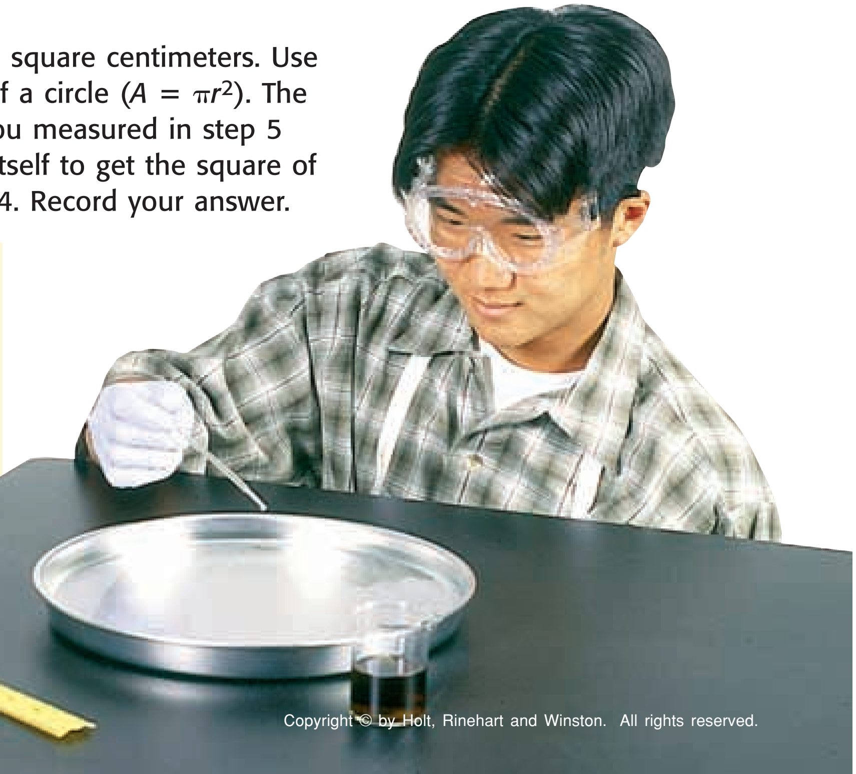
If your diameter is 10 cm,

$r = 5$ cm, $r^2 = 25$ cm^2, $\pi = 3.14$

$$A = \pi r^2$$

$$A = 3.14 \times 25 \text{ cm}^2$$

$$A = 78.5 \text{ cm}^2$$



Analyze the Results

1. What happened to the drop of oil when it came in contact with the water?
2. What total surface area was covered by the oil slick? (Show your calculations.)

Draw Conclusions

3. What can you conclude about the density of oil compared with the density of water?

Finding the Number of Drops in a Liter

"It's only a few drops," you may think as you spill something toxic on the ground. But those drops eventually add up. Just how many drops does it take to make a difference? In this activity, you'll learn just what an impact a few drops can have.

Procedure

1. Using a clean pipet, count the number of water drops it takes to fill the graduated cylinder to 10 mL. Be sure to add the drops slowly so you get an accurate count.
2. Since there are 1,000 mL in a liter, multiply the number of drops in 10 mL by 100. The result is the number of drops in a liter.

Analyze the Results

1. How many drops of water from your pipet did it take to fill a 1 L container?
2. What would happen if someone spilled 4 L of oil into a lake?

Applying Your Data

Can you devise a way to clean the oil from the water? Get permission from your teacher before testing your cleaning method.

Do you think oil behaves the same way in ocean water? Devise an experiment to test your hypothesis.

Model-Making Lab

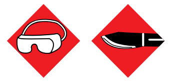
Turning the Tides

Daily tides are caused by two "bulges" on the ocean's surface—one on the side of the Earth facing the moon and the other on the opposite side of the Earth. The bulge on the side facing the moon is caused by the moon's gravitational pull on the water. But the bulge on the opposite side of the Earth is slightly more difficult to explain. Whereas the moon pulls the water on one side of the Earth, the combined rotation of the Earth and the moon "pushes" the water on the opposite side of the Earth. In this activity, you will model the motion of the Earth and the moon to investigate the tidal bulge on the side of Earth facing away from the moon.

MATERIALS

- cardboard, 1 cm × 1 cm piece
- corrugated cardboard, one large and one small, with centers marked (2 disks)
- dowel, $\frac{1}{4}$ in. in diameter and 36 cm long
- glue, white
- pencil, sharp
- stapler with staples
- string, 5 cm length

SAFETY



Procedure

1. Draw a line from the center of each disk along the folds in the cardboard to the edge of the disk. This line is the radius.
2. Place a drop of white glue on one end of the dowel. Lay the larger disk flat, and align the dowel with the line for the radius you drew in step 1. Insert about 2.5 cm of the dowel into the edge of the disk.
3. Add a drop of glue to the other end of the dowel, and push that end into the smaller disk, again along its radius. The setup should look like a large, two-headed lollipop, as shown below. This setup is a model of the Earth-moon system.
4. Staple the string to the edge of the large disk on the side opposite the dowel. Staple the cardboard square to the other end of the string. This smaller piece of cardboard represents the Earth's oceans that face away from the moon.

5. Place the tip of the pencil at the center of the large disk, as shown in the figure on the next page, and spin the model. You may poke a small hole in the bottom of the disk with your pencil, but DO NOT poke all the way through the cardboard. Record your observations. **Caution:** Be sure you are at a safe distance from other people before spinning your model.

6. Now, find your model's center of mass. The center of mass is the point at which the model can be balanced on the end of the pencil. (Hint: It might be easier to find the center of mass by using the eraser end. Then, use the sharpened end of the pencil to balance the model.) This balance point should be just inside the edge of the larger disk.

7. Place the pencil at the center of mass, and spin the model around the pencil. Again, you may wish to poke a small hole in the disk. Record your observations.

Analyze the Results

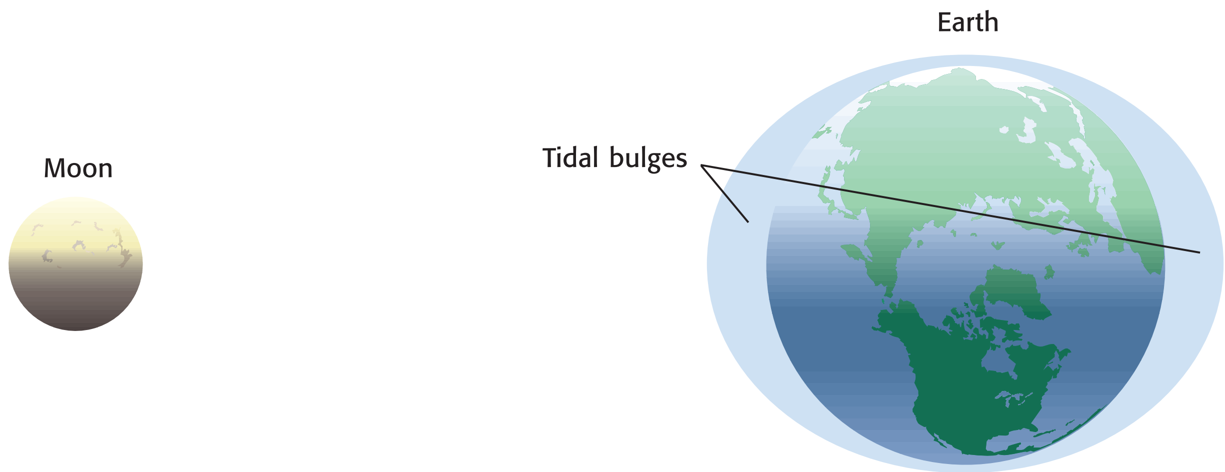
1. What happened when you tried to spin the model around the center of the large disk? This model, called the Earth-centered model, represents the incorrect view that the moon orbits the center of the Earth.

2. What happened when you tried to spin the model around its center of mass? This point, called the *barycenter,* is the point around which both the Earth and the moon rotate.

3. In each case, what happened to the string and cardboard square when the model was spun?

Draw Conclusions

4. Which model—the Earth-centered model or the barycentric model—explains why the Earth has a tidal bulge on the side opposite the moon? Explain.



Skills Practice Lab

Volumania!

You have learned how to measure the volume of a solid object that has square or rectangular sides. But there are lots of objects in the world that have irregular shapes. In this lab activity, you'll learn some ways to find the volume of objects that have irregular shapes.

MATERIALS

Part A

- graduated cylinder
- water
- various small objects supplied by your teacher

Part B

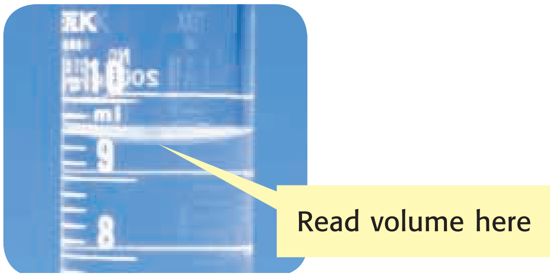
- bottle, plastic (or similar container), 2L, bottom half
- funnel
- graduated cylinder
- pan, aluminum pie
- paper towels
- water

SAFETY

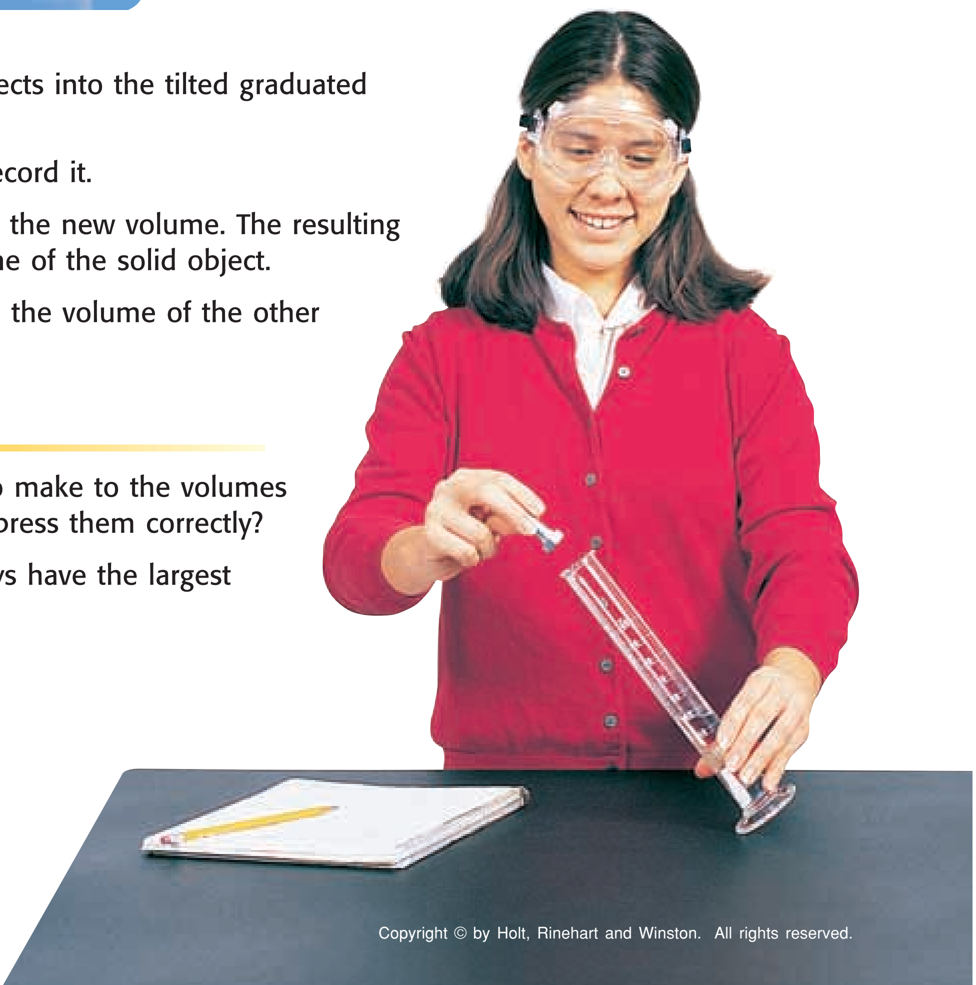
Part A: Finding the Volume of Small Objects

Procedure

1. Fill a graduated cylinder half full with water. Read and record the volume of the water. Be sure to look at the surface of the water at eye level and to read the volume at the bottom of the meniscus, as shown below.



2. Carefully slide one of the objects into the tilted graduated cylinder, as shown below.
3. Read the new volume, and record it.
4. Subtract the old volume from the new volume. The resulting amount is equal to the volume of the solid object.
5. Use the same method to find the volume of the other objects. Record your results.



Analyze the Results

1. What changes do you have to make to the volumes you determine in order to express them correctly?
2. Do the heaviest objects always have the largest volumes? Why or why not?

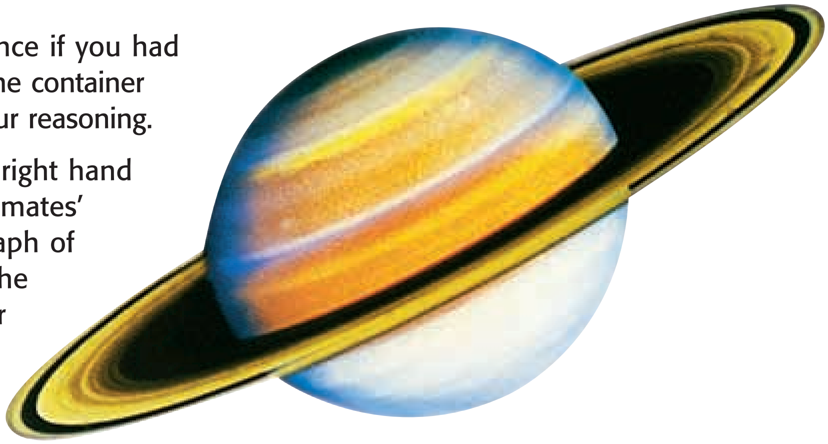
Part B: Finding the Volume of Your Hand

Procedure

1. Completely fill the container with water. Put the container in the center of the pie pan. Be sure not to spill any of the water into the pie pan.
2. Make a fist, and put your hand into the container up to your wrist.
3. Remove your hand, and let the excess water drip into the container, not the pie pan. Dry your hand with a paper towel.
4. Use the funnel to pour the overflow water into the graduated cylinder. Measure the volume. This measurement is the volume of your hand. Record the volume. (Remember to use the correct unit of volume for a solid object.)
5. Repeat this procedure with your other hand.

Analyze the Results

1. Was the volume the same for both of your hands? If not, were you surprised? What might account for a person's hands having different volumes?
2. Would it have made a difference if you had placed your open hand into the container instead of your fist? Explain your reasoning.
3. Compare the volume of your right hand with the volume of your classmates' right hands. Create a class graph of right-hand volumes. What is the average right-hand volume for your class?



Applying Your Data

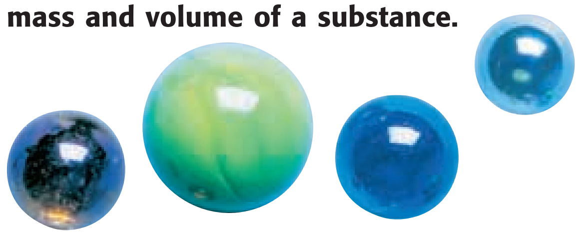
Design an experiment to determine the volume of a person's body. In your plans, be sure to include the materials needed for the experiment and the procedures that must be followed. Include a sketch that shows how your materials and methods would be used in this experiment.

Using an encyclopedia, the Internet, or other reference materials, find out how the volumes of very large samples of matter—such as an entire planet—are determined.

Skills Practice Lab

Determining Density

The density of an object is its mass divided by its volume. But how does the density of a small amount of a substance relate to the density of a larger amount of the same substance? In this lab, you will calculate the density of one marble and of a group of marbles. Then, you will confirm the relationship between the mass and volume of a substance.



MATERIALS

- balance, metric
- graduated cylinder, 100 mL
- marbles, glass (8–10)
- paper, graph
- paper towels
- water

SAFETY

Procedure

1. Copy the table below. Include one row for each marble.

Mass of marble (g)	Total mass of marbles (g)	Total volume (mL)	Volume of marbles (mL) (total volume minus 50.0 mL)	Density of marbles (g/mL) (total mass divided by volume)
		DO NOT WRITE IN BOOK		

2. Fill the graduated cylinder with 50 mL of water. If you put in too much water, twist one of the paper towels, and use it to absorb excess water.
3. Measure the mass of a marble as accurately as you can (to at least .01 g). Record the mass in the table.
4. Carefully drop the marble in the tilted cylinder, and measure the total volume. Record the volume in the third column.
5. Measure and record the mass of another marble. Add the masses of the marbles together, and record this value in the second column of the table.
6. Carefully drop the second marble in the graduated cylinder. Complete the row of information in the table.
7. Repeat steps 5 and 6. Add one marble at a time. Stop when you run out of marbles, the water no longer completely covers the marbles, or the graduated cylinder is full.

Analyze the Results

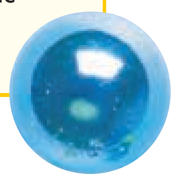
1. Examine the data in your table. As the number of marbles increases, what happens to the total mass of the marbles? What happens to the volume of the marbles? What happens to the density of the marbles?
2. Graph the total mass of the marbles (y-axis) versus the volume of the marbles (x-axis). Is the graph a straight line?

Draw Conclusions

3. Does the density of a substance depend on the amount of substance present? Explain how your results support your answer.

Applying Your Data

Calculate the slope of the graph. How does the slope compare with the values in the column entitled "Density of marbles"? Explain.



Using Scientific Methods

Skills Practice Lab

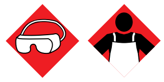
Layering Liquids

You have learned that liquids form layers according to the densities of the liquids. In this lab, you'll discover whether it matters in which order you add the liquids.

MATERIALS

- beaker (or other small, clear container)
- funnel (3)
- graduated cylinder, 10 mL (3)
- liquid A
- liquid B
- liquid C

SAFETY



Ask a Question

1. Does the order in which you add liquids of different densities to a container affect the order of the layers formed by those liquids?

Form a Hypothesis

2. Write a possible answer to the question above.

Test the Hypothesis

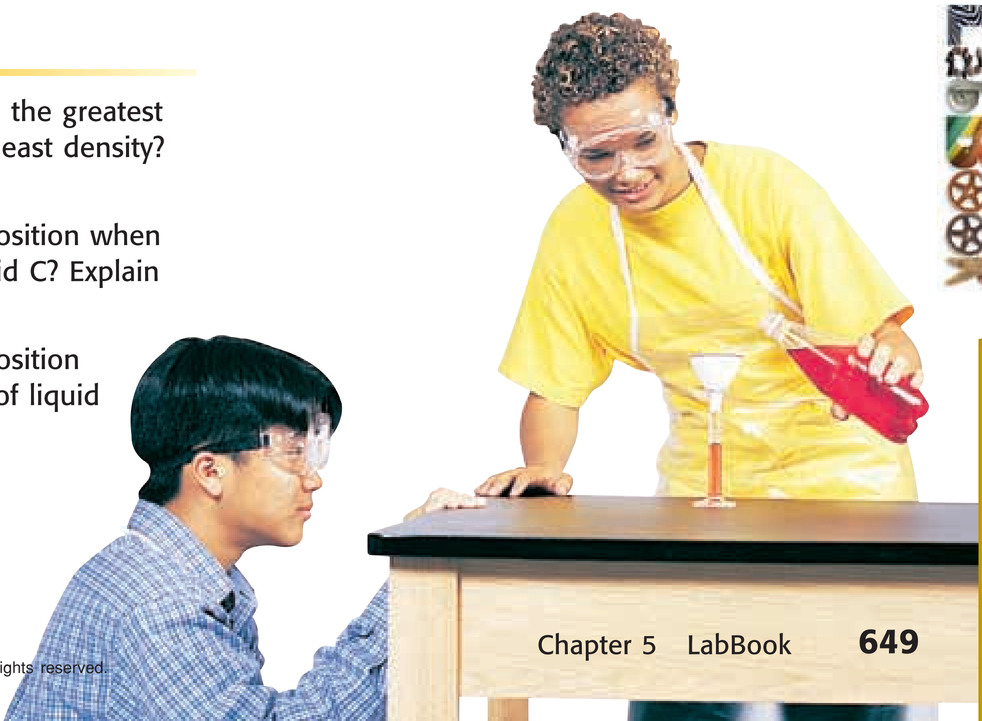
3. Using the graduated cylinders, add 10 mL of each liquid to the clear container. Remember to read the volume at the bottom of the meniscus, as shown below. Record the order in which you added the liquids.
4. Observe the liquids in the container. Sketch what you see. Be sure to label the layers and the colors.
5. Add 10 mL more of liquid C. Observe what happens, and record your observations.
6. Add 20 mL more of liquid A. Observe what happens, and record your observations.

Analyze the Results

1. Which of the liquids has the greatest density? Which has the least density? How can you tell?
2. Did the layers change position when you added more of liquid C? Explain your answer.
3. Did the layers change position when you added more of liquid A? Explain your answer.
4. Find out in what order your classmates added the liquids to the container. Compare your results with those of a classmate who added the liquids in a different order. Were your results different? Explain why or why not.

Draw Conclusions

5. Based on your results, evaluate your hypothesis from step 2.



Using Scientific Methods

Skills Practice Lab

Full of Hot Air!

Why do hot-air balloons float gracefully above Earth, but balloons you blow up fall to the ground? The answer has to do with the density of the air inside the balloon. *Density* is mass per unit volume, and volume is affected by changes in temperature. In this experiment, you will investigate the relationship between the temperature of a gas and its volume. Then, you will be able to determine how the temperature of a gas affects its density.

MATERIALS

- balloon
- beaker, 250 mL
- gloves, heat-resistant
- hot plate
- ice water
- pan, aluminum (2)
- ruler, metric
- water

SAFETY

Ask a Question

1. How does an increase or decrease in temperature affect the volume of a balloon?

Form a Hypothesis

2. Write a hypothesis that answers the question above.

Test the Hypothesis

3. Fill an aluminum pan with water about 4 cm to 5 cm deep. Put the pan on the hot plate, and turn the hot plate on.
4. Fill the other pan 4 cm to 5 cm deep with ice water.
5. Blow up a balloon inside the 500 mL beaker, as shown. The balloon should fill the beaker but should not extend outside the beaker. Tie the balloon at its opening.

6. Place the beaker and balloon in the ice water. Observe what happens. Record your observations.
7. Remove the balloon and beaker from the ice water. Observe the balloon for several minutes. Record any changes.
8. Put on heat-resistant gloves. When the hot water begins to boil, put the beaker and balloon in the hot water. Observe the balloon for several minutes, and record your observations.
9. Turn off the hot plate. When the water has cooled, carefully pour it into a sink.

Analyze the Results

1. Summarize your observations of the balloon. Relate your observations to thermal expansion.
2. Was your hypothesis from step 2 supported? If not, revise your hypothesis.

Draw Conclusions

3. Based on your observations, how is the density of a gas affected by an increase or decrease in temperature?

Skills Practice Lab

Can Crusher

Condensation can occur when gas particles come near the surface of a liquid. The gas particles slow down because they are attracted to the liquid. This reduction in speed causes the gas particles to condense into a liquid. In this lab, you'll see that particles that have condensed into a liquid don't take up as much space and therefore don't exert as much pressure as they did in the gaseous state.

MATERIALS

- beaker, 1 L
- can, aluminum (2)
- gloves, heat-resistant
- hot plate
- tongs
- water

SAFETY

Procedure

1. Fill the beaker with room-temperature water.
2. Place just enough water in an aluminum can to slightly cover the bottom.
3. Put on heat-resistant gloves. Place the aluminum can on a hot plate turned to the highest temperature setting.
4. Heat the can until the water is boiling. Steam should be rising vigorously from the top of the can.
5. Using tongs, quickly pick up the can, and place the top 2 cm of the can upside down in the 1 L beaker filled with water.
6. Describe your observations.

Analyze the Results

1. The can was crushed because the atmospheric pressure outside the can became greater than the pressure inside the can. Explain what happened inside the can to cause the difference in pressure.

Draw Conclusions

2. Inside every popcorn kernel is a small amount of water. When you make popcorn, the water inside the kernels is heated until it becomes steam. Explain how the popping of the kernels is the opposite of what you saw in this lab. Be sure to address the effects of pressure in your explanation.

Applying Your Data

Try the experiment again, but use ice water instead of room-temperature water. Explain your results in terms of the effects of temperature.

Using Scientific Methods

Skills Practice Lab

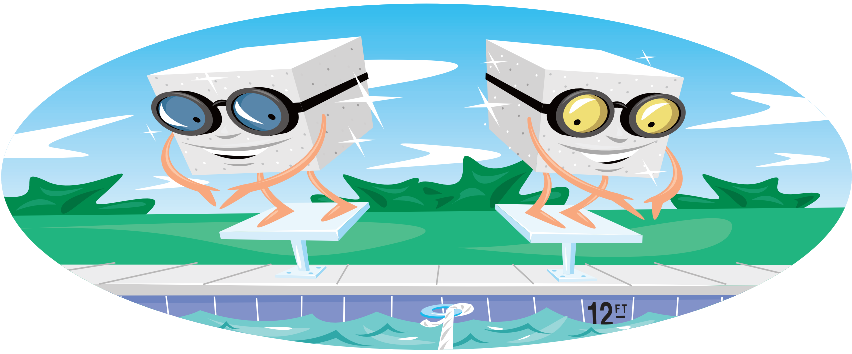
A Sugar Cube Race!

If you drop a sugar cube into a glass of water, how long will it take to dissolve? What can you do to speed up the rate at which it dissolves? Should you change something about the water, the sugar cube, or the process? In other words, what variable should you change? Before reading further, make a list of variables that could be changed in this situation. Record your list.

MATERIALS

- beakers or other clear containers (2)
- clock or stopwatch
- graduated cylinder
- sugar cubes (2)
- water
- other materials approved by your teacher

SAFETY



Ask a Question

1. Write a question you can test about factors that affect the rate sugar dissolves.

Form a Hypothesis

2. Choose one variable to test. Record your choice, and predict how changing your variable will affect the rate of dissolving.

Test the Hypothesis

3. Pour 150 mL of water into one of the beakers. Add one sugar cube, and use the stopwatch to measure how long it takes for the sugar cube to dissolve. You must not disturb the sugar cube in any way! Record this time.

4. Be sure to get your teacher's approval before you begin. You may need additional equipment.

5. Prepare your materials to test the variable you have picked. When you are ready, start your procedure for speeding up the rate at which the sugar cube dissolves. Use the stopwatch to measure the time. Record this time.

Analyze the Results

1. Compare your results with the prediction you made in step 2. Was your prediction correct? Why or why not?

Draw Conclusions

2. Why was it necessary to observe the sugar cube dissolving on its own before you tested the variable?

3. Do you think changing more than one variable would speed up the rate of dissolving even more? Explain your reasoning.

4. Discuss your results with a group that tested a different variable. Which variable had a greater effect on the rate of dissolving?

Skills Practice Lab

Making Butter

A colloid is an interesting substance. It has properties of both solutions and suspensions. Colloidal particles are not heavy enough to settle out, so they remain evenly dispersed throughout the mixture. In this activity, you will make butter—a very familiar colloid—and observe the characteristics that classify butter as a colloid.

MATERIALS

- clock or stopwatch
- container with lid, small, clear
- heavy cream
- marble

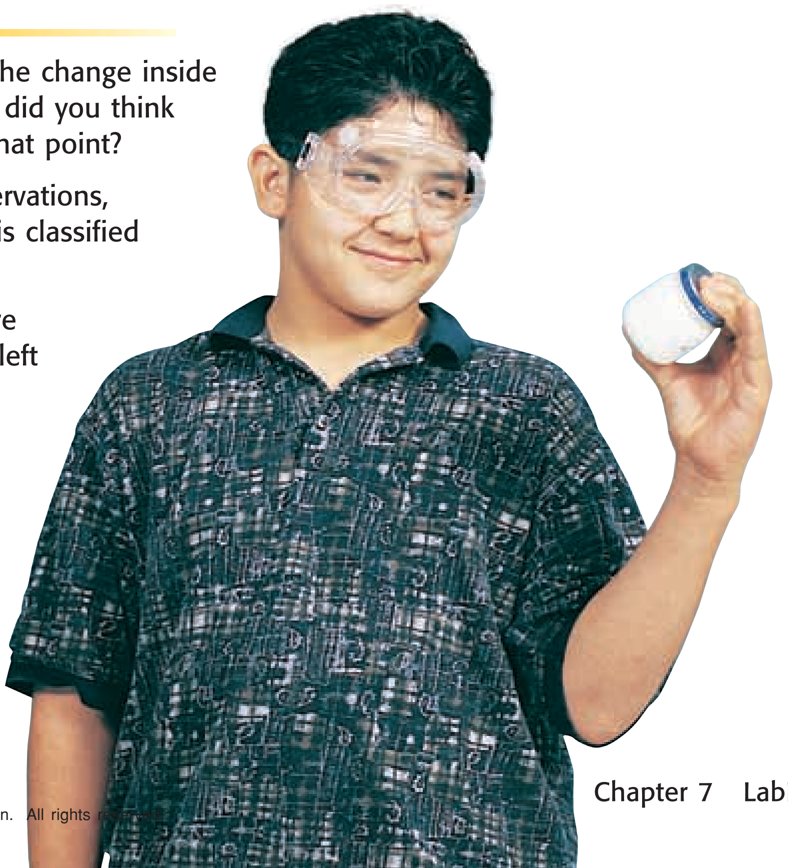
SAFETY

Procedure

1. Place a marble inside the container, and fill the container with heavy cream. Put the lid tightly on the container.
2. Take turns shaking the container vigorously and constantly for 10 min. Record the time when you begin shaking. Every minute, stop shaking the container, and hold it up to the light. Record your observations.
3. Continue shaking the container, taking turns if necessary. When you see, hear, or feel any changes inside the container, note the time and change.
4. After 10 min of shaking, you should have a lump of "butter" surrounded by liquid inside the container. Describe both the butter and the liquid in detail.
5. Let the container sit for about 10 min. Observe the butter and liquid again, and record your observations.

Analyze the Results

1. When you noticed the change inside the container, what did you think was happening at that point?
2. Based on your observations, explain why butter is classified as a colloid.
3. What kind of mixture is the liquid that is left behind? Explain.



Model-Making Lab

Unpolluting Water

In many cities, the water supply comes from a river, lake, or reservoir. This water may include several mixtures, including suspensions (with suspended dirt, oil, or living organisms) and solutions (with dissolved chemicals). To make the water safe to drink, your city's water supplier must remove impurities. In this lab, you will model the procedures used in real water treatment plants.

MATERIALS

- beaker, 250 mL (4)
- charcoal, activated, washed
- cup, plastic-foam, 8 oz (2)
- graduated cylinder
- nail, small
- paper, filter (2 pieces)
- rubber band
- ruler, metric
- sand, fine, washed
- scissors
- spoon, plastic (2)
- water, "polluted"

SAFETY

Part A: Untreated Water

Procedure

1. Measure 100 mL of "polluted" water into a graduated cylinder. Be sure to shake the bottle of water before you pour so your sample will include all the impurities.
2. Pour the contents of the graduated cylinder into one of the beakers.
3. Copy the table below, and record your observations of the water in the "Before treatment" row.

Observations

	Color	Clearness	Odor	Any layers?	Any solids?	Water volume
Before treatment						
After oil separation						
After sand filtration						
After charcoal						

Part B: Settling In

If a suspension is left standing, the suspended particles will settle to the top or bottom. You should see a layer of oil at the top.

Procedure

1. Separate the oil by carefully pouring the oil into another beaker. You can use a plastic spoon to get the last bit of oil from the water. Record your observations.

Part C: Filtration

Cloudy water can be a sign of small particles still in suspension. These particles can usually be removed by filtering. Water treatment plants use sand and gravel as filters.

Procedure

1. Make a filter as follows:
    - **a.** Use the nail to poke 5 to 10 small holes in the bottom of one of the cups.
    - **b.** Cut a circle of filter paper to fit inside the bottom of the cup. (This filter will keep the sand in the cup.)
    - **c.** Fill the cup to 2 cm below the rim with wet sand. Pack the sand tightly.
    - **d.** Set the cup inside an empty beaker.
2. Pour the polluted water on top of the sand, and let the water filter through. Do not pour any of the settled mud onto the sand. (Dispose of the mud as instructed by your teacher.) In your table, record your observations of the water collected in the beaker.

Part D: Separating Solutions

Something that has been dissolved in a solvent cannot be separated using filters. Water treatment plants use activated charcoal to absorb many dissolved chemicals.

Procedure

1. Place activated charcoal about 3 cm deep in the unused cup. Pour the water collected from the sand filtration into the cup, and stir with a spoon for 1 min.
2. Place a piece of filter paper over the top of the cup, and fasten it in place with a rubber band. With the paper securely in place, pour the water through the filter paper and back into a clean beaker. Record your observations in your table.

Analyze the Results

1. Is your unpolluted water safe to drink? Why or why not?
2. When you treat a sample of water, do you get out exactly the same amount of water that you put in? Explain your answer.
3. Some groups may still have cloudy water when they finish. Explain a possible cause for this.

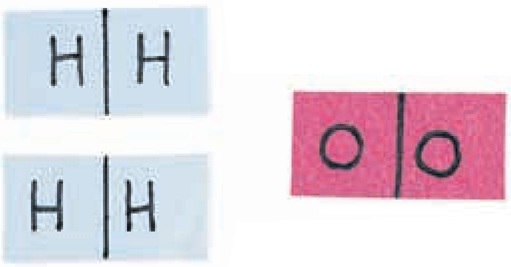
Model-Making Lab

Finding a Balance

Usually, balancing a chemical equation involves just writing. But in this activity, you will use models to practice balancing chemical equations, as shown below. By following the rules, you will soon become an expert equation balancer!

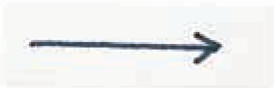
MATERIALS

- envelopes, each labeled with an unbalanced equation



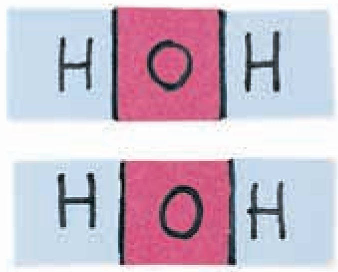
Example

$\_\_H_2 + \_\_O_2 \rightarrow \_\_H_2O$



Balanced Equation

$2H_2 + O_2 \rightarrow 2H_2O$



Procedure

1. The rules are as follows:
   a. Reactant-molecule models may be placed only to the left of the arrow.
   b. Product-molecule models may be placed only to the right of the arrow.
   c. You may use only complete molecule models.
   d. At least one of each of the reactant and product molecules shown in the equation must be included in the model when you are finished.
2. Select one of the labeled envelopes. Copy the unbalanced equation written on the envelope.
3. Open the envelope, and pull out the molecule models and the arrow. Place the arrow in the center of your work area.
4. Put one model of each molecule that is a reactant on the left side of the arrow and one model of each product on the right side.
5. Add one reactant-molecule or product-molecule model at a time until the number of each of the different-colored squares on each side of the arrow is the same. Remember to follow the rules.
6. When the equation is balanced, count the number of each of the molecule models you used. Write these numbers as coefficients, as shown in the balanced equation above.
7. Select another envelope, and repeat the steps until you have balanced all of the equations.

Analyze the Results

1. The rules specify that you are allowed to use only complete molecule models. How are these rules similar to what occurs in a real chemical reaction?
2. In chemical reactions, energy is either released or absorbed. Devise a way to improve the model to show energy being released or absorbed.

Using Scientific Methods

Skills Practice Lab

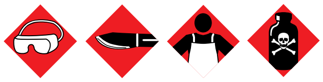
Cata-what? Catalyst!

Catalysts increase the rate of a chemical reaction without being changed during the reaction. In this experiment, hydrogen peroxide, H_2O_2, decomposes into oxygen, O_2, and water, H_2O. An enzyme present in liver cells acts as a catalyst for this reaction. You will investigate the relationship between the amount of the catalyst and the rate of the decomposition reaction.

MATERIALS

- beaker, 600 mL
- funnel
- graduated cylinder, 10 mL
- hydrogen peroxide, 3% solution
- liver cubes, small (2)
- mortar and pestle
- tape, masking
- test tubes, 10 mL (3)
- tweezers
- water, hot

SAFETY



Ask a Question

1. How does the amount of a catalyst affect reaction rate?

Form a Hypothesis

2. Write a statement that answers the question above. Explain your reasoning.

Test the Hypothesis

3. Put a small piece of masking tape near the top of each test tube, and label the tubes “1,” “2,” and “3.”
4. Create a hot-water bath by filling the beaker half full with hot water.
5. Using the funnel and graduated cylinder, measure 5 mL of the hydrogen peroxide solution into each test tube. Place the test tubes in the hot-water bath for 5 min.
6. While the test tubes warm up, grind one liver cube with the mortar and pestle.
7. After 5 min, use the tweezers to place the cube of liver in test tube 1. Place the ground liver in test tube 2. Leave test tube 3 alone.
8. Observe the reaction rate (the amount of bubbling) in all three test tubes, and record your observations.

Analyze the Results

1. Does liver appear to be a catalyst? Explain your answer.
2. Which type of liver (whole or ground) produced a faster reaction? Why?
3. What is the purpose of test tube 3?

Draw Conclusions

4. How do your results support or disprove your hypothesis?
5. Why was a hot-water bath used? (Hint: Look in your book for a definition of *activation energy.*)

Skills Practice Lab

Putting Elements Together

A synthesis reaction is a reaction in which two or more substances combine to form a single compound. The resulting compound has different chemical and physical properties than the substances from which it is composed. In this activity, you will synthesize, or create, copper(II) oxide from the elements copper and oxygen.

MATERIALS

- balance, metric
- Bunsen burner (or portable burner)
- copper powder
- evaporating dish
- gauze, wire
- gloves, protective
- igniter
- paper, weighing
- ring stand and ring
- tongs

SAFETY

Procedure

1. Copy the table below.

Data Collection Table

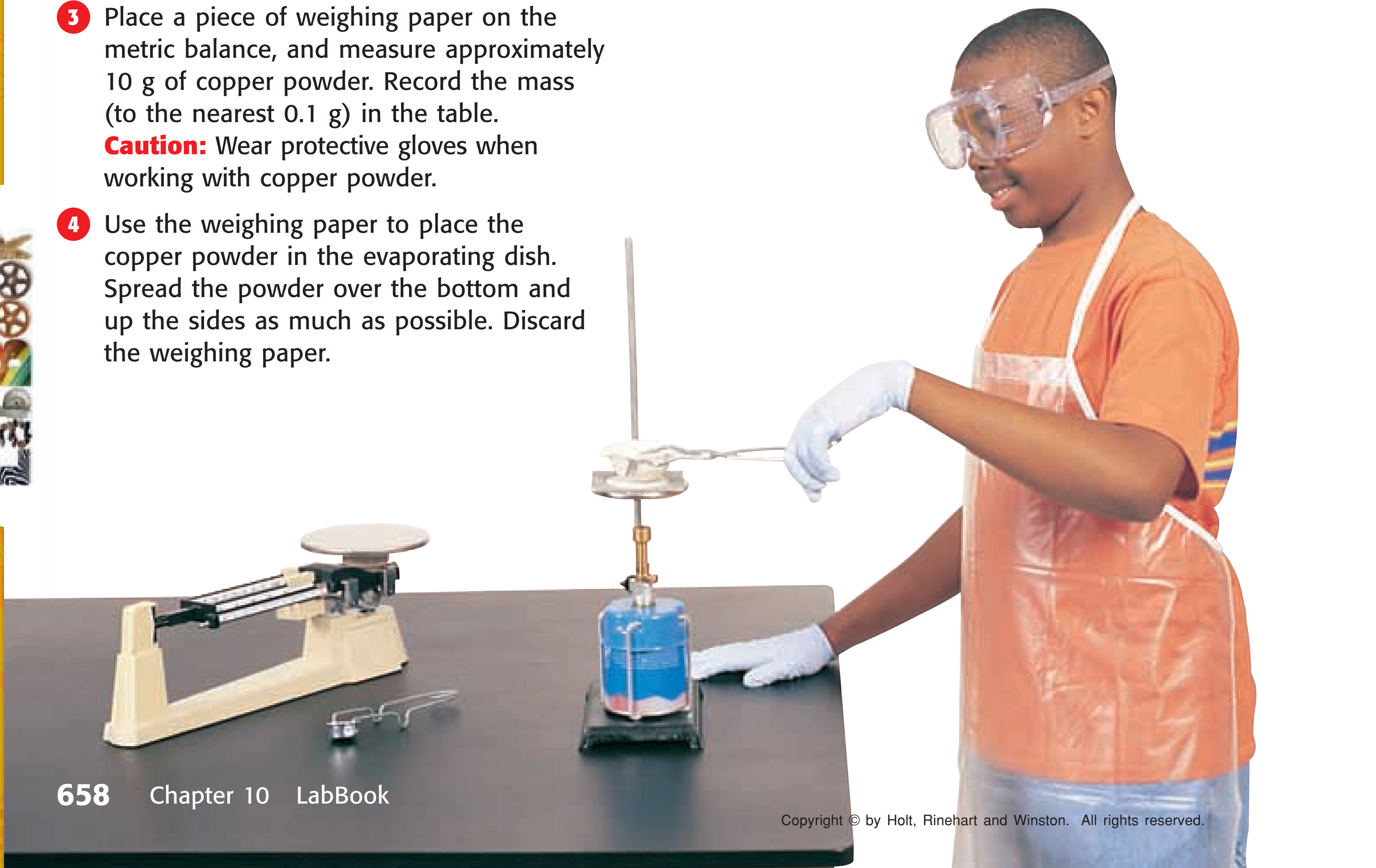
Object	Mass (g)
Evaporating dish	
Copper powder	
Copper + evaporating dish after heating	
Copper(II) oxide	

DO NOT WRITE IN BOOK

2. Use the metric balance to measure the mass (to the nearest 0.1 g) of the empty evaporating dish. Record this mass in the table.

3. Place a piece of weighing paper on the metric balance, and measure approximately 10 g of copper powder. Record the mass (to the nearest 0.1 g) in the table. **Caution:** Wear protective gloves when working with copper powder.

4. Use the weighing paper to place the copper powder in the evaporating dish. Spread the powder over the bottom and up the sides as much as possible. Discard the weighing paper.



5. Set up the ring stand and ring. Place the wire gauze on top of the ring. Carefully place the evaporating dish on the wire gauze.
6. Place the Bunsen burner under the ring and wire gauze. Use the igniter to light the Bunsen burner. **Caution:** Use extreme care when working near an open flame.
7. Heat the evaporating dish for 10 min.
8. Turn off the burner, and allow the evaporating dish to cool for 10 min. Use tongs to remove the evaporating dish and to place it on the balance to determine the mass. Record the mass in the table.
9. Determine the mass of the reaction product—copper(II) oxide—by subtracting the mass of the evaporating dish from the mass of the evaporating dish and copper powder after heating. Record this mass in the table.

Analyze the Results

1. What evidence of a chemical reaction did you observe after the copper was heated?
2. Explain why there was a change in mass.
3. How does the change in mass support the idea that this reaction is a synthesis reaction?

Draw Conclusions

4. Why was powdered copper used rather than a small piece of copper? (Hint: How does surface area affect the rate of the reaction?)
5. Why was the copper heated? (Hint: Look in your book for the discussion of activation energy.)
6. The copper bottoms of cooking pots can turn black when used. How is that similar to the results you obtained in this lab?

Applying Your Data

Rust, shown below, is iron(III) oxide—the product of a synthesis reaction between iron and oxygen. How does painting a car help prevent this type of reaction?

Using Scientific Methods

Inquiry Lab

Save the Cube!

The biggest enemy of an ice cube is the transfer of thermal energy—heat. Energy can be transferred to an ice cube in three ways: conduction (the transfer of energy through direct contact), convection (the transfer of energy by the movement of a liquid or gas), and radiation (the transfer of energy through matter or space). Your challenge in this activity is to design a way to protect an ice cube as much as possible from all three types of energy transfer.

MATERIALS

- bag, plastic, small
- balance, metric
- cup, plastic or paper, small
- ice cube
- milk carton, empty, half-pint
- assorted materials provided by your teacher

Ask a Question

1. What materials prevent energy transfer most efficiently?

Form a Hypothesis

2. Design a system that protects an ice cube against each type of energy transfer. Describe your proposed design.

Test the Hypothesis

3. Use a plastic bag to hold the ice cube and any water if the ice cube melts. You may use any of the materials to protect the ice cube. The whole system must fit inside a milk carton.
4. Find the mass of the empty cup, and record it. Then, find and record the mass of an empty plastic bag.
5. Find and record the mass of the ice cube and cup together.
6. Quickly wrap the bag (and the ice cube inside) in its protection. Remember that the package must fit in the milk carton.
7. Place your ice cube in the "thermal zone" set up by your teacher. After 10 min, remove the ice cube from the zone.
8. Open the bag. Pour any water into the cup. Find and record the mass of the cup and water together.
9. Find and record the mass of the water by subtracting the mass of the empty cup from the mass of the cup and water.
10. Use the same method to determine the mass of the ice cube.
11. Using the following equation, find and record the percentage of the ice cube that melted:

$$\%\ melted = \frac{mass\ of\ water}{mass\ of\ ice\ cube} \times 100$$

Analyze the Results

1. Compared with other designs in your class, how well did your design protect against each type of energy transfer? How could you improve your design?

Model-Making Lab

Counting Calories

Energy transferred by heat is often expressed in units called *calories.* In this lab, you will build a model of a device called a *calorimeter.* Scientists often use calorimeters to measure the amount of energy that can be transferred by a substance. In this experiment, you will construct your own calorimeter and test it by measuring the energy released by a hot penny.

MATERIALS

- cup, plastic-foam, large
- cup, plastic-foam, small, with lid
- graduated cylinder, 100 mL
- heat source
- penny
- stopwatch
- thermometer
- tongs
- water

SAFETY

Procedure

1. Copy the table below.

Data Collection Table									
Seconds	0	15	30	45	60	75	90	105	120
Water temperature (°C)									

2. Place the lid on the small plastic-foam cup, and insert a thermometer through the hole in the top of the lid. (The thermometer should not touch the bottom of the cup.) Place the small cup inside the large cup to complete the calorimeter.
3. Remove the lid from the small cup, and add 50 mL of room-temperature water to the cup. Measure the water's temperature, and record the value in the first column (0 s) of the table.
4. Using tongs, heat the penny carefully. Add the penny to the water in the small cup, and replace the lid. Start your stopwatch.
5. Every 15 s, measure and record the temperature. Gently swirl the large cup to stir the water, and continue recording temperatures for 2 min (120 s).

Analyze the Results

1. What was the total temperature change of the water after 2 min?
2. The number of calories absorbed by the water is the mass of the water (in grams) multiplied by the temperature change (in °C) of the water. How many calories were absorbed by the water? (Hint: 1 mL water = 1 g water)
3. In terms of heat, explain where the calories to change the water temperature came from.

Using Scientific Methods

Model-Making Lab

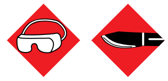
Tune In!

You probably have listened to radios many times in your life. Modern radios are complicated electronic devices. However, radios do not have to be so complicated. The basic parts of all radios include a diode, an inductor, a capacitor, an antenna, a ground wire, and an earphone (or a speaker and amplifier on a large radio). In this activity, you will examine each of these components one at a time as you build a working model of a radio-wave receiver.

MATERIALS

- aluminum foil
- antenna
- cardboard, 20 cm × 30 cm
- cardboard tubes (2)
- connecting wires, 30 cm each (7)
- diode
- earphone
- ground wire
- paper (1 sheet)
- paper clips (3)
- scissors
- tape
- wire, insulated, 2 m

SAFETY



Ask a Question

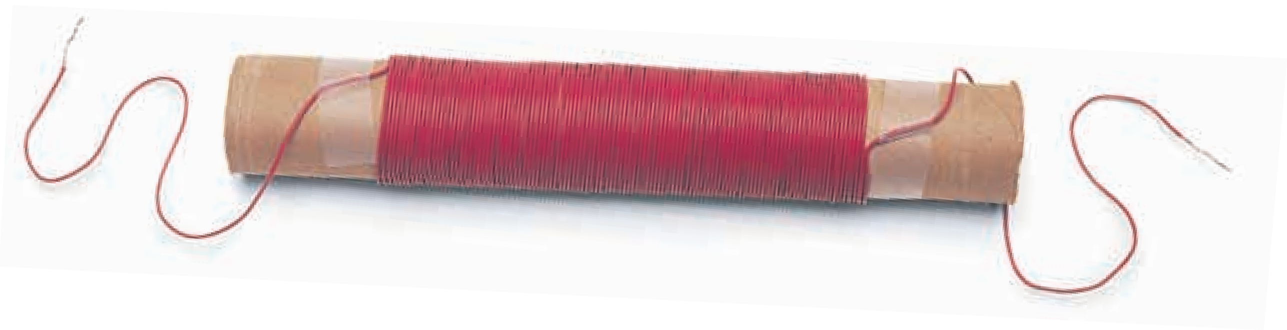
1. Write a question you can test using the procedure in this lab.

Form a Hypothesis

2. Write a possible answer to the question you wrote in the step above. Explain your reasoning.

Test the Hypothesis

3. Examine the diode. Describe it on another sheet of paper.
4. A diode carries current in only one direction. Draw the inside of a diode, and illustrate how the diode might allow current in only one direction.
5. An inductor controls the amount of electric current because of the resistance of the wire. Make an inductor by winding the insulated wire around a cardboard tube approximately 100 times. Wind the wire so that all the turns of the coil are neat and in an orderly row, as shown below. Leave about 25 cm of wire on each end of the coil. The coil of wire may be held on the tube using tape.



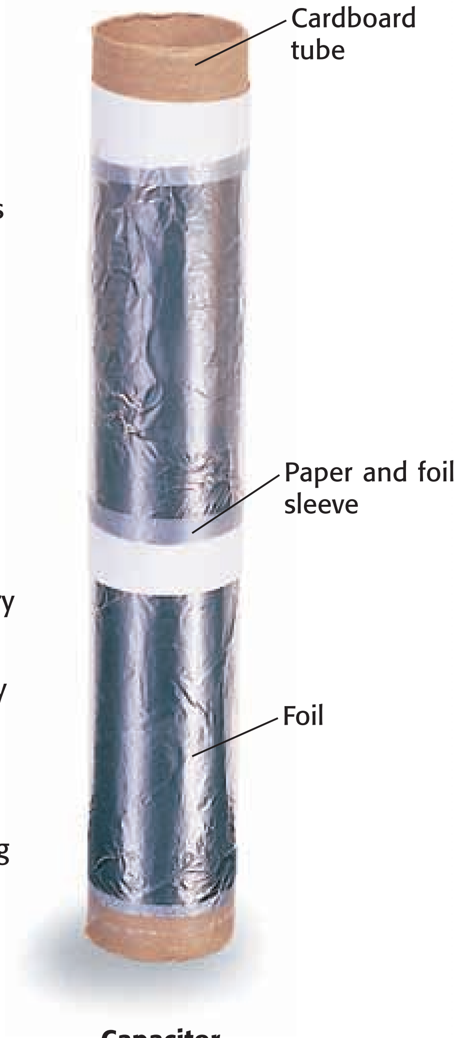
6. Now, you will construct the variable capacitor. A capacitor stores electrical energy when an electric current is applied. A variable capacitor is a capacitor in which the amount of energy stored can be changed. Cut a piece of aluminum foil to go around the tube but only half the length of the tube, as shown at right. Keep the foil as wrinkle-free as possible as you wrap it around the tube, and tape the foil to itself. Now, tape the foil to the tube.

7. Use the sheet of paper and tape to make a sliding cover on the tube. The paper should completely cover the foil on the tube with about 1 cm extra.

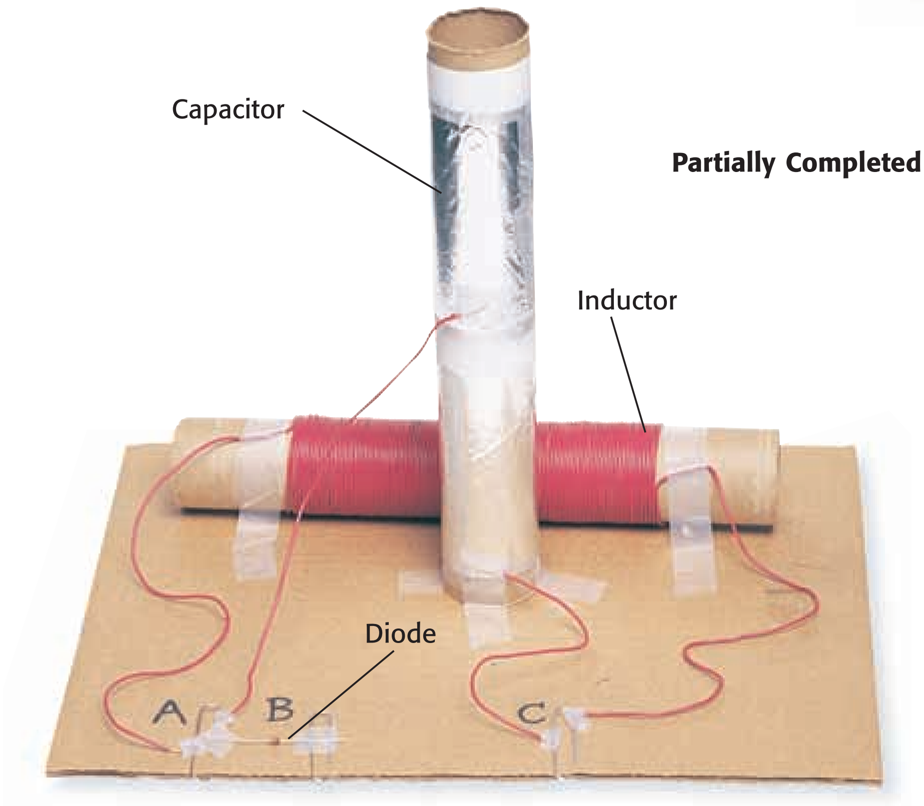
8. Cut another sheet of aluminum foil to wrap completely around the paper. Leave approximately 1 cm of paper showing at each end of the foil. Tape this foil sheet to the paper sleeve. If you have done this correctly, you have a paper/foil sheet that will slide up and down the tube over the stationary foil. The two pieces of foil should not touch.

9. Stand your variable capacitor on its end so that the stationary foil is at the bottom. The amount of stored energy is greater when the sleeve is down than when the sleeve is up.

10. Use tape to attach one connecting wire to the stationary foil at the end of the tube. Use tape to attach another connecting wire to the sliding foil sleeve. Be sure that the metal part of the wire touches the foil.

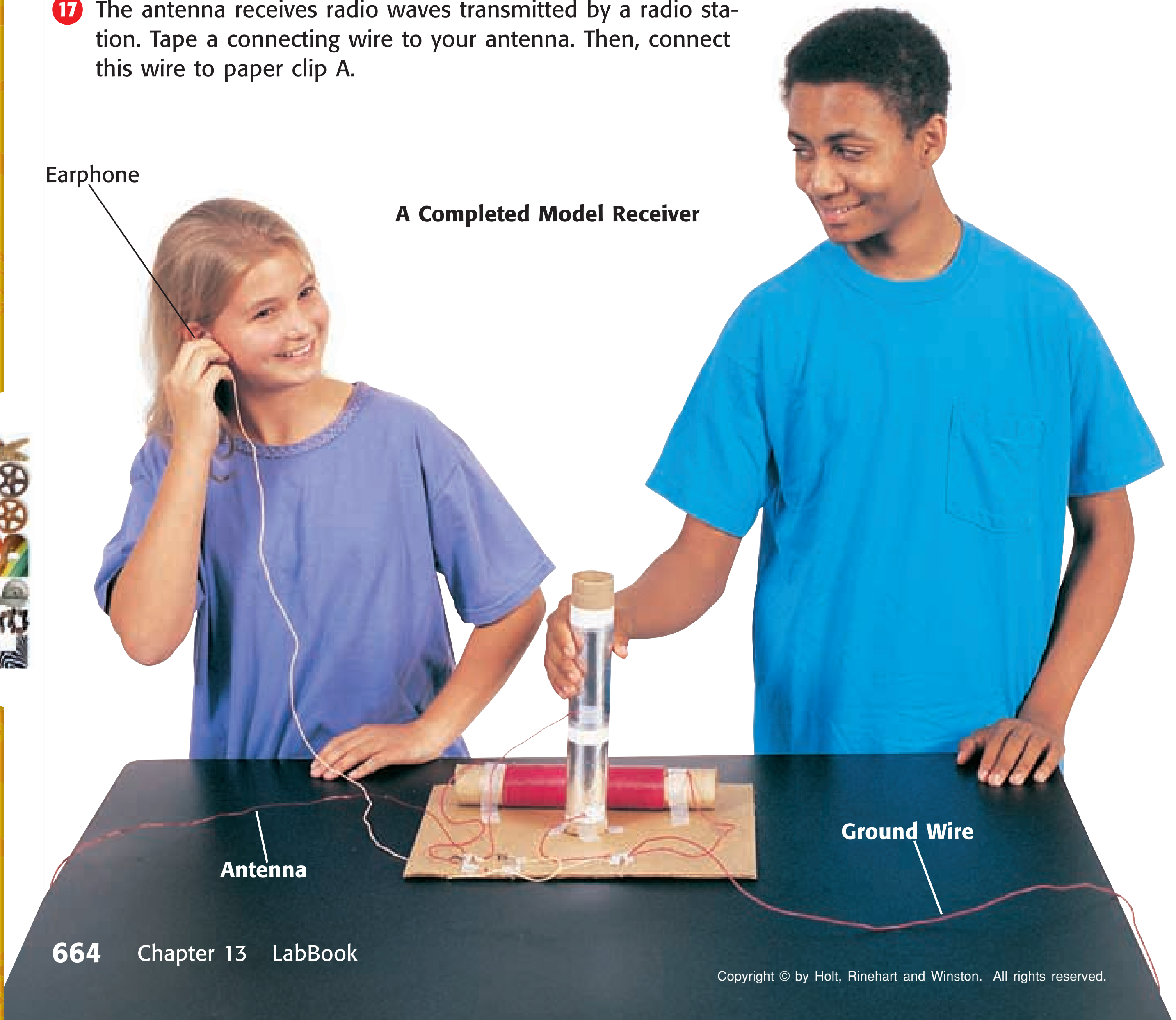


Capacitor



Partially Completed Model Receiver

11. Hook three paper clips on one edge of the cardboard, as shown below. Label one paper clip “A,” the second one “B,” and the third one “C.”
12. Lay the inductor on the piece of cardboard, and tape it to the cardboard.
13. Stand the capacitor next to the inductor, and tape the tube to the cardboard. Be sure not to tape the sleeve—it must be free to slide.
14. Use tape to connect the diode to paper clips A and B. The cathode should be closest to paper clip B. (The cathode end of the diode is the one with the dark band.) Make sure that all connections have good metal-to-metal contact.
15. Connect one end of the inductor to paper clip A and the other end to paper clip C. Use tape to hold the wires in place.
16. Connect the wire from the sliding part of the capacitor to paper clip A. Connect the other wire (from the stationary foil) to paper clip C.
17. The antenna receives radio waves transmitted by a radio station. Tape a connecting wire to your antenna. Then, connect this wire to paper clip A.



A Completed Model Receiver

18 Use tape to connect one end of the ground wire to paper clip C. The other end of the ground wire should be connected to an object specified by your teacher.

19 The earphone will allow you to detect the radio waves you receive. Connect one wire from the earphone to paper clip B and the other wire to paper clip C.

20 You are now ready to begin listening. With everything connected and the earphone in your ear, slowly slide the paper/foil sheet of the capacitor up and down. Listen for a very faint sound. You may have to troubleshoot many of the parts to get your receiver to work. As you troubleshoot, check to be sure there is good contact between all the connections.

Analyze the Results

1 Describe the process of operating your receiver.

2 Considering what you have learned about a diode, why is it important to have the diode connected the correct way?

3 A function of the inductor on a radio is to "slow the current down." Why does the inductor you made slow the current down more than does a straight wire the length of your coil?

4 A capacitor consists of any two conductors separated by an insulator. For your capacitor, list the two conductors and the insulator.

Draw Conclusions

5 Explain why the amount of stored energy is increased down when you slide the foil sleeve and decreased when you slide the foil sleeve up.

6 Make a list of ways that your receiver is similar to a modern radio. Make a second list of ways that your receiver is different from a modern radio.

Inquiry Lab

Orient Yourself!

You have been invited to attend an orienteering event with your neighbors. In orienteering events, participants use maps and compasses to find their way along a course. There are several control points that each participant must reach. The object is to reach each control point and then the finish line. Orienteering events are often timed competitions. In order to find the fastest route through the course, the participants must read the map and use their compass correctly. Being the fastest runner does not necessarily guarantee finishing first. You also must choose the most direct route to follow.

Your neighbors participate in several orienteering events each year. They always come home raving about how much fun they had. You would like to join them, but you will need to learn how to use your compass first.

MATERIALS

- compass, magnetic
- course map
- pencils (or markers), colored (2)
- ruler

Procedure

1. Together as a class, go outside to the orienteering course your teacher has made.
2. Hold your compass flat in your hand. Turn the compass until the N is pointing straight in front of you. (The needle in your compass will always point north.) Turn your body until the needle lines up with the N on your compass. You are now facing north.
3. Regardless of which direction you want to face, you should always align the end of the needle with the N on your compass. If you are facing south, the needle will be pointing directly toward your body. When the N is aligned with the needle, the S will be directly in front of you, and you will be facing south.
4. Use your compass to face east. Align the needle with the N. Where is the E? Turn to face that direction. You are facing east when the needle and the N are aligned and the E is directly in front of you.
5. In an orienteering competition, you will need to know how to determine which direction you are traveling. Now, face any direction you choose.

6. Do not move, but rotate the compass to align the needle on your compass with the N. What direction are you facing? You are probably not facing directly north, south, east, or west. If you are facing between north and west, you are facing northwest. If you are facing between north and east, you are facing northeast.
7. Find a partner or partners to follow the course your teacher has made. Get a copy of the course map from your teacher. It will show several control points. You must stop at each one. You will need to follow this map to find your way through the course. Find and stand at the starting point.
8. Face the next control point on your map. Rotate your compass to align the needle on your compass with the N. What direction are you facing?
9. Use the ruler to draw a line on your map between the two control points. On your map, write the direction between the starting point and the next control point.
10. Walk toward the control point. Keep your eyes on the horizon, not on your compass. You might need to go around an obstacle, such as a fence or a building. Use the map to find the easiest way around.
11. Next to the control point symbol on your map, record the color or code word you find at the control point.
12. Repeat steps 8–11 for each control point. Follow the points in order as they are labeled. For example, determine the direction from control point 1 to control point 2. Be sure to include the direction between the final control point and the starting point.

Analyze the Results

1. The object of an orienteering competition is to arrive at the finish line first. The maps provided at these events do not instruct the participants to follow a specific path. In one form of orienteering, called *score orienteering,* competitors may find the control points in any order. Look at your map. If this course were used for a score-orienteering competition, would you change your route? Explain.

Draw Conclusions

2. If there is time, follow the map again. This time, use your own path to find the control points. Draw this path and the directions on your map in a different color. Do you believe this route was faster? Why?

Applying Your Data

Do some research to find out about orienteering events in your area. The Internet and local newspapers may be good sources for the information. Are there any events that you would like to attend?

Using Scientific Methods

Skills Practice Lab

Topographic Tuber

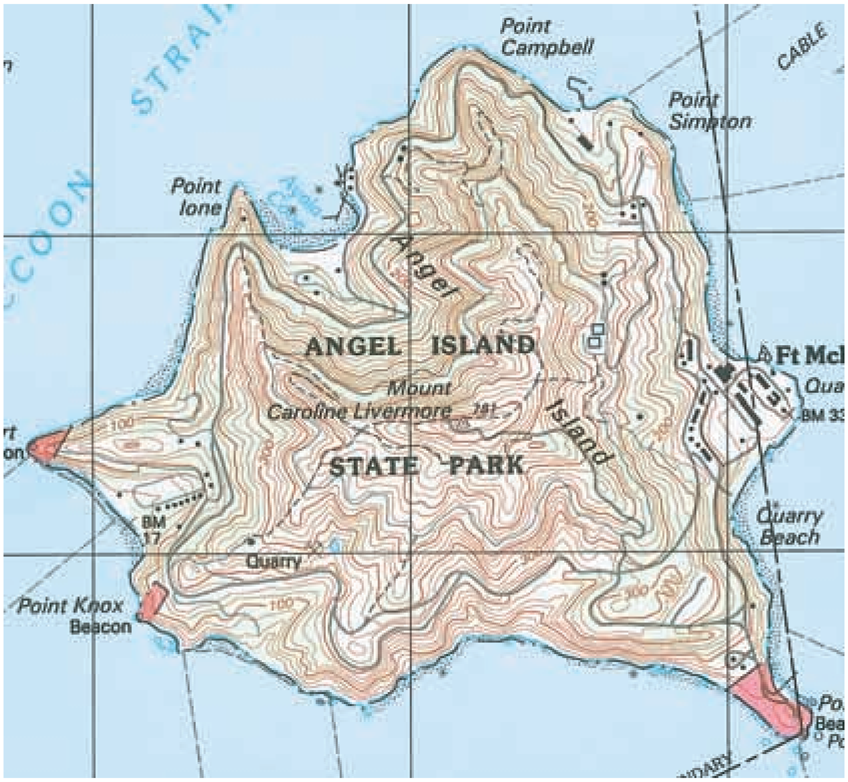
Imagine that you live on top of a tall mountain and often look down on the lake below. Every summer, an island appears. You call it Sometimes Island because it goes away again during heavy fall rains. This summer, you begin to wonder if you could make a topographic map of Sometimes Island. You don't have fancy equipment to make the map, but you have an idea. What if you place a meterstick with the 0 m mark at the water level in the summer? Then, as the expected fall rains come, you could draw the island from above as the water rises. Would this idea really work?

MATERIALS

- container, clear plastic storage, with transparent lid
- marker, transparency
- paper, tracing
- potato, cut in half
- ruler, metric
- water

Ask a Question

1. How do I make a topographic map?



Form a Hypothesis

2. Write a hypothesis that is a possible answer to the question above. Describe the method you would use.

Test the Hypothesis

3. Place a mark at the storage container's base. Label this mark "0 cm" with a transparency marker.
4. Measure and mark 1 cm increments up the side of the container until you reach the top of the container. Label these marks "1 cm," "2 cm," "3 cm," and so on.
5. The scale for your map will be 1 cm = 10 m. Draw a line 2 cm long in the bottom right-hand corner of the lid. Place hash marks at 0 cm, 1 cm, and 2 cm. Label these marks "0 m," "10 m," and "20 m."
6. Place the potato, flat side down, in the center of the container.
7. Place the lid on the container, and seal it.

8. Viewing the potato from above, use the transparency marker to trace the outline of the potato where it rests on the bottom of the container. The floor of the container corresponds to the summer water level in the lake.
9. Label this contour “0 m.” (For this activity, assume that the water level in the lake during the summer is the same as sea level.)
10. Pour water into the container until it reaches the line labeled “1 cm.”
11. Again, place the lid on the container, and seal it. Part of the potato will be sticking out above the water. Viewing the potato from above, trace the part of the potato that touches the top of the water.
12. Label the elevation of the contour line you drew in step 11. According to the scale, the elevation is 10 m.
13. Remove the lid. Carefully pour water into the container until it reaches the line labeled “2 cm.”
14. Place the lid on the container, and seal it. Viewing the potato from above, trace the part of the potato that touches the top of the water at this level.
15. Use the scale to calculate the elevation of this line. Label the elevation on your drawing.
16. Repeat steps 13–15, adding 1 cm to the depth of the water each time. Stop when the potato is completely covered.
17. Remove the lid, and set it on a tabletop. Place tracing paper on top of the lid. Trace the contours from the lid onto the paper. Label the elevation of each contour line. Congratulations! You have just made a topographic map!

Analyze the Results

1. What is the contour interval of this topographic map?

2. By looking at the contour lines, how can you tell which parts of the potato are steeper?
3. What is the elevation of the highest point on your map?

Draw Conclusions

4. Do all topographic maps have a 0 m elevation contour line as a starting point? How would this affect a topographic map of Sometimes Island? Explain your answer.
5. Would this method of measuring elevation be an effective way to make a topographic map of an actual area on Earth’s surface? Why or why not?

Applying Your Data

Place all of the potatoes on a table or desk at the front of the room. Your teacher will mix up the potatoes as you trade topographic maps with another group. By reading the topographic map you just received, can you pick out the matching potato?

Using Scientific Methods

Model-Making Lab

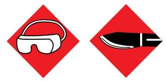
Oh, the Pressure!

When scientists want to understand natural processes, such as mountain formation, they often make models to help them. Models are useful in studying how rocks react to the forces of plate tectonics. A model can demonstrate in a short amount of time geological processes that take millions of years. Do the following activity to find out how folding and faulting occur in the Earth's crust.

MATERIALS

- can, soup (or rolling pin)
- clay, modeling, 4 colors
- knife, plastic
- newspaper
- pencils, colored
- poster board, 5 cm × 5 cm squares (2)
- poster board, 5 cm × 15 cm strip

SAFETY



Ask a Question

1. How do synclines, anticlines, and faults form?

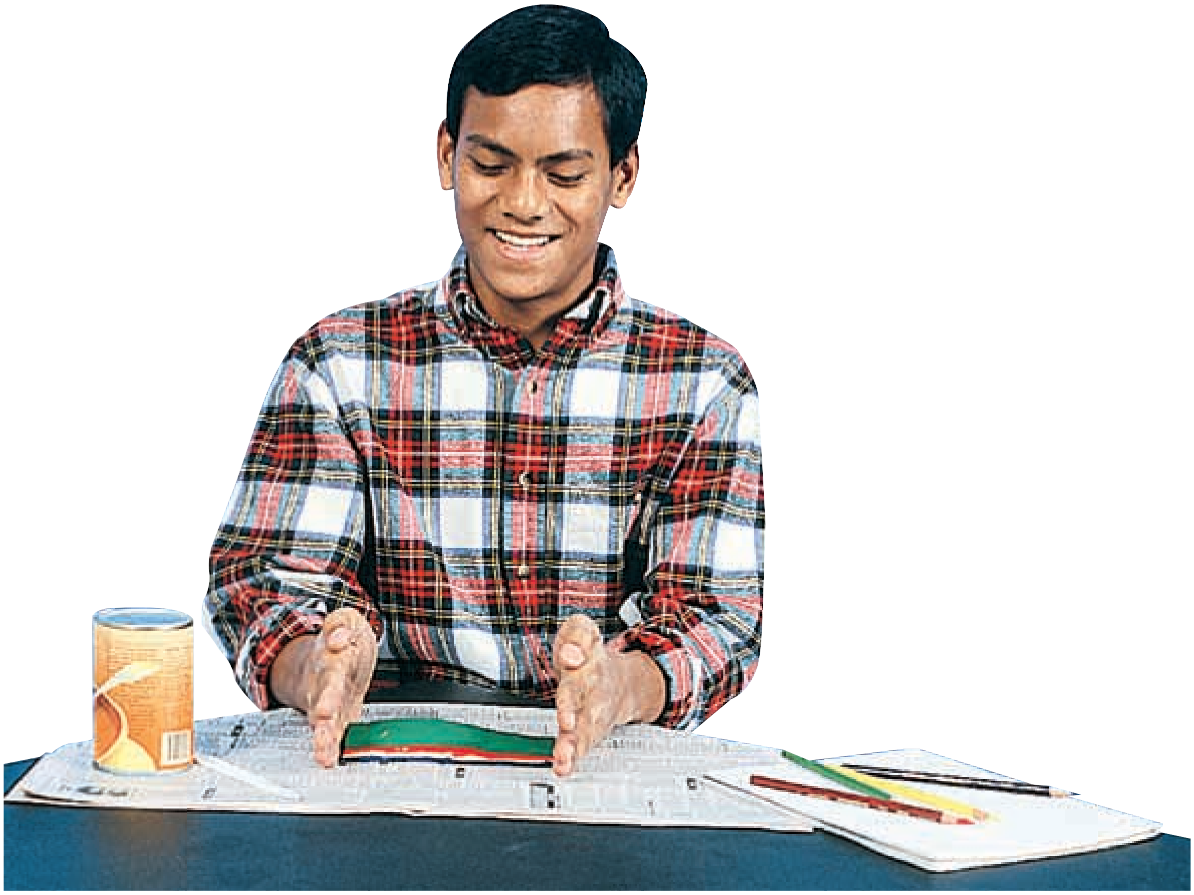
Form a Hypothesis

2. On a separate piece of paper, write a hypothesis that is a possible answer to the question above. Explain your reasoning.

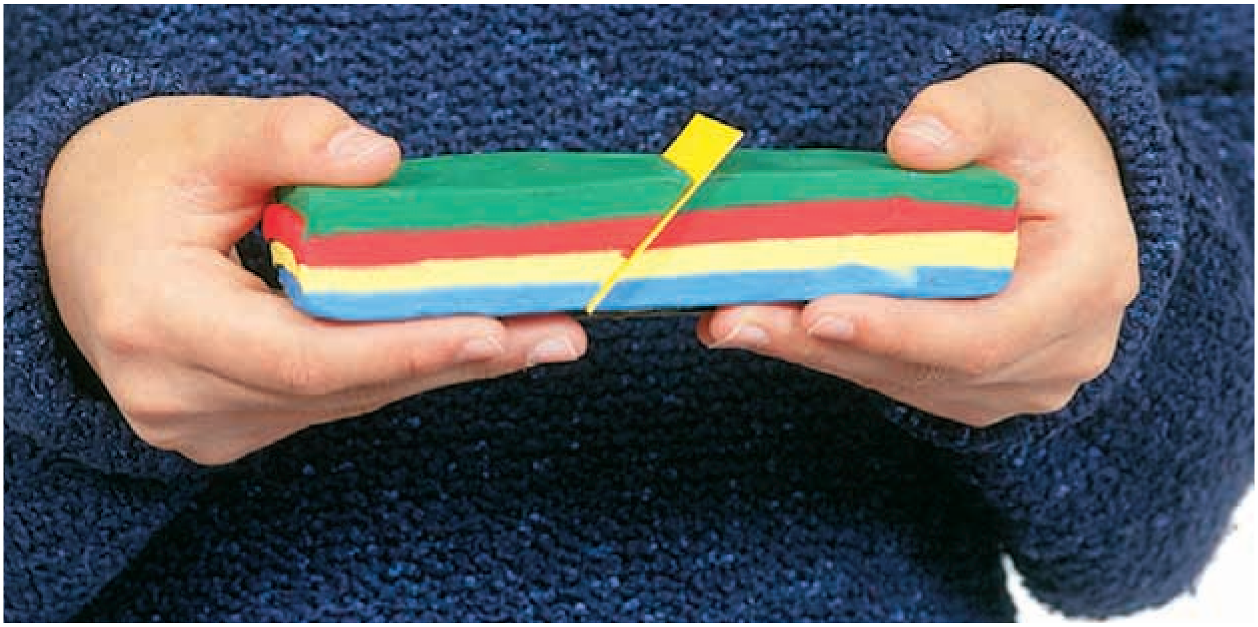
Test the Hypothesis

3. Use modeling clay of one color to form a long cylinder, and place the cylinder in the center of the glossy side of the poster-board strip.
4. Mold the clay to the strip. Try to make the clay layer the same thickness all along the strip; you can use the soup can or rolling pin to even it out. Pinch the sides of the clay so that the clay is the same width and length as the strip. Your strip should be at least 15 cm long and 5 cm wide.

5. Flip the strip over on the newspaper your teacher has placed across your desk. Carefully peel the strip from the modeling clay.
6. Repeat steps 3–5 with the other colors of modeling clay. Each person should have a turn molding the clay. Each time you flip the strip over, stack the new clay layer on top of the previous one. When you are finished, you should have a block of clay made of four layers.
7. Lift the block of clay, and hold it parallel to and just above the tabletop. Push gently on the block from opposite sides, as shown below.



8. Use the colored pencils to draw the results of step 6. Use the terms *syncline* and *anticline* to label your diagram. Draw arrows to show the direction that each edge of the clay was pushed.
9. Repeat steps 3–6 to form a second block of clay.
10. Cut the second block of clay in two at a 45° angle as seen from the side of the block.



11. Press one poster-board square on the angled end of each of the block's two pieces. The poster board represents a fault. The two angled ends represent a hanging wall and a footwall. The model should resemble the one in the photograph above.
12. Keeping the angled edges together, lift the blocks, and hold them parallel to and just above the tabletop. Push gently on the two blocks until they move. Record your observations.
13. Now, hold the two pieces of the clay block in their original position, and slowly pull them apart, allowing the hanging wall to move downward. Record your observations.

Analyze the Results

1. What happened to the first block of clay in step 7? What kind of force did you apply to the block of clay?
2. What happened to the pieces of the second block of clay in step 12? What kind of force did you apply to them?
3. What happened to the pieces of the second block of clay in step 13? Describe the forces that acted on the block and the way the pieces of the block reacted.

Draw Conclusions

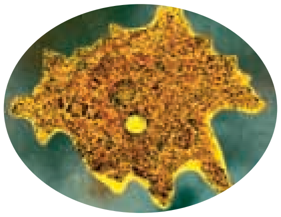
4. Summarize how the forces you applied to the blocks of clay relate to the way tectonic forces affect rock layers. Be sure to use the terms *fold, fault, anticline, syncline, hanging wall, footwall, tension,* and *compression* in your summary.

Skills Practice Lab

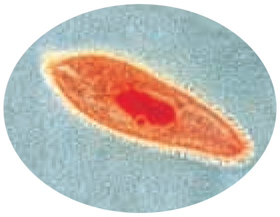
Cells Alive!

You have probably used a microscope to look at single-celled organisms such as those shown below. They can be found in pond water. In the following exercise, you will look at *Protococcus*—algae that form a greenish stain on tree trunks, wooden fences, flowerpots, and buildings.

Euglena



Amoeba



Paramecium

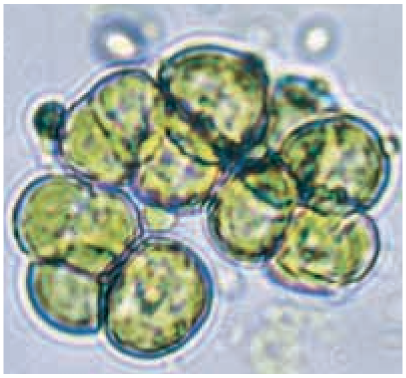
MATERIALS

- eyedropper
- microscope
- microscope slide and coverslip
- *Protococcus* (or other algae)
- water

SAFETY

Procedure

1. Locate some *Protococcus*. Scrape a small sample into a container. Bring the sample to the classroom, and make a wet mount of it as directed by your teacher. If you can't find *Protococcus* outdoors, look for algae on the glass in an aquarium. Such algae may not be *Protococcus,* but it will be a very good substitute.
2. Set the microscope on low power to examine the algae. On a separate sheet of paper, draw the cells that you see.
3. Switch to high power to examine a single cell. Draw the cell.
4. You will probably notice that each cell contains several chloroplasts. Label a chloroplast on your drawing. What is the function of the chloroplast?
5. Another structure that should be clearly visible in all the algae cells is the nucleus. Find the nucleus in one of your cells, and label it on your drawing. What is the function of the nucleus?
6. What does the cytoplasm look like? Describe any movement you see inside the cells.



Protococcus

Analyze the Results

1. Are *Protococcus* single-celled organisms or multicellular organisms?
2. How are *Protococcus* different from amoebas?

Skills Practice Lab

Stayin' Alive!

Every second of your life, your body's trillions of cells take in, use, and store energy. They repair themselves, reproduce, and get rid of waste. Together, these processes are called *metabolism.* Your cells use the food that you eat to provide the energy you need to stay alive.

Your Basal Metabolic Rate (BMR) is a measurement of the energy that your body needs to carry out all the basic life processes while you are at rest. These processes include breathing, keeping your heart beating, and keeping your body's temperature stable. Your BMR is influenced by your gender, your age, and many other things. Your BMR may be different from everyone else's, but it is normal for you. In this activity, you will find the amount of energy, measured in Calories, you need every day in order to stay alive.

MATERIALS

- bathroom scale
- tape measure

Procedure

1. Find your weight on a bathroom scale. If the scale measures in pounds, you must convert your weight in pounds to your mass in kilograms. To convert your weight in pounds (lb) to mass in kilograms (kg), multiply the number of pounds by 0.454.

Example: If Carlos weighs 125 lb, his mass in kilograms is:

$$\begin{array}{r} 125\ \text{lb} \\ \times\ \underline{0.454} \\ 56.75\ \text{kg} \end{array}$$

2. Use a tape measure to find your height. If the tape measures in inches, convert your height in inches to height in centimeters. To convert your height in inches (in.) to your height in centimeters (cm), multiply the number of inches by 2.54.

If Carlos is 62 in. tall, his height in centimeters is:

$$\begin{array}{r} 62\ \text{in.} \\ \times\ \underline{2.54} \\ 157.48\ \text{cm} \end{array}$$

3. Now that you know your height and mass, use the appropriate formula below to get a close estimate of your BMR. Your answer will give you an estimate of the number of Calories your body needs each day just to stay alive.

Calculating Your BMR	
Females	**Males**
65 + (10 × your mass in kilograms)	66 + (13.5 × your mass in kilograms)
+ (1.8 × your height in centimeters)	+ (5 × your height in centimeters)
− (4.7 × your age in years)	− (6.8 × your age in years)

4. Your metabolism is also influenced by how active you are. Talking, walking, and playing games all take more energy than being at rest. To get an idea of how many Calories your body needs each day to stay healthy, select the lifestyle that best describes yours from the table at right. Then multiply your BMR by the activity factor.

Activity Factors	
Activity lifestyle	**Activity factor**
Moderately inactive (normal, everyday activities)	1.3
Moderately active (exercise 3 to 4 times a week)	1.4
Very active (exercise 4 to 6 times a week)	1.6
Extremely active (exercise 6 to 7 times a week)	1.8

Analyze the Results

1. In what way could you compare your whole body to a single cell? Explain.
2. Does an increase in activity increase your BMR? Does an increase in activity increase your need for Calories? Explain your answers.

Draw Conclusions

3. If you are moderately inactive, how many more Calories would you need if you began to exercise every day?

Applying Your Data

The best energy sources are those that supply the correct amount of Calories for your lifestyle and also provide the nutrients you need. Research in the library or on the Internet to find out which kinds of foods are the best energy sources for you. How does your list of best energy sources compare with your diet?

List everything you eat and drink in 1 day. Find out how many Calories are in each item, and find the total number of Calories you have consumed. How does this number of Calories compare with the number of Calories you need each day for all your activities?

Model-Making Lab

Making a Protist Mobile

You have studied many of the diverse species of organisms within the kingdom Protista. This may be the first time you have ever seen many of these single-celled eukaryotes. In this activity, you will have an opportunity to express a bit of creativity by using what you have learned about these interesting organisms.

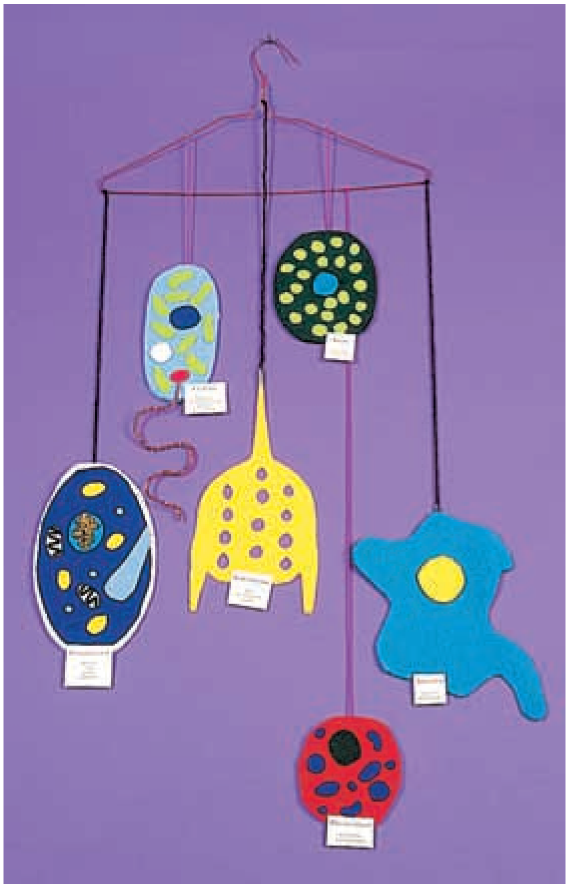
MATERIALS

- clothes hanger, wire
- markers, colored
- paper (heavyweight construction paper or poster board)
- recycled material of your choice
- scissors
- string, yarn, lightweight wire, or fishing line
- tape, transparent (or glue)

SAFETY

Procedure

1. Research the different kinds of protists you have studied. You may cut out pictures of them from magazines, or you may find examples of protists on the Internet. You may want to investigate *Plasmodium, Euglena,* amoebas, slime molds, *Radiolaria, Paramecium, Foraminifera,* various other protozoans, or even algae.
2. Using the paper and recycled materials, make a model of each protist you want to include on your mobile. Be sure to include the special features of each protist, such as vacuoles, pseudopods, shells, cilia, or flagella.
3. Use tape or glue to attach special features to give your protists a three-dimensional look.
4. Provide labels for your protist models. For each protist, provide its name, classification, method of movement (if any), method for obtaining food, and any other interesting facts you have learned about it.
5. Attach your protist models to the wire hanger with wire or string. Use tape or glue to attach your labels to each model.



Analyze the Results

1. What have you learned about the diversity of protists? Include at least three habitats where protists may be found.

Communicating Your Data

Choose a disease-causing protist. Write a report describing the disease, its effect on people or the environment, and the efforts being made to control it.

Model-Making Lab

Antibodies to the Rescue

Some cells of the immune system, called *B cells,* make antibodies that attack and kill invading viruses and microorganisms. These antibodies help make you immune to disease. Have you ever had chickenpox? If you have, your body has built up antibodies that can recognize that particular virus. Antibodies will attach themselves to the virus, tagging it for destruction. If you are exposed to the same disease again, the antibodies remember that virus. They will attack the virus even quicker and in greater number than they did the first time. This is the reason that you will probably never have chickenpox more than once.

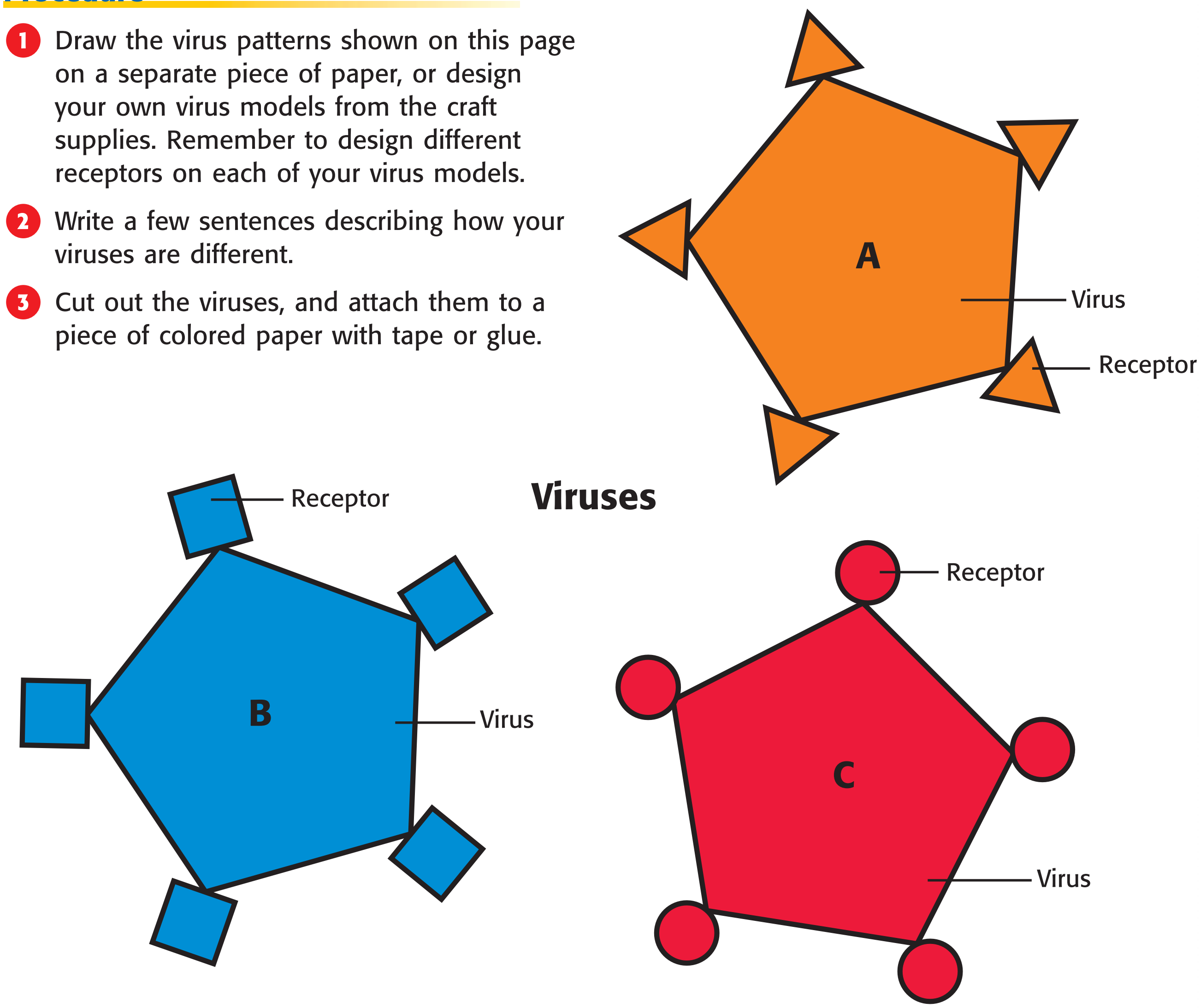
In this activity, you will construct simple models of viruses and their antibodies. You will see how antibodies are specific for a particular virus.

MATERIALS

- craft materials, such as buttons, fabric scraps, pipe cleaners, and recycled materials
- paper, colored
- scissors
- tape (or glue)

Procedure

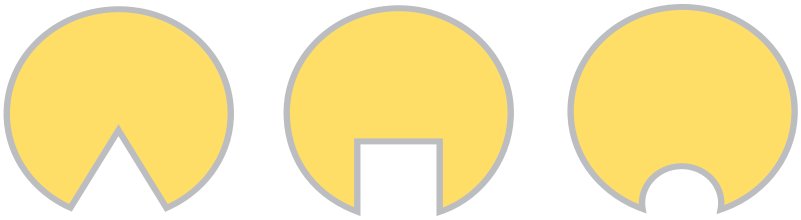
1. Draw the virus patterns shown on this page on a separate piece of paper, or design your own virus models from the craft supplies. Remember to design different receptors on each of your virus models.
2. Write a few sentences describing how your viruses are different.
3. Cut out the viruses, and attach them to a piece of colored paper with tape or glue.



Viruses

4. Select the antibodies drawn below, or design your own antibodies that will exactly fit on the receptors on your virus models. Draw or create each antibody enough times to attach one to each receptor site on the virus.

Antibodies



5. Cut out the antibodies you have drawn. Arrange the antibodies so that they bind to the virus at the appropriate receptor. Attach them to the virus with tape or glue.

Analyze the Results

1. Explain how an antibody "recognizes" a particular virus.
2. After the attachment of antibodies to the receptors, what would be the next step in the immune response?
3. Many vaccines use weakened copies of the virus to protect the body. Use the model of a virus and its specific antibody to explain how vaccines work.

Draw Conclusions

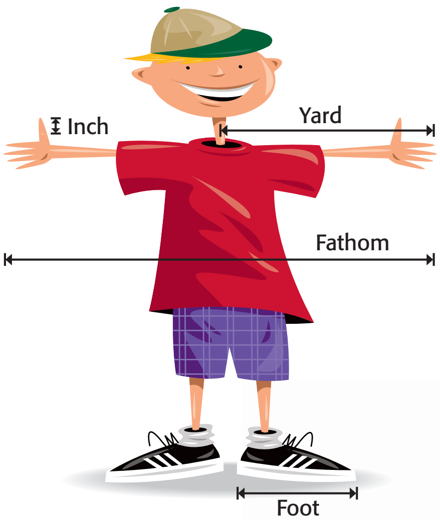
4. Use your model of a virus to demonstrate to the class how a receptor might change or mutate so that a vaccine would no longer be effective.

Applying Your Data

Research in the library or on the Internet to find information about the discovery of the Salk vaccine for polio. Include information on how polio affects people today.

Research in the library or on the Internet to find information and write a report about filoviruses. What do they look like? What diseases do they cause? Why are they especially dangerous? Is there an effective vaccine against any filovirus? Explain.

Contents



Reading Check Answers

Chapter 1 Science in Our World

Section 1

Page 5: If your materials are hard to find, you can do more research and look for new ideas or resources from the results of someone else's experiment.

Page 7: A meteorologist is a scientist who studies Earth's atmosphere.

Page 9: A science illustrator uses art and science skills to draw scientific diagrams.

Section 2

Page 9: A science illustrator uses art and science skills to draw scientific diagrams.

Page 13: A prediction is a statement that describes what a scientist thinks will happen during the test of a hypothesis.

Section 3

Page 19: A conceptual model is a system of ideas or a model based on making comparisons with familiar things to explain an idea.

Page 20: A theory is a unifying explanation for a broad range of hypotheses and observations that have been supported by testing.

Section 4

Page 23: Stopwatches, metersticks, and balances are some of the tools that you can use to make measurements.

Page 26: The kelvin is the SI basic unit for temperature.

Chapter 2 The Flow of Fresh Water

Section 1

Page 40: The Colorado River eroded the rock over millions of years.

Page 42: A divide is the boundary that separates drainage areas, whereas a watershed is the area of land that is drained by a water system.

Page 43: An increase in a stream's gradient and discharge can cause the stream to flow faster.

Page 45: A mature river erodes its channel wider rather than deeper. It is not steep and has fewer falls and rapids. It also has good drainage and more discharge than a youthful river does.

Page 46: Rejuvenated rivers form when the land is raised by tectonic forces.

Section 2

Page 49: Deltas are made of the deposited load of the river, which is mostly mud.

Page 51: The flow of water can be controlled by dams and levees.

Section 3

Page 52: The zone of aeration is located underground. It is the area above the water table.

Page 54: The size of the recharge zone depends on how permeable rock is at the surface.

Page 55: A well must be deeper than the water table for it to be able to reach water.

Page 56: Deposition is the process that causes the formation of stalactites and stalagmites.

Section 4

Page 58: Nonpoint-source pollution is the hardest to control.

Page 61: The purpose of a water-quality monitoring program is to detect imbalances in a body of water that indicate poor water-system health.

Page 63: Drip irrigation systems deliver small amounts of water directly to the roots of the plant so that the plant absorbs the water before it can evaporate or runoff.

Page 64: Answers may vary. Sample answer: taking shorter showers, avoiding running water while brushing your teeth, and using the dishwasher only when it is full.

Chapter 3 Exploring the Oceans

Section 1

Page 77: The first oceans began to form sometime before 4 billion years ago as the Earth cooled enough for water vapor to condense and fall as rain.

Page 78: Gases dissolve better in cold water than in warm water. So, as water temperature rises, less gas remains dissolved in ocean water and more gas is released into the atmosphere.

Page 78: Salinity is a measure of the amount of dissolved solids in a given amount of liquid.

Page 80: Parts of the ocean along the equator are warmer because they receive more sunlight per year.

Page 82: If the ocean did not release thermal energy so slowly, the air temperature on land would vary greatly from above 100°C during the day to below -100°C at night.

Section 2

Page 85: Satellite photos from *Seasat* send images of the ocean back to Earth. These images allow scientists to measure the direction and speed of ocean currents. Satellite photos and information from *Geosat* have been used to measure slight changes in the height of the ocean's surface.

Page 86: 64,000 km; on the ocean floor

Page 87: continental shelf, continental slope, and continental rise

Appendix

Page 88: It is unique because some of the organisms living around the vent do not rely on photosynthesis for energy.

Section 3

Page 91: A food web is a diagram that shows the feeding relationships between organisms in an ecosystem.

Page 93: Sample answer: Some animals get food from material that sinks to the bottom from the surface. Other animals get energy from chemicals released by thermal vents.

Page 94: Sample answer: When corals die, they leave behind their skeletons. Other corals grow on these remains. Over time, the layers build up to form a coral reef.

Page 95: Estuaries are very productive ecosystems because they constantly receive fresh nutrients from the river and from the ocean.

Page 96: Sargassum are floating rafts of algae in the middle of the Atlantic Ocean.

Section 4

Page 99: Fish farms can help reduce overfishing because the fish are raised instead of fished directly out of the ocean.

Page 100: Nonrenewable resources are resources that cannot be replenished. Oil and natural gas are nonrenewable resources.

Page 101: Desalination plants are most likely to be built in drier parts of the world, and where governments can afford to buy expensive equipment. Most desalination plants are in the Middle East where the fuel needed to run the plants is relatively inexpensive.

Page 103: Wave energy would be a good alternative energy resource because it is a clean and renewable resource.

Section 5

Page 105: One effect of trash dumping is that plastic materials may harm and kill marine animals because these animals may mistake the trash for food.

Page 107: An oil tanker that has two hulls can prevent an oil spill, because if the outer hull is damaged, the inner hull will prevent oil from spilling into the ocean.

Page 109: The U.S. Marine Protection, Research, and Sanctuaries Act prohibits the dumping of any material that would affect human health or welfare, the marine environment or ecosystems, or businesses that depend on the ocean.

Chapter 4 The Movement of Ocean Water

Section 1

Page 120: Heyerdahl theorized that the inhabitants of Polynesia originally sailed from Peru on rafts powered only by the wind and ocean currents. Heyerdahl proved his theory by sailing from Peru to Polynesia on a raft powered only by wind and ocean currents.

Page 122: The Earth's rotation causes surface currents to move in curved paths rather than in straight lines.

Page 123: The three factors that form a pattern of surface currents on Earth are global winds, the Coriolis effect, and continental deflections.

Page 124: Density causes variations in the movement of deep currents.

Section 2

Page 127: Cold-water currents keep coastal climates cooler than inland climates all year long.

Page 129: Answers may vary. Sample answer: It is important to study El Niño because El Niño can greatly affect organisms and land. One way that scientists study El Niño is through a network of buoys located along the equator. These buoys record information that helps scientists predict when an El Niño is likely to occur.

Section 3

Page 130: The lowest point of a wave is called a *trough*.

Page 132: Deep-water waves become shallow-water waves as they move toward the shore and reach water that is shallower than one-half their wavelength.

Page 135: A storm surge is a local rise in sea level near the shore and is caused by strong winds from a storm, such as a hurricane. Storm surges are difficult to study because they disappear as quickly as they form.

Section 4

Page 136: The gravity of the moon pulls on every particle of the Earth.

Page 138: A tidal range is the difference between levels of ocean water at high tide and low tide.

Chapter 5 The Properties of Matter

Section 1

Page 153: liters (L) and milliliters (mL)

Page 154: You could measure the volume of an apple by submerging the apple in a container of water and measuring the volume of the water that the apple displaces.

Page 156: kilograms (kg), grams (g), and milligrams (mg)

Section 2

Page 158: Some physical properties are color, shape, odor, weight, volume, texture, state, and density.

Page 160: If the object's density is less than the water's density, the object will float.

Page 162: The solid is sodium bromide. Although sodium chloride and sodium bromide melt above 700°C, only sodium bromide boils below 1,400°C.

Page 163: The metal is iron.

Page 164: A physical change is a change that occurs to a substance or object and that does not change the identity of the substance.

Section 3

Page 166: Reactivity describes the ability of two or more substances to combine and form one or more new substances.

Page 168: Chemical changes occur when one or more substances are changed into entirely new substances with different properties. A chemical property of a substance determines whether a chemical change will occur.

Section 4

Page 173: Magnetism is used in some alarm systems. A magnet holds an iron switch closed until the window or door is opened. Then, the magnet is too far from the switch to keep the switch closed, and the alarm sounds.

Page 175: Wood would not be a suitable material. Although wood can be cut into sheets, it cannot be flattened into sheets because wood is not malleable.

Page 176: Answers may vary. Sample answer: Soluble packing peanuts will not take up space in a landfill.

Chapter 6 States of Matter

Section 1

Page 189: The particles in a crystalline solid are arranged in a repeating pattern of rows that forms an orderly, three-dimensional arrangement.

Page 190: Viscosity is a liquid's resistance to flow.

Section 2

Page 193: Temperature is a measure of the average kinetic energy of the particles of a substance.

Page 194: Thermal expansion makes thermometers work.

Section 3

Page 196: A change of state is the change of a substance from one physical form to another.

Page 198: Evaporation is the change of a substance from a liquid to a gas.

Page 200: As a substance changes state, its temperature remains constant until the change of state is complete.

Chapter 7 Elements, Compounds, and Mixtures

Section 1

Page 212: An element is a pure substance because it contains only one type of particle.

Page 214: Metals are shiny, conduct heat energy, and conduct electric current.

Section 2

Page 217: Three physical properties used to identify compounds are melting point, density, and color.

Page 219: Unique properties of water include its strong cohesive attraction to other water molecules, its strong adhesive attraction to other substances, the polar shape of water, water's ability to dissolve almost any substances, its high specific heat capacity, and its strong buoyant force.

Page 220: Compounds can be broken down into elements or simpler compounds.

Section 3

Page 222: Substances in a mixture keep their identities because no chemical change takes place when a mixture is made.

Page 225: An alloy is a solid solution of metal or nonmetal dissolved in another metal.

Page 227: As temperature increases, the solubility of a gas decreases.

Page 228: The particles of a suspension can be separated by passing the suspension through a filter.

Chapter 8 The Periodic Table

Section 1

Page 240: Mendeleev had arranged elements based on increasing atomic mass.

Page 241: atomic number

Page 244: Most metals are solid at room temperature, ductile, malleable, and shiny. In addition, they are good conductors of electric current and thermal energy.

Page 245: Elements in a group often have similar chemical and physical properties.

Section 2

Page 249: It is easier for atoms of alkali metals to lose their outer electron than for atoms of transition metals to lose their outer electrons. Therefore, alkali metals are more reactive than transition metals.

Page 250: Yes, lanthanides and actinides are transition metals.

Page 251: silicon and germanium

Page 252: nitrogen and oxygen

Page 254: Atoms of noble gases have a full set of electrons in their outer level.

Chapter 9 Chemical Bonding

Section 1

Page 269: Most atoms form bonds only with their valence electrons.

Page 270: Atoms in Group 18 (the noble gases) rarely form chemical bonds.

Section 2

Page 271: Atoms are neutral because the number of protons in an atom always equals the number of electrons in the atom.

Page 273: Atoms in Group 17 give off the most energy when forming negative ions.

Section 3

Page 276: A covalent bond is a bond that forms when atoms share one or more pairs of electrons.

Page 278: There are two atoms in a diatomic molecule.

Page 280: Ductility is the ability to be drawn into wires.

Chapter 10 Chemical Reactions

Section 1

Page 293: A precipitate is a solid substance that is formed in a solution.

Page 294: In a chemical reaction, the chemical bonds in the starting substances break, and then new bonds form to make new substances.

Section 2

Page 297: Ionic compounds are made up of a metal and a nonmetal.

Page 298: Reactants are the starting substances in a chemical reaction, and products are the substances that are formed.

Page 300: The mass of a closed system stays the same during a chemical reaction.

Page 301: Lavoisier based his work on the idea that many changes may take place when materials react with each other but that the total amount of matter afterward is the same as it was before.

Page 302: The coefficient is 4.

Section 3

Page 304: A synthesis reaction is a reaction in which two or more substances combine to form one new compound.

Page 305: In a decomposition reaction, a substance breaks down into simpler substances. In a synthesis reaction, two or more substances combine to form one new compound.

Page 306: In a single-displacement reaction, one element can replace another element if the replacing element is more reactive than the starting element.

Section 4

Page 309: An endothermic reaction is a chemical reaction in which energy is taken in.

Page 310: Activation energy is the energy that is needed to start a chemical reaction.

Page 312: A high concentration of reactants allows the particles of the reactants to run into each other more often, so the reaction proceeds at a faster rate.

Chapter 11 Chemicals and Our World

Section 1

Page 325: Three kinds of natural chemicals that your body makes are carbon dioxide, proteins, and fats

Page 326: A synthetic chemical is a chemical that is not found in nature and that is not made by natural processes.

Section 2

Page 329: Potency is the power of a medicine to produce its desired effect.

Page 331: The three most important elements for plant growth are nitrogen, phosphorus, and potassium.

Page 332: Chlorine helps clean wastewater by killing harmful bacteria and other microorganisms.

Section 3

Page 335: Cancer is a disease that is caused by uncontrolled cell growth.

Page 337: Three examples of heart disease are strokes, heart attacks, and atherosclerosis.

Page 338: Two laws that help reduce people's exposure to chemical pollutants are the Clean Air Act and the Clean Water Act.

Chapter 12 Heat Technology

Section 1

Page 353: Insulation helps save energy costs by keeping thermal energy from passing into or escaping from a building.

Page 355: A refrigerant is a substance that condenses and evaporates easily.

Page 356: The inside of a refrigerator is able to stay cooler than the outside because thermal energy inside the refrigerator is continuously being transferred outside of the refrigerator.

Section 2

Page 359: The four strokes are called the *intake stroke*, the *compression stroke*, the *power stroke*, and the *exhaust stroke*.

Page 360: A diesel engine has no spark plugs. Instead, the fuel-air mixture is compressed so much that it becomes hot enough to ignite without a spark from a spark plug.

Chapter 13 Electronic Technology

Section 1

Page 373: An analog signal is a signal whose properties can change continuously in a given range.

Page 375: A digital recording can be made to sound more like the original sound by taking more samples each second.

Page 377: analog signals and digital signals

Page 378: A plasma display does not use electron beams to activate the fluorescent materials. Instead, each tiny cell is activated individually.

Section 2

Page 380: input, processing, storage, and output

Page 381: A microprocessor is a single semiconductor chip that controls and executes a microcomputer's instructions.

Page 382: central processing unit

Page 385: operating-system software and application software

Page 386: Sample answer: The World Wide Web is a collection of pages that share a format that can be viewed on any computer.

Chapter 14 Maps as Models of the Earth

Section 1

Page 401: A reference point is a fixed place on the Earth's surface from which direction and location can be described.

Page 402: True north is the direction to the geographic North Pole.

Page 404: lines of longitude

Section 2

Page 406: Distortions are inaccuracies produced when information is transferred from a curved surface to a flat surface.

Page 409: Azimuthal and conic projections are similar because they are both ways to represent the curved surface of the Earth on a flat map. Azimuthal projections show the surface of a globe transferred to a flat plane, whereas conic projections show the surface of a globe transferred to a cone.

Page 410: Every map should have a title, a compass rose, a scale, the date, and a legend.

Section 3

Page 413: A GIS stores information in layers.

Page 414: Emission is the continuous giving off of electromagnetic radiation by an object. Reflection happens when electromagnetic radiation bounces, or reflects, off an object.

Page 416: Two important differences between active and passive remote-sensing systems are that an active remote-sensing system produces its own electromagnetic radiation and collects data in the microwave region of wavelengths. A passive remote-sensing system measures reflected electromagnetic radiation and collects data largely in the infrared and visible regions of the electromagnetic spectrum.

Section 4

Page 419: An index contour is a darker contour line that is usually every fifth line. Index contours make it easier to read a map.

Chapter 15 The Rock and Fossil Record

Section 1

Page 433: Catastrophists believed that all geologic change occurs rapidly.

Page 434: A global catastrophe can cause the extinction of species.

Section 2

Page 437: Geologists use the geologic column to interpret rock sequences and to identify layers in puzzling rock sequences.

Page 439: An unconformity is a surface that represents a missing part of the geologic column.

Page 440: A disconformity is found where part of a sequence of parallel rock layers is missing. A nonconformity is found where horizontal sedimentary rock layers lie on top of an eroded surface of igneous or metamorphic rock. Angular unconformities are found between horizontal sedimentary rock layers and rock layers that have been tilted or folded.

Section 3

Page 443: A half-life is the time it takes one-half of a radioactive sample to decay.

Page 444: strontium-87

Section 4

Page 446: An organism is caught in soft, sticky tree sap, which hardens and preserves the organism.

Page 448: A mold is a cavity in rock where a plant or an animal was buried. A cast is an object created when sediment fills a mold and becomes rock.

Page 450: To fill in missing information about changes in organisms in the fossil record, paleontologists look for similarities between fossilized organisms or between fossilized organisms and their closest living relatives.

Page 451: *Phacops* can be used to establish the age of rock layers because *Phacops* lived during a relatively short, well-defined time span and is found in rock layers throughout the world.

Section 5

Page 453: approximately 2 billion years

Page 454: The geological time scale is a scale that divides Earth's 4.6 billion–year history into distinct intervals of time.

Page 456: During the process of glaciation, large amounts of the Earth's water are frozen in ice sheets. Because so much of the Earth's water is frozen, a lowering of sea level results.

Page 458: The Mesozoic era is known as the *Age of Reptiles* because reptiles, including the dinosaurs, were the dominant organisms on land.

Chapter 16 The Restless Earth

Section 1

Page 470: Similar fossils were found on landmasses that are very far apart. The best explanation for this phenomenon is that the landmasses were once joined.

Page 473: The molten rock at mid-ocean ridges contains tiny grains of magnetic minerals. The minerals align with the Earth's magnetic field before the rock cools and hardens. When the Earth's magnetic field reverses, the orientation of the mineral grains in the rocks will also change.

Section 2

Page 475: A transform boundary forms when two tectonic plates slide past each other horizontally.

Page 476: The circulation of thermal energy causes changes in density in the asthenosphere. As rock is heated, it expands, becomes less dense, and rises. As rock cools, it contracts, becomes denser, and sinks.

Section 3

Page 478: Compression can cause rocks to be pushed into mountain ranges as tectonic plates collide at convergent boundaries. Tension can pull rocks apart as tectonic plates separate at divergent boundaries.

Page 480: In a normal fault, the hanging wall moves down. In a reverse fault, the hanging wall moves up.

Page 482: Folded mountains form when rock layers are squeezed together and pushed upward.

Chapter 17 Cells: The Basic Units of Life

Section 1

Page 499: Sample answer: All organisms are made of one or more cells, the cell is the basic unit of all living things, and all cells come from existing cells.

Page 500: If a cell's volume gets too large, the cell's surface area will not be able to take in enough nutrients or get rid of wastes fast enough to keep the cell alive.

Page 501: Organelles are structures within a cell that perform specific functions for the cell.

Page 503: One difference between eubacteria and archaea is that bacterial ribosomes are different from archaebacterial ribosomes.

Page 504: The main difference between prokaryotes and eukaryotes is that eukaryotic cells have a nucleus and membrane-bound organelles and prokaryotic cells do not.

Section 2

Page 506: Plant, algae, and fungi cells have cell walls.

Page 507: A cell membrane encloses the cell and separates and protects the cell's contents from the cell's environment. The cell wall also controls the movement of materials into and out of the cell.

Page 508: The cytoskeleton is a web of proteins in the cytoplasm. It gives the cell support and structure.

Page 510: Most of a cell's ATP is made in the cell's mitochondria.

Page 512: Lysosomes destroy worn-out organelles, attack foreign invaders, and get rid of waste material from inside the cell.

Section 3

Page 514: Sample answer: larger size, longer life, and cell specialization

Page 515: An organ is a structure of two or more tissues working together to perform a specific function in the body.

Page 516: cell, tissue, organ, organ system

Chapter 18 The Working Cell

Section 1

Page 529: Red blood cells would burst in pure water because water particles move from outside, where particles were dense, to inside the cell, where particles were less dense. This movement of water would cause red blood cells to fill up and burst.

Page 531: Exocytosis is the process by which a cell moves large particles to the outside of the cell.

Section 2

Page 533: Cellular respiration is a chemical process by which cells produce energy from food. Breathing supplies oxygen for cellular respiration and removes the carbon dioxide produced by cellular respiration.

Page 535: One kind of fermentation produces CO2, and the other kind produces lactic acid.

Section 3

Page 537: No, the number of chromosomes is not always related to the complexity of organisms.

Page 538: During cytokinesis in plant cells, a cell plate is formed. During cytokinesis in animal cells, a cell plate does not form.

Section 4

Page 541: As the blood-glucose level decreases, the hormone glucagon is released. Glucagon triggers the body to release more glucose into the blood until homeostasis is reached. When the blood-glucose level increases, the hormone insulin is released. Insulin triggers the body to remove glucose from the blood until homeostasis is reached.

Page 543: ADH is important because it tells the kidneys to reabsorb more water. This action helps the body maintain a proper water balance.

Chapter 19 Understanding DNA

Section 1

Page 555: Guanine and cytosine are always found in DNA in equal amounts, as are adenine and thymine.

Page 557: every time a cell divides

Section 2

Page 558: a string of nucleotides that give the cell information about how to make a specific trait

Page 561: They transfer amino acids to the ribosome.

Page 562: a physical or chemical agent that can cause a mutation in DNA

Page 563: Sickle cell disease is caused by a mutation in a single nucleotide of DNA, which then causes a different amino acid to be assembled in a protein used in blood cells.

Page 564: a near-identical copy of another organism, created with the original organism's genes

Chapter 20 Protists and Fungi

Section 1

Page 579: Protist producers make their own food through photosynthesis.

Page 580: binary fission and multiple fission

Section 2

Page 583: Red algae also have a red pigment in their cells that gives the algae a red color.

Page 584: salt water, fresh water, and snow

Page 586: radiolarians and foraminiferans

Page 588: as decomposers or as parasites

Section 3

Page 591: hyphae breaking apart so that each piece becomes a new fungus or fungi producing spores

Page 592: asexually by releasing spores from sporangia or sexually by different individuals growing together into specialized sporangia

Page 594: the spore-forming structures, called *basidia*

Page 596: Lichens make acids that break down rocks, which causes cracks.

Chapter 21 Bacteria, Viruses, and Disease

Section 1

Page 608: Bacteria make up the kingdoms Eubacteria and Archaebacteria.

Page 610: Binary fission is a process of cell division in which one cell splits into two. All bacteria reproduce by binary fission.

Section 2

Page 614: Nitrogen fixing is the process by which nitrogen gas in the air is transformed into a form that plants can use.

Page 616: In genetic engineering, scientists change the genes of bacteria or other living things.

Section 3

Page 619: Viruses can be classified by shape or by the type of genetic material that they contain. Other possible answers are that viruses can be classified by life cycle or by the kind of disease that they cause.

Page 620: when a virus attacks living cells and turns them into virus factories

Section 4

Page 623: Cooking kills dangerous bacteria or parasites living in meat, fish, and eggs.

Page 624: Colds are caused by many different viruses. Finding a medicine that is effective against many different viruses is difficult.

Page 627: Antibiotics would not affect a cold because the common cold is caused by a virus.

Study Skills

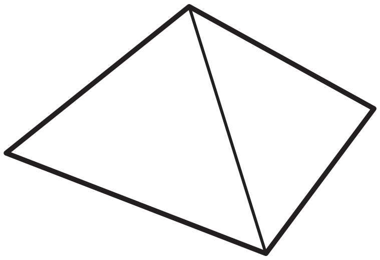
FoldNote Instructions

Have you ever tried to study for a test or quiz but didn't know where to start? Or have you read a chapter and found that you can remember only a few ideas? Well, FoldNotes are a fun and exciting way to help you learn and remember the ideas you encounter as you learn science!

FoldNotes are tools that you can use to organize concepts. By focusing on a few main concepts, FoldNotes help you learn and remember how the concepts fit together. They can help you see the "big picture." Below you will find instructions for building 10 different FoldNotes.

Pyramid

1. Place a sheet of paper in front of you. Fold the lower left-hand corner of the paper diagonally to the opposite edge of the paper.
2. Cut off the tab of paper created by the fold (at the top).
3. Open the paper so that it is a square. Fold the lower right-hand corner of the paper diagonally to the opposite corner to form a triangle.
4. Open the paper. The creases of the two folds will have created an X.
5. Using scissors, cut along one of the creases. Start from any corner, and stop at the center point to create two flaps. Use tape or glue to attach one of the flaps on top of the other flap.

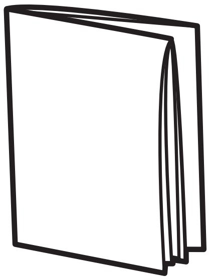


Double Door

1. Fold a sheet of paper in half from the top to the bottom. Then, unfold the paper.
2. Fold the top and bottom edges of the paper to the crease.

Appendix

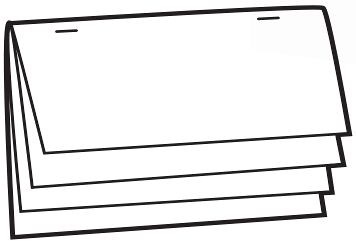
Booklet

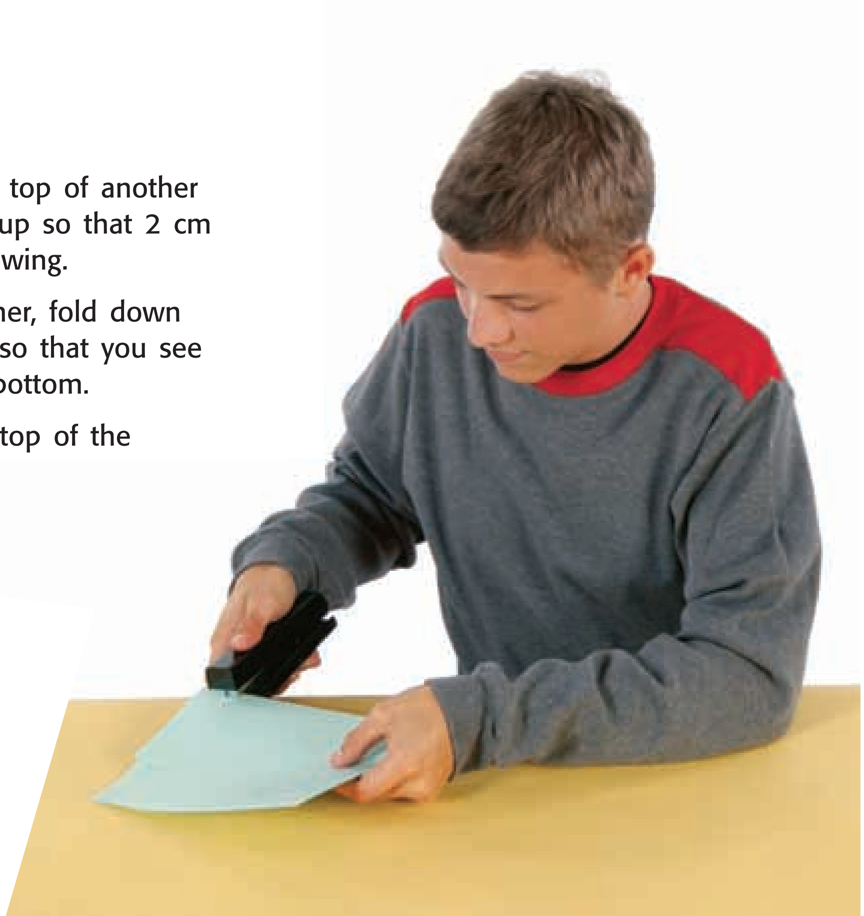


1. Fold a sheet of paper in half from left to right. Then, unfold the paper.
2. Fold the sheet of paper in half again from the top to the bottom. Then, unfold the paper.
3. Refold the sheet of paper in half from left to right.
4. Fold the top and bottom edges to the center crease.
5. Completely unfold the paper.
6. Refold the paper from top to bottom.
7. Using scissors, cut a slit along the center crease of the sheet from the folded edge to the creases made in step 4. Do not cut the entire sheet in half.
8. Fold the sheet of paper in half from left to right. While holding the bottom and top edges of the paper, push the bottom and top edges together so that the center collapses at the center slit. Fold the four flaps to form a four-page book.

Layered Book

1. Lay one sheet of paper on top of another sheet. Slide the top sheet up so that 2 cm of the bottom sheet is showing.
2. Hold the two sheets together, fold down the top of the two sheets so that you see four 2 cm tabs along the bottom.
3. Using a stapler, staple the top of the FoldNote.



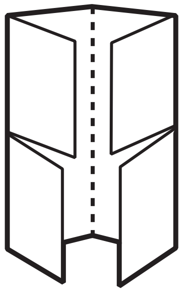


Appendix

Key-Term Fold

1. Fold a sheet of lined notebook paper in half from left to right.
2. Using scissors, cut along every third line from the right edge of the paper to the center fold to make tabs.

Four-Corner Fold



1. Fold a sheet of paper in half from left to right. Then, unfold the paper.
2. Fold each side of the paper to the crease in the center of the paper.
3. Fold the paper in half from the top to the bottom. Then, unfold the paper.
4. Using scissors, cut the top flap creases made in step 3 to form four flaps.

Three-Panel Flip Chart

1. Fold a piece of paper in half from the top to the bottom.
2. Fold the paper in thirds from side to side. Then, unfold the paper so that you can see the three sections.
3. From the top of the paper, cut along each of the vertical fold lines to the fold in the middle of the paper. You will now have three flaps.

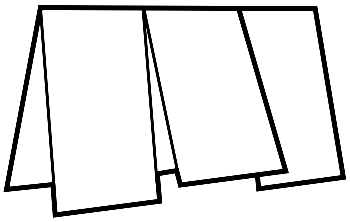
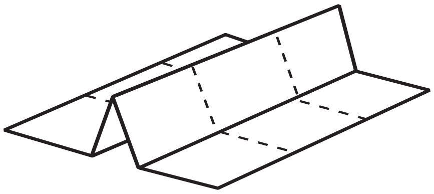


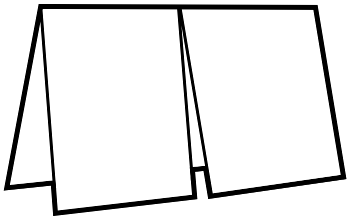
Table Fold

1. Fold a piece of paper in half from the top to the bottom. Then, fold the paper in half again.
2. Fold the paper in thirds from side to side.
3. Unfold the paper completely. Carefully trace the fold lines by using a pen or pencil.



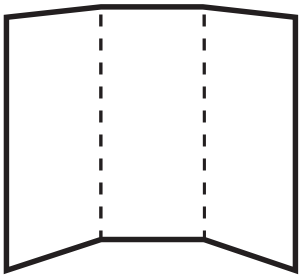
Two-Panel Flip Chart

1. Fold a piece of paper in half from the top to the bottom.
2. Fold the paper in half from side to side. Then, unfold the paper so that you can see the two sections.
3. From the top of the paper, cut along the vertical fold line to the fold in the middle of the paper. You will now have two flaps.



Tri-Fold

1. Fold a piece a paper in thirds from the top to the bottom.
2. Unfold the paper so that you can see the three sections. Then, turn the paper sideways so that the three sections form vertical columns.
3. Trace the fold lines by using a pen or pencil. Label the columns "Know," "Want," and "Learn."



Appendix

Graphic Organizer Instructions

Graphic Organizer

Have you ever wished that you could "draw out" the many concepts you learn in your science class? Sometimes, being able to *see* how concepts are related really helps you remember what you've learned. Graphic Organizers do just that! They give you a way to draw or map out concepts.

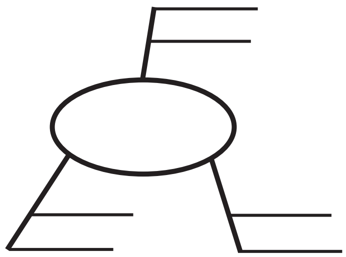
All you need to make a Graphic Organizer is a piece of paper and a pencil. Below you will find instructions for four different Graphic Organizers designed to help you organize the concepts you'll learn in this book.

Spider Map

1. Draw a diagram like the one shown. In the circle, write the main topic.

2. From the circle, draw legs to represent different categories of the main topic. You can have as many categories as you want.

3. From the category legs, draw horizontal lines. As you read the chapter, write details about each category on the horizontal lines.

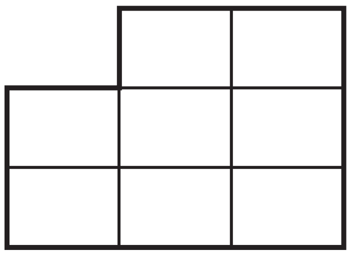


Comparison Table

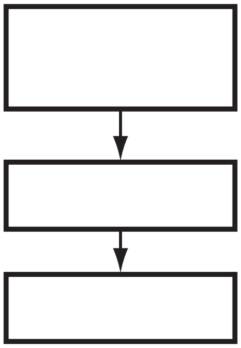
1. Draw a chart like the one shown. Your chart can have as many columns and rows as you want.

2. In the top row, write the topics that you want to compare.

3. In the left column, write characteristics of the topics that you want to compare. As you read the chapter, fill in the characteristics for each topic in the appropriate boxes.

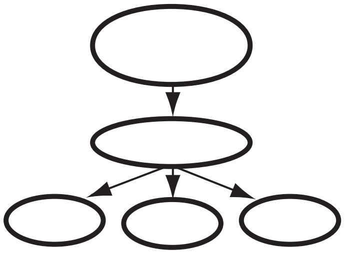


Chain-of-Events-Chart



1. Draw a box. In the box, write the first step of a process or the first event of a timeline.
2. Under the box, draw another box, and use an arrow to connect the two boxes. In the second box, write the next step of the process or the next event in the timeline.
3. Continue adding boxes until the process or timeline is finished.

Concept Map



1. Draw a circle in the center of a piece of paper. Write the main idea of the chapter in the center of the circle.
2. From the circle, draw other circles. In those circles, write characteristics of the main idea. Draw arrows from the center circle to the circles that contain the characteristics.
3. From each circle that contains a characteristic, draw other circles. In those circles, write specific details about the characteristic. Draw arrows from each circle that contains a characteristic to the circles that contain specific details. You may draw as many circles as you want.

Appendix

SI Measurement

The International System of Units, or SI, is the standard system of measurement used by many scientists. Using the same standards of measurement makes it easier for scientists to communicate with one another.

SI works by combining prefixes and base units. Each base unit can be used with different prefixes to define smaller and larger quantities. The table below lists common SI prefixes.

SI Prefixes

Prefix	Symbol	Factor	Example
kilo-	k	1,000	kilogram, 1 kg = 1,000 g
hecto-	h	100	hectoliter, 1 hL = 100 L
deka-	da	10	dekameter, 1 dam = 10 m
		1	meter, liter, gram
deci-	d	0.1	decigram, 1 dg = 0.1 g
centi-	c	0.01	centimeter, 1 cm = 0.01 m
milli-	m	0.001	milliliter, 1 mL = 0.001 L
micro-	μ	0.000 001	micrometer, 1 μm = 0.000 001 m

SI Conversion Table

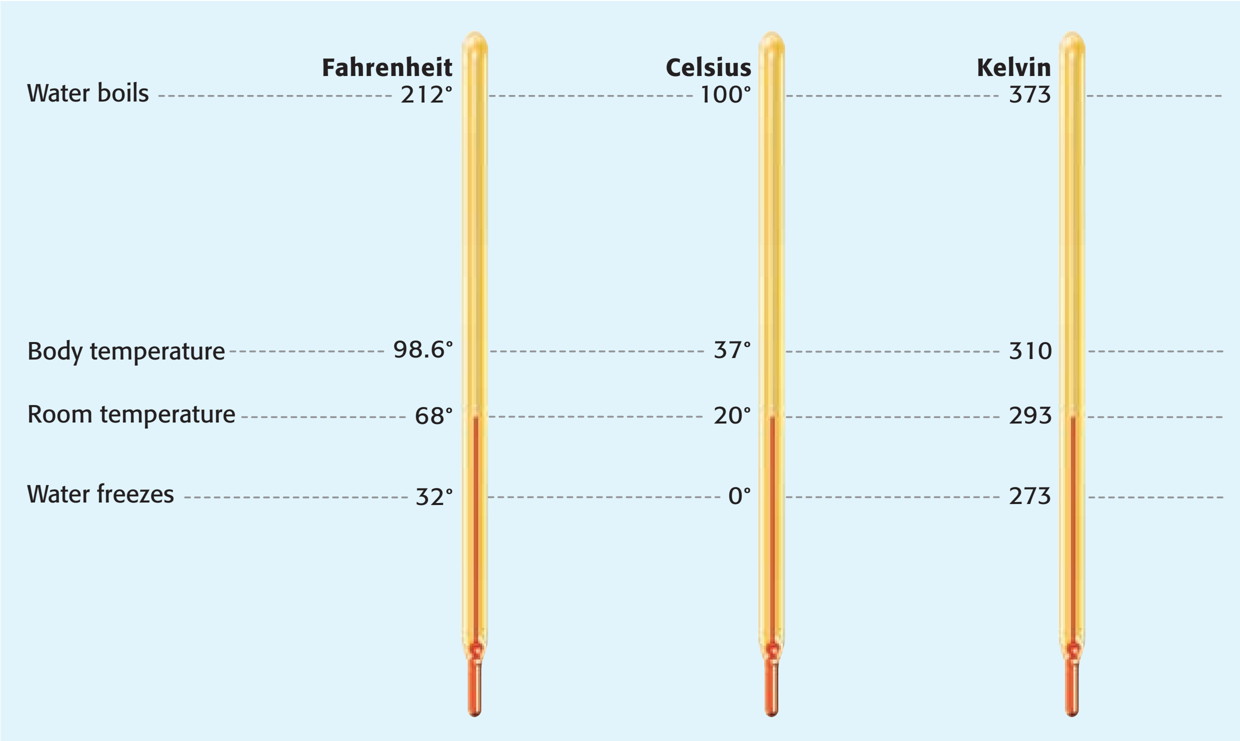
SI units	From SI to English	From English to SI
Length		
kilometer (km) = 1,000 m	1 km = 0.621 mi	1 mi = 1.609 km
meter (m) = 100 cm	1 m = 3.281 ft	1 ft = 0.305 m
centimeter (cm) = 0.01 m	1 cm = 0.394 in.	1 in. = 2.540 cm
millimeter (mm) = 0.001 m	1 mm = 0.039 in.	
micrometer (μm) = 0.000 001 m		
nanometer (nm) = 0.000 000 001 m		
Area		
square kilometer (km^2) = 100 hectares	1 km^2 = 0.386 mi^2	1 mi^2 = 2.590 km^2
hectare (ha) = 10,000 m^2	1 ha = 2.471 acres	1 acre = 0.405 ha
square meter (m^2) = 10,000 cm^2	1 m^2 = 10.764 ft^2	1 ft^2 = 0.093 m^2
square centimeter (cm^2) = 100 mm^2	1 cm^2 = 0.155 $in.^2$	1 $in.^2$ = 6.452 cm^2
Volume		
liter (L) = 1,000 mL = 1 dm^3	1 L = 1.057 fl qt	1 fl qt = 0.946 L
milliliter (mL) = 0.001 L = 1 cm^3	1 mL = 0.034 fl oz	1 fl oz = 29.574 mL
microliter (μL) = 0.000 001 L		
Mass		
kilogram (kg) = 1,000 g	1 kg = 2.205 lb	1 lb = 0.454 kg
gram (g) = 1,000 mg	1 g = 0.035 oz	1 oz = 28.350 g
milligram (mg) = 0.001 g		
microgram (μg) = 0.000 001 g		

Temperature Scales

Temperature can be expressed by using three different scales: Fahrenheit, Celsius, and Kelvin. The SI unit for temperature is the kelvin (K).

Although 0 K is much colder than 0°C, a change of 1 K is equal to a change of 1°C.

Three Temperature Scales



Temperature Conversions Table

To convert	Use this equation:	Example
Celsius to Fahrenheit °C → °F	$°F = \left(\frac{9}{5} \times °C\right) + 32$	Convert 45°C to °F. $°F = \left(\frac{9}{5} \times 45°C\right) + 32 = 113°F$
Fahrenheit to Celsius °F → °C	$°C = \frac{5}{9} \times (°F - 32)$	Convert 68°F to °C. $°C = \frac{5}{9} \times (68°F - 32) = 20°C$
Celsius to Kelvin °C → K	$K = °C + 273$	Convert 45°C to K. $K = 45°C + 273 = 318\ K$
Kelvin to Celsius K → °C	$°C = K - 273$	Convert 32 K to °C. $°C = 32K - 273 = -241°C$

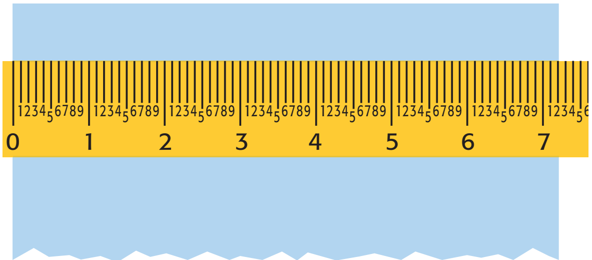
Measuring Skills

Using a Graduated Cylinder

When using a graduated cylinder to measure volume, keep the following procedures in mind:

1. Place the cylinder on a flat, level surface before measuring liquid.
2. Move your head so that your eye is level with the surface of the liquid.
3. Read the mark closest to the liquid level. On glass graduated cylinders, read the mark closest to the center of the curve in the liquid's surface.

Using a Meterstick or Metric Ruler



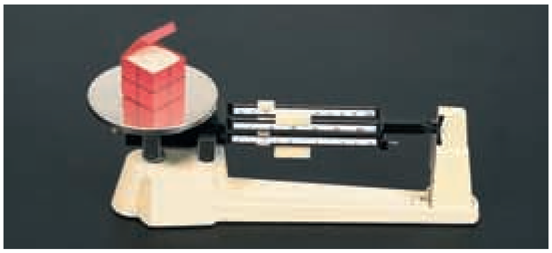
When using a meterstick or metric ruler to measure length, keep the following procedures in mind:

1. Place the ruler firmly against the object that you are measuring.
2. Align one edge of the object exactly with the 0 end of the ruler.
3. Look at the other edge of the object to see which of the marks on the ruler is closest to that edge. (Note: Each small slash between the centimeters represents a millimeter, which is one-tenth of a centimeter.)

Using a Triple-Beam Balance

When using a triple-beam balance to measure mass, keep the following procedures in mind:

1. Make sure the balance is on a level surface.
2. Place all of the countermasses at 0. Adjust the balancing knob until the pointer rests at 0.
3. Place the object you wish to measure on the pan. **Caution:** Do not place hot objects or chemicals directly on the balance pan.
4. Move the largest countermass along the beam to the right until it is at the last notch that does not tip the balance. Follow the same procedure with the next-largest countermass. Then, move the smallest countermass until the pointer rests at 0.
5. Add the readings from the three beams together to determine the mass of the object.
6. When determining the mass of crystals or powders, first find the mass of a piece of filter paper. Then, add the crystals or powder to the paper, and remeasure. The actual mass of the crystals or powder is the total mass minus the mass of the paper. When finding the mass of liquids, first find the mass of the empty container. Then, find the combined mass of the liquid and container. The mass of the liquid is the total mass minus the mass of the container.



Scientific Methods

The ways in which scientists answer questions and solve problems are called **scientific methods.** The same steps are often used by scientists as they look for answers. However, there is more than one way to use these steps. Scientists may use all of the steps or just some of the steps during an investigation. They may even repeat some of the steps. The goal of using scientific methods is to come up with reliable answers and solutions.

Six Steps of Scientific Methods

1 Ask a Question

Good questions come from careful **observations.** You make observations by using your senses to gather information. Sometimes, you may use instruments, such as microscopes and telescopes, to extend the range of your senses. As you observe the natural world, you will discover that you have many more questions than answers. These questions drive investigations.

Questions beginning with *what, why, how,* and *when* are important in focusing an investigation. Here is an example of a question that could lead to an investigation.

Question: How does acid rain affect plant growth?

2 Form a Hypothesis

After you ask a question, you need to form a **hypothesis.** A hypothesis is a clear statement of what you expect the answer to your question to be. Your hypothesis will represent your best "educated guess" based on what you have observed and what you already know. A good hypothesis is testable. Otherwise, the investigation can go no further. Here is a hypothesis based on the question, "How does acid rain affect plant growth?"

Hypothesis: Acid rain slows plant growth.

The hypothesis can lead to predictions. A prediction is what you think the outcome of your experiment or data collection will be. Predictions are usually stated in an if-then format. Here is a sample prediction for the hypothesis that acid rain slows plant growth.

Prediction: If a plant is watered with only acid rain (which has a pH of 4), then the plant will grow at half its normal rate.

3 Test the Hypothesis

After you have formed a hypothesis and made a prediction, your hypothesis should be tested. One way to test a hypothesis is with a controlled experiment. A **controlled experiment** tests only one factor at a time. In an experiment to test the effect of acid rain on plant growth, the **control group** would be watered with normal rain water. The **experimental group** would be watered with acid rain. All of the plants should receive the same amount of sunlight and water each day. The air temperature should be the same for all groups. However, the acidity of the water will be a variable. In fact, any factor that is different from one group to another is a **variable.** If your hypothesis is correct, then the acidity of the water and plant growth are *dependant variables.* The amount a plant grows is dependent on the acidity of the water. However, the amount of water each plant receives and the amount of sunlight each plant receives are *independent variables.* Either of these factors could change without affecting the other factor.

Sometimes, the nature of an investigation makes a controlled experiment impossible. For example, the Earth's core is surrounded by thousands of meters of rock. Under such circumstances, a hypothesis may be tested by making detailed observations.

4 Analyze the Results

After you have completed your experiments, made your observations, and collected your data, you must analyze all the information you have gathered. Tables and graphs are often used in this step to organize the data.

5 Draw Conclusions

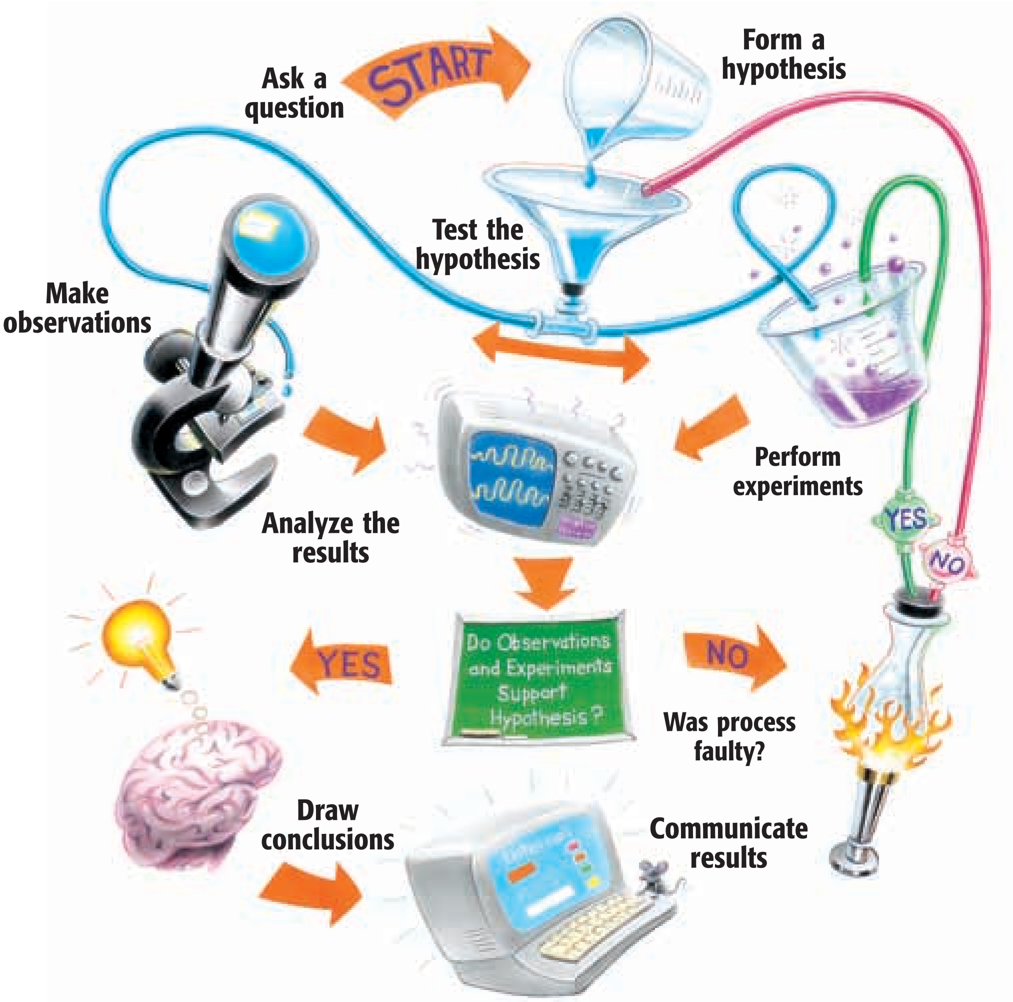
After analyzing your data, you can determine if your results support your hypothesis. If your hypothesis is supported, you (or others) might want to repeat the observations or experiments to verify your results. If your hypothesis is not supported by the data, you may have to check your procedure for errors. You may even have to reject your hypothesis and make a new one. If you cannot draw a conclusion from your results, you may have to try the investigation again or carry out further observations or experiments.

6 Communicate Results

After any scientific investigation, you should report your results. By preparing a written or oral report, you let others know what you have learned. They may repeat your investigation to see if they get the same results. Your report may even lead to another question and then to another investigation.

Scientific Methods in Action

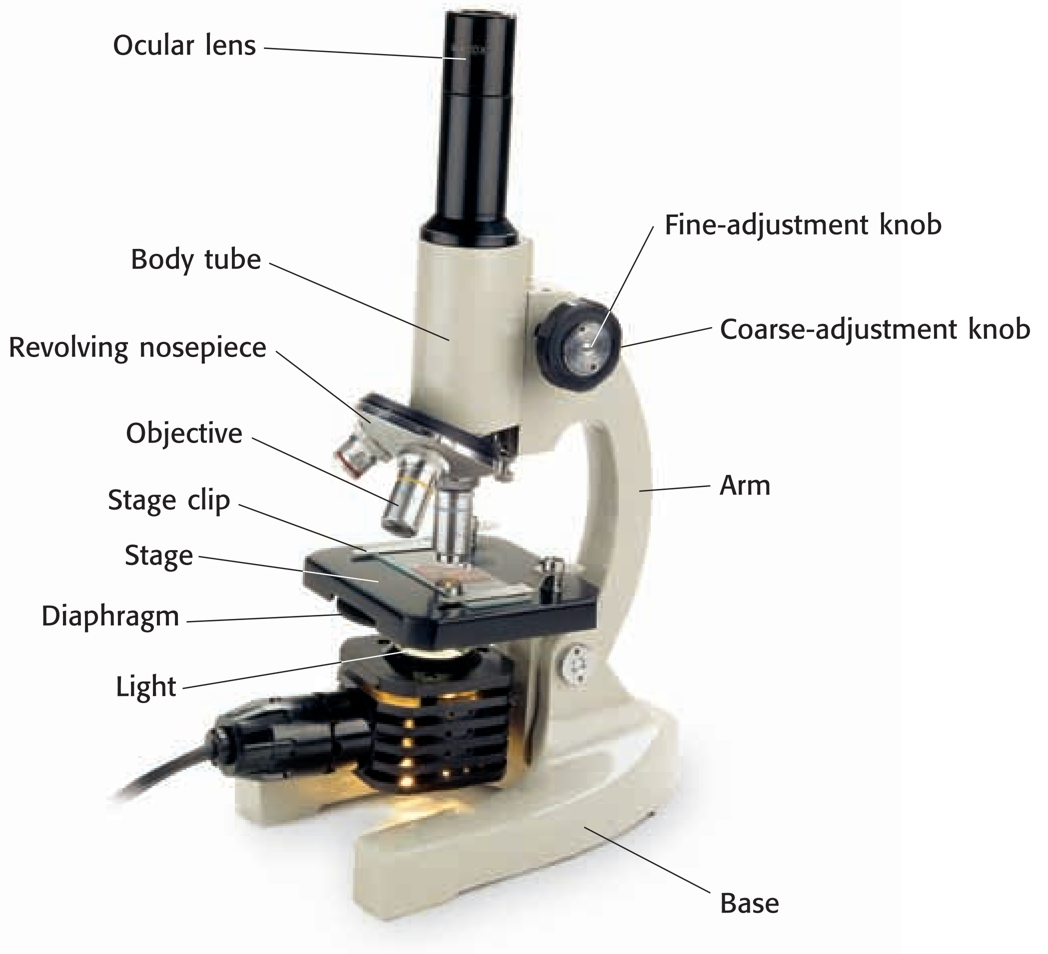
Scientific methods contain loops in which several steps may be repeated over and over again. In some cases, certain steps are unnecessary. Thus, there is not a "straight line" of steps. For example, sometimes scientists find that testing one hypothesis raises new questions and new hypotheses to be tested. And sometimes, testing the hypothesis leads directly to a conclusion. Furthermore, the steps in scientific methods are not always used in the same order. Follow the steps in the diagram, and see how many different directions scientific methods can take you.



Using the Microscope

Parts of the Compound Light Microscope

- The **ocular lens** magnifies the image 10×.
- The **low-power objective** magnifies the image 10×.
- The **high-power objective** magnifies the image either 40× or 43×.
- The **revolving nosepiece** holds the objectives and can be turned to change from one magnification to the other.
- The **body tube** maintains the correct distance between the ocular lens and objectives.
- The **coarse-adjustment knob** moves the body tube up and down to allow focusing of the image.
- The **fine-adjustment knob** moves the body tube slightly to bring the image into sharper focus.
- The **stage** supports a slide.
- **Stage clips** hold the slide in place for viewing.
- The **diaphragm** controls the amount of light coming through the stage.
- The light source provides a **light** for viewing the slide.
- The **arm** supports the body tube.
- The **base** supports the microscope.



Proper Use of the Compound Light Microscope

1. Use both hands to carry the microscope to your lab table. Place one hand beneath the base, and use the other hand to hold the arm of the microscope. Hold the microscope close to your body while carrying it to your lab table.
2. Place the microscope on the lab table at least 5 cm from the edge of the table.
3. Check to see what type of light source is used by your microscope. If the microscope has a lamp, plug it in and make sure that the cord is out of the way. If the microscope has a mirror, adjust the mirror to reflect light through the hole in the stage. **Caution:** If your microscope has a mirror, do not use direct sunlight as a light source. Direct sunlight can damage your eyes.
4. Always begin work with the low-power objective in line with the body tube. Adjust the revolving nosepiece.
5. Place a prepared slide over the hole in the stage. Secure the slide with the stage clips.
6. Look through the ocular lens. Move the diaphragm to adjust the amount of light coming through the stage.
7. Look at the stage from eye level. Slowly turn the coarse adjustment to lower the objective until the objective almost touches the slide. Do not allow the objective to touch the slide.
8. Look through the ocular lens. Turn the coarse adjustment to raise the low-power objective until the image is in focus. Always focus by raising the objective away from the slide. Never focus the objective downward. Use the fine adjustment to sharpen the focus. Keep both eyes open while viewing a slide.
9. Make sure that the image is exactly in the center of your field of vision. Then, switch to the high-power objective. Focus the image by using only the fine adjustment. Never use the coarse adjustment at high power.
10. When you are finished using the microscope, remove the slide. Clean the ocular lens and objectives with lens paper. Return the microscope to its storage area. Remember to use both hands when carrying the microscope.

Making a Wet Mount

1. Use lens paper to clean a glass slide and a coverslip.
2. Place the specimen that you wish to observe in the center of the slide.
3. Using a medicine dropper, place one drop of water on the specimen.
4. Hold the coverslip at the edge of the water and at a 45° angle to the slide. Make sure that the water runs along the edge of the coverslip.
5. Lower the coverslip slowly to avoid trapping air bubbles.
6. Water might evaporate from the slide as you work. Add more water to keep the specimen fresh. Place the tip of the medicine dropper next to the edge of the coverslip. Add a drop of water. (You can also use this method to add stain or solutions to a wet mount.) Remove excess water from the slide by using the corner of a paper towel as a blotter. Do not lift the coverslip to add or remove water.

Periodic Table of the Elements

Each square on the table includes an element's name, chemical symbol, atomic number, and atomic mass.

The color of the chemical symbol indicates the physical state at room temperature. Carbon is a solid.

6	Atomic number
C	Chemical symbol
Carbon	Element name
12.0	Atomic mass

The background color indicates the type of element. Carbon is a nonmetal.

Background	
Metals	light blue
Metalloids	light green
Nonmetals	yellow

Chemical symbol	
Solid	magenta
Liquid	blue
Gas	green

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	1 **H** Hydrogen 1.0								
Period 2	3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0							
Period 3	11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3							
Period 4	19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9
Period 5	37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9
Period 6	55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2
Period 7	87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (265)†	109 **Mt** Meitnerium (268)†

A row of elements is called a *period*.

A column of elements is called a *group* or *family*.

Values in parentheses are of the most stable isotope of the element.

† Estimated from currently available IUPAC data.

Lanthanides	58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4
Actinides	90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)

These elements are placed below the table to allow the table to be narrower.

Topic: Periodic Table
Go To: go.hrw.com
Keyword: HN0 PERIODIC
Visit the HRW Web site for updates on the periodic table.

This zigzag line reminds you where the metals, nonmetals, and metalloids are.

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 He Helium 4.0
			5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
			13 Al Aluminum 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
110 Ds Darmstadtium (269)†	111 Uuu Unununium (272)†	112 Uub Ununbium (277)†		114 Uuq Ununquadium (285)†				

The names and three-letter symbols of elements are temporary. They are based on the atomic numbers of the elements. Official names and symbols will be approved by an international committee of scientists.

63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Appendix

Properties of Common Minerals

	Mineral	Color	Luster	Streak	Hardness
Silicate Minerals	**Beryl**	deep green, pink, white, bluish green, or yellow	vitreous	white	7.5–8
	Chlorite	green	vitreous to pearly	pale green	2–2.5
	Garnet	green, red, brown, black	vitreous	white	6.5–7.5
	Hornblende	dark green, brown, or black	vitreous	none	5–6
	Muscovite	colorless, silvery white, or brown	vitreous or pearly	white	2–2.5
	Olivine	olive green, yellow	vitreous	white or none	6.5–7
	Orthoclase	colorless, white, pink, or other colors	vitreous	white or none	6
	Plagioclase	colorless, white, yellow, pink, green	vitreous	white	6
	Quartz	colorless or white; any color when not pure	vitreous or waxy	white or none	7
Nonsilicate Minerals	**Native Elements**				
	Copper	copper-red	metallic	copper-red	2.5–3
	Diamond	pale yellow or colorless	adamantine	none	10
	Graphite	black to gray	submetallic	black	1–2
	Carbonates				
	Aragonite	colorless, white, or pale yellow	vitreous	white	3.5–4
	Calcite	colorless or white to tan	vitreous	white	3
	Halides				
	Fluorite	light green, yellow, purple, bluish green, or other colors	vitreous	none	4
	Halite	white	vitreous	white	2.0–2.5
	Oxides				
	Hematite	reddish brown to black	metallic to earthy	dark red to red-brown	5.6–6.5
	Magnetite	iron-black	metallic	black	5.5–6.5
	Sulfates				
	Anhydrite	colorless, bluish, or violet	vitreous to pearly	white	3–3.5
	Gypsum	white, pink, gray, or colorless	vitreous, pearly, or silky	white	2.0
	Sulfides				
	Galena	lead-gray	metallic	lead-gray to black	2.5–2.8
	Pyrite	brassy yellow	metallic	greenish, brownish, or black	6–6.5

Density (g/cm^3)	Cleavage, Fracture, Special Properties	Common Uses
2.6–2.8	1 cleavage direction; irregular fracture; some varieties fluoresce in ultraviolet light	gemstones, ore of the metal beryllium
2.6–3.3	1 cleavage direction; irregular fracture	
4.2	no cleavage; conchoidal to splintery fracture	gemstones, abrasives
3.0–3.4	2 cleavage directions; hackly to splintery fracture	
2.7–3	1 cleavage direction; irregular fracture	electrical insulation, wallpaper, fireproofing material, lubricant
3.2–3.3	no cleavage; conchoidal fracture	gemstones, casting
2.6	2 cleavage directions; irregular fracture	porcelain
2.6–2.7	2 cleavage directions; irregular fracture	ceramics
2.6	no cleavage; conchoidal fracture	gemstones, concrete, glass, porcelain, sandpaper, lenses
8.9	no cleavage; hackly fracture	wiring, brass, bronze, coins
3.5	4 cleavage directions; irregular to conchoidal fracture	gemstones, drilling
2.3	1 cleavage direction; irregular fracture	pencils, paints, lubricants, batteries
2.95	2 cleavage directions; irregular fracture; reacts with hydrochloric acid	no important industrial uses
2.7	3 cleavage directions; irregular fracture; reacts with weak acid; double refraction	cements, soil conditioner, whitewash, construction materials
3.0–3.3	4 cleavage directions; irregular fracture; some varieties fluoresce	hydrofluoric acid, steel, glass, fiberglass, pottery, enamel
2.1–2.2	3 cleavage directions; splintery to conchoidal fracture; salty taste	tanning hides, salting icy roads, food preservation
5.2–5.3	no cleavage; splintery fracture; magnetic when heated	iron ore for steel, pigments
5.2	no cleavage; splintery fracture; magnetic	iron ore
3.0	3 cleavage directions; conchoidal to splintery fracture	soil conditioner, sulfuric acid
2.3	3 cleavage directions; conchoidal to splintery fracture	plaster of Paris, wallboard, soil conditioner
7.4–7.6	3 cleavage directions; irregular fracture	batteries, paints
5	no cleavage; conchoidal to splintery fracture	sulfuric acid

Making Charts and Graphs

Pie Charts

A pie chart shows how each group of data relates to all of the data. Each part of the circle forming the chart represents a category of the data. The entire circle represents all of the data. For example, a biologist studying a hardwood forest in Wisconsin found that there were five different types of trees. The data table at right summarizes the biologist's findings.

Wisconsin Hardwood Trees

Type of tree	Number found
Oak	600
Maple	750
Beech	300
Birch	1,200
Hickory	150
Total	3,000

How to Make a Pie Chart

1. To make a pie chart of these data, first find the percentage of each type of tree. Divide the number of trees of each type by the total number of trees, and multiply by 100.

$$\frac{600 \text{ oak}}{3{,}000 \text{ trees}} \times 100 = 20\%$$

$$\frac{750 \text{ maple}}{3{,}000 \text{ trees}} \times 100 = 25\%$$

$$\frac{300 \text{ beech}}{3{,}000 \text{ trees}} \times 100 = 10\%$$

$$\frac{1{,}200 \text{ birch}}{3{,}000 \text{ trees}} \times 100 = 40\%$$

$$\frac{150 \text{ hickory}}{3{,}000 \text{ trees}} \times 100 = 5\%$$

2. Now, determine the size of the wedges that make up the pie chart. Multiply each percentage by 360°. Remember that a circle contains 360°.

$20\% \times 360° = 72°$ $25\% \times 360° = 90°$

$10\% \times 360° = 36°$ $40\% \times 360° = 144°$

$5\% \times 360° = 18°$

3. Check that the sum of the percentages is 100 and the sum of the degrees is 360.

$20\% + 25\% + 10\% + 40\% + 5\% = 100\%$

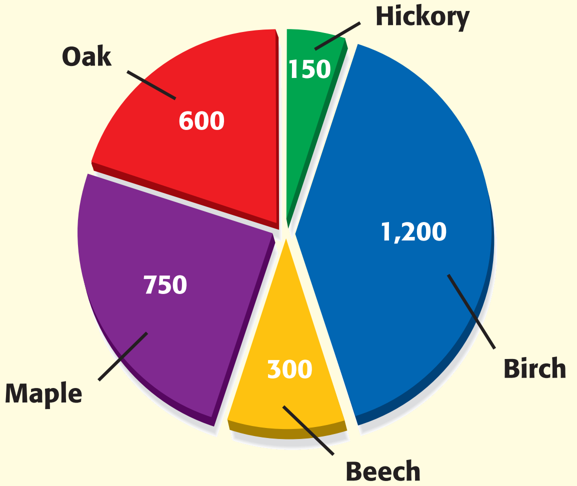
$72° + 90° + 36° + 144° + 18° = 360°$

4. Use a compass to draw a circle and mark the center of the circle.

5. Then, use a protractor to draw angles of 72°, 90°, 36°, 144°, and 18° in the circle.

6. Finally, label each part of the chart, and choose an appropriate title.

A Community of Wisconsin Hardwood Trees



Line Graphs

Line graphs are most often used to demonstrate continuous change. For example, Mr. Smith's students analyzed the population records for their hometown, Appleton, between 1900 and 2000. Examine the data at right.

Because the year and the population change, they are the *variables*. The population is determined by, or dependent on, the year. Therefore, the population is called the **dependent variable,** and the year is called the **independent variable.** Each set of data is called a **data pair.** To prepare a line graph, you must first organize data pairs into a table like the one at right.

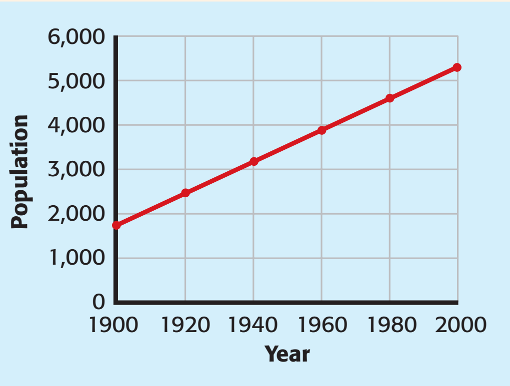
Population of Appleton, 1900–2000

Year	Population
1900	1,800
1920	2,500
1940	3,200
1960	3,900
1980	4,600
2000	5,300

How to Make a Line Graph

1. Place the independent variable along the horizontal (x) axis. Place the dependent variable along the vertical (y) axis.
2. Label the x-axis "Year" and the y-axis "Population." Look at your largest and smallest values for the population. For the y-axis, determine a scale that will provide enough space to show these values. You must use the same scale for the entire length of the axis. Next, find an appropriate scale for the x-axis.
3. Choose reasonable starting points for each axis.
4. Plot the data pairs as accurately as possible.
5. Choose a title that accurately represents the data.

Population of Appleton, 1900–2000



How to Determine Slope

Slope is the ratio of the change in the y-value to the change in the x-value, or "rise over run."

1. Choose two points on the line graph. For example, the population of Appleton in 2000 was 5,300 people. Therefore, you can define point *a* as (2000, 5,300). In 1900, the population was 1,800 people. You can define point *b* as (1900, 1,800).
2. Find the change in the y-value.
(y at point a) − (y at point b) = 5,300 people − 1,800 people = 3,500 people
3. Find the change in the x-value.
(x at point a) − (x at point b) = 2000 − 1900 = 100 years
4. Calculate the slope of the graph by dividing the change in y by the change in x.

$$slope = \frac{change\ in\ y}{change\ in\ x}$$

$$slope = \frac{3{,}500 \text{ people}}{100 \text{ years}}$$

$$slope = 35 \text{ people per year}$$

In this example, the population in Appleton increased by a fixed amount each year. The graph of these data is a straight line. Therefore, the relationship is **linear.** When the graph of a set of data is not a straight line, the relationship is **nonlinear.**

Using Algebra to Determine Slope

The equation in step 4 may also be arranged to be

$$y = kx$$

where y represents the change in the y-value, k represents the slope, and x represents the change in the x-value.

$$slope = \frac{change\ in\ y}{change\ in\ x}$$

$$k = \frac{y}{x}$$

$$k \times x = \frac{y \times x}{x}$$

$$kx = y$$

Bar Graphs

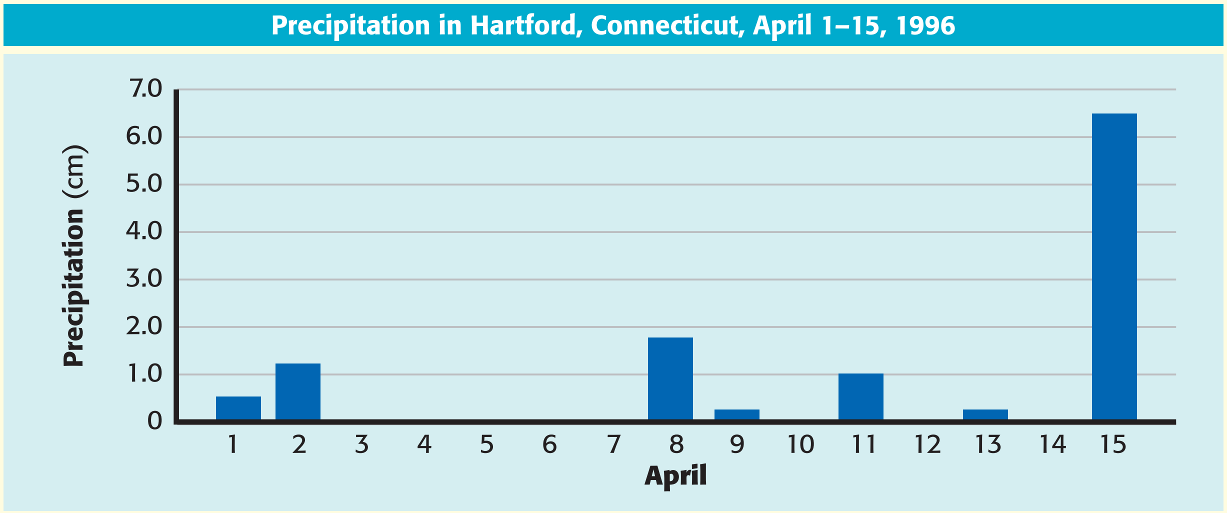
Bar graphs are used to demonstrate change that is not continuous. These graphs can be used to indicate trends when the data cover a long period of time. A meteorologist gathered the precipitation data shown here for Hartford, Connecticut, for April 1–15, 1996, and used a bar graph to represent the data.

Precipitation in Hartford, Connecticut April 1–15, 1996

Date	Precipitation (cm)	Date	Precipitation (cm)
April 1	0.5	April 9	0.25
April 2	1.25	April 10	0.0
April 3	0.0	April 11	1.0
April 4	0.0	April 12	0.0
April 5	0.0	April 13	0.25
April 6	0.0	April 14	0.0
April 7	0.0	April 15	6.50
April 8	1.75		

How to Make a Bar Graph

1. Use an appropriate scale and a reasonable starting point for each axis.
2. Label the axes, and plot the data.
3. Choose a title that accurately represents the data.



Math Refresher

Science requires an understanding of many math concepts. The following pages will help you review some important math skills.

Averages

An **average,** or **mean,** simplifies a set of numbers into a single number that *approximates* the value of the set.

Example: Find the average of the following set of numbers: 5, 4, 7, and 8.

Step 1: Find the sum.

$$5 + 4 + 7 + 8 = 24$$

Step 2: Divide the sum by the number of numbers in your set. Because there are four numbers in this example, divide the sum by 4.

$$\frac{24}{4} = 6$$

The average, or mean, is **6.**

Ratios

A **ratio** is a comparison between numbers, and it is usually written as a fraction.

Example: Find the ratio of thermometers to students if you have 36 thermometers and 48 students in your class.

Step 1: Make the ratio.

$$\frac{36 \text{ thermometers}}{48 \text{ students}}$$

Step 2: Reduce the fraction to its simplest form.

$$\frac{36}{48} = \frac{36 \div 12}{48 \div 12} = \frac{3}{4}$$

The ratio of thermometers to students is **3 to 4,** or $\frac{3}{4}$. The ratio may also be written in the form 3:4.

Proportions

A **proportion** is an equation that states that two ratios are equal.

$$\frac{3}{1} = \frac{12}{4}$$

To solve a proportion, first multiply across the equal sign. This is called *cross-multiplication*. If you know three of the quantities in a proportion, you can use cross-multiplication to find the fourth.

Example: Imagine that you are making a scale model of the solar system for your science project. The diameter of Jupiter is 11.2 times the diameter of the Earth. If you are using a plastic-foam ball that has a diameter of 2 cm to represent the Earth, what must the diameter of the ball representing Jupiter be?

$$\frac{11.2}{1} = \frac{x}{2 \text{ cm}}$$

Step 1: Cross-multiply.

$$\frac{11.2}{1} \times \frac{x}{2}$$

$$11.2 \times 2 = x \times 1$$

Step 2: Multiply.

$$22.4 = x \times 1$$

Step 3: Isolate the variable by dividing both sides by 1.

$$x = \frac{22.4}{1}$$

$$x = 22.4 \text{ cm}$$

You will need to use a ball that has a diameter of **22.4** cm to represent Jupiter.

Appendix

Percentages

A **percentage** is a ratio of a given number to 100.

Example: What is 85% of 40?

Step 1: Rewrite the percentage by moving the decimal point two places to the left.

0.85

Step 2: Multiply the decimal by the number that you are calculating the percentage of.

$0.85 \times 40 = 34$

85% of 40 is **34.**

Decimals

To **add** or **subtract decimals,** line up the digits vertically so that the decimal points line up. Then, add or subtract the columns from right to left. Carry or borrow numbers as necessary.

Example: Add the following numbers: 3.1415 and 2.96.

Step 1: Line up the digits vertically so that the decimal points line up.

$$\begin{array}{r} 3.1415 \\ +\ 2.96 \\ \hline \end{array}$$

Step 2: Add the columns from right to left, and carry when necessary.

$$\begin{array}{r} {\scriptstyle 1\ \ 1} \\ 3.1415 \\ +\ 2.96 \\ \hline 6.1015 \end{array}$$

The sum is **6.1015.**

Fractions

Numbers tell you how many; **fractions** tell you *how much of a whole*.

Example: Your class has 24 plants. Your teacher instructs you to put 5 plants in a shady spot. What fraction of the plants in your class will you put in a shady spot?

Step 1: In the denominator, write the total number of parts in the whole.

$$\frac{?}{24}$$

Step 2: In the numerator, write the number of parts of the whole that are being considered.

$$\frac{5}{24}$$

So, $\mathbf{\frac{5}{24}}$ of the plants will be in the shade.

Reducing Fractions

It is usually best to express a fraction in its simplest form. Expressing a fraction in its simplest form is called *reducing* a fraction.

Example: Reduce the fraction $\frac{30}{45}$ to its simplest form.

Step 1: Find the largest whole number that will divide evenly into both the numerator and denominator. This number is called the *greatest common factor* (GCF).

Factors of the numerator 30:

1, 2, 3, 5, 6, 10, **15,** 30

Factors of the denominator 45:

1, 3, 5, 9, **15,** 45

Step 2: Divide both the numerator and the denominator by the GCF, which in this case is 15.

$$\frac{30}{45} = \frac{30 \div 15}{45 \div 15} = \frac{2}{3}$$

Thus, $\frac{30}{45}$ reduced to its simplest form is $\mathbf{\frac{2}{3}}$.

Adding and Subtracting Fractions

To **add** or **subtract fractions** that have the **same denominator,** simply add or subtract the numerators.

Examples:

$$\frac{3}{5} + \frac{1}{5} = ? \text{ and } \frac{3}{4} - \frac{1}{4} = ?$$

Step 1: Add or subtract the numerators.

$$\frac{3}{5} + \frac{1}{5} = \frac{4}{} \text{ and } \frac{3}{4} - \frac{1}{4} = \frac{2}{}$$

Step 2: Write the sum or difference over the denominator.

$$\frac{3}{5} + \frac{1}{5} = \frac{4}{5} \text{ and } \frac{3}{4} - \frac{1}{4} = \frac{2}{4}$$

Step 3: If necessary, reduce the fraction to its simplest form.

$\mathbf{\frac{4}{5}}$ cannot be reduced, and $\frac{2}{4} = \mathbf{\frac{1}{2}}$.

To **add** or **subtract fractions** that have **different denominators,** first find the least common denominator (LCD).

Examples:

$$\frac{1}{2} + \frac{1}{6} = ? \text{ and } \frac{3}{4} - \frac{2}{3} = ?$$

Step 1: Write the equivalent fractions that have a common denominator.

$$\frac{3}{6} + \frac{1}{6} = ? \text{ and } \frac{9}{12} - \frac{8}{12} = ?$$

Step 2: Add or subtract the fractions.

$$\frac{3}{6} + \frac{1}{6} = \frac{4}{6} \text{ and } \frac{9}{12} - \frac{8}{12} = \frac{1}{12}$$

Step 3: If necessary, reduce the fraction to its simplest form.

The fraction $\frac{4}{6} = \mathbf{\frac{2}{3}}$, and $\mathbf{\frac{1}{12}}$ cannot be reduced.

Multiplying Fractions

To **multiply fractions,** multiply the numerators and the denominators together, and then reduce the fraction to its simplest form.

Example:

$$\frac{5}{9} \times \frac{7}{10} = ?$$

Step 1: Multiply the numerators and denominators.

$$\frac{5}{9} \times \frac{7}{10} = \frac{5 \times 7}{9 \times 10} = \frac{35}{90}$$

Step 2: Reduce the fraction.

$$\frac{35}{90} = \frac{35 \div 5}{90 \div 5} = \mathbf{\frac{7}{18}}$$

Dividing Fractions

To **divide fractions,** first rewrite the divisor (the number you divide by) upside down. This number is called the *reciprocal* of the divisor. Then multiply and reduce if necessary.

Example:

$$\frac{5}{8} \div \frac{3}{2} = ?$$

Step 1: Rewrite the divisor as its reciprocal.

$$\frac{3}{2} \rightarrow \frac{2}{3}$$

Step 2: Multiply the fractions.

$$\frac{5}{8} \times \frac{2}{3} = \frac{5 \times 2}{8 \times 3} = \frac{10}{24}$$

Step 3: Reduce the fraction.

$$\frac{10}{24} = \frac{10 \div 2}{24 \div 2} = \mathbf{\frac{5}{12}}$$

Scientific Notation

Scientific notation is a short way of representing very large and very small numbers without writing all of the place-holding zeros.

Example: Write 653,000,000 in scientific notation.

Step 1: Write the number without the place-holding zeros.

653

Step 2: Place the decimal point after the first digit.

6.53

Step 3: Find the exponent by counting the number of places that you moved the decimal point.

6.53000000

The decimal point was moved eight places to the left. Therefore, the exponent of 10 is positive 8. If you had moved the decimal point to the right, the exponent would be negative.

Step 4: Write the number in scientific notation.

$\mathbf{6.53 \times 10^8}$

Area

Area is the number of square units needed to cover the surface of an object.

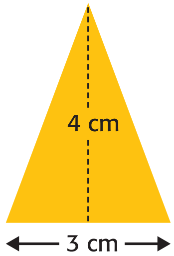
Formulas:

area of a square = *side* × *side*

area of a rectangle = *length* × *width*

area of a triangle = $\frac{1}{2}$ × *base* × *height*

Examples: Find the areas.



Triangle

area = $\frac{1}{2}$ × *base* × *height*

area = $\frac{1}{2}$ × 3 cm × 4 cm

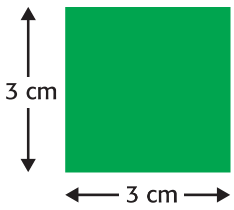
area = **6 cm²**

Rectangle

area = *length* × *width*

area = 6 cm × 3 cm

area = **18 cm²**



Square

area = *side* × *side*

area = 3 cm × 3 cm

area = **9 cm²**

Volume

Volume is the amount of space that something occupies.

Formulas:

volume of a cube = *side* × *side* × *side*

volume of a prism = *area of base* × *height*

Examples:

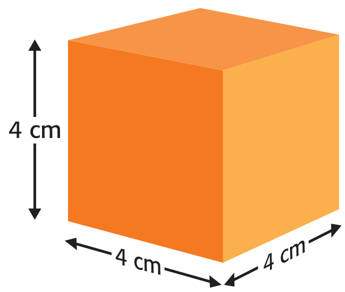
Find the volume of the solids.

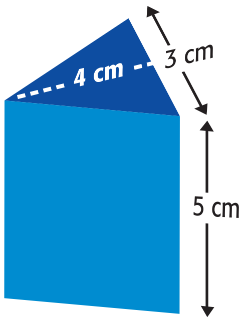
Cube

volume = *side* × *side* × *side*

volume = 4 cm × 4 cm × 4 cm

volume = **64 cm³**





Prism

volume = *area of base* × *height*

volume = (*area of triangle*) × *height*

volume = ($\frac{1}{2}$ × 3 cm × 4 cm) × 5 cm

volume = 6 cm² × 5 cm

volume = **30 cm³**

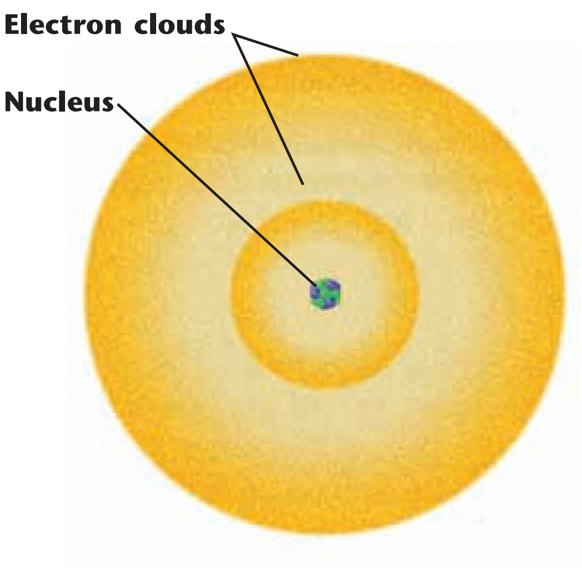
Physical Science Refresher

Atoms and Elements

Every object in the universe is made up of particles of some kind of matter. **Matter** is anything that takes up space and has mass. All matter is made up of elements. An **element** is a substance that cannot be separated into simpler components by ordinary chemical means. This is because each element consists of only one kind of atom. An **atom** is the smallest unit of an element that has all of the properties of that element.

Atomic Structure

Atoms are made up of small particles called subatomic particles. The three major types of subatomic particles are **electrons, protons,** and **neutrons.** Electrons have a negative electric charge, protons have a positive charge, and neutrons have no electric charge. The protons and neutrons are packed close to one another to form the **nucleus.** The protons give the nucleus a positive charge. Electrons are most likely to be found in regions around the nucleus called **electron clouds.** The negatively charged electrons are attracted to the positively charged nucleus. An atom may have several energy levels in which electrons are located.



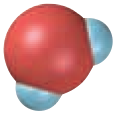
Atomic Number

To help in the identification of elements, scientists have assigned an **atomic number** to each kind of atom. The atomic number is the number of protons in the atom. Atoms with the same number of protons are all the same kind of element. In an uncharged, or electrically neutral, atom there are an equal number of protons and electrons. Therefore, the atomic number equals the number of electrons in an uncharged atom. The number of neutrons, however, can vary for a given element. Atoms of the same element that have different numbers of neutrons are called **isotopes.**

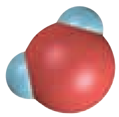
Periodic Table of the Elements

In the periodic table, the elements are arranged from left to right in order of increasing atomic number. Each element in the table is in a separate box. An uncharged atom of each element has one more electron and one more proton than an uncharged atom of the element to its left. Each horizontal row of the table is called a **period.** Changes in chemical properties of elements across a period correspond to changes in the electron arrangements of their atoms. Each vertical column of the table, known as a **group,** lists elements with similar properties. The elements in a group have similar chemical properties because their atoms have the same number of electrons in their outer energy level. For example, the elements helium, neon, argon, krypton, xenon, and radon all have similar properties and are known as the noble gases.

Molecules and Compounds



When two or more elements are joined chemically, the resulting substance is called a **compound.** A compound is a new substance with properties different from those of the elements that compose it. For example, water, H_2O, is a compound formed when hydrogen (H) and oxygen (O) combine. The smallest complete unit of a compound that has the properties of that compound is called a **molecule.** A chemical formula indicates the elements in a compound. It also indicates the relative number of atoms of each element present. The chemical formula for water is H_2O, which indicates that each water molecule consists of two atoms of hydrogen and one atom of oxygen. The subscript number after the symbol for an element indicates how many atoms of that element are in a single molecule of the compound.



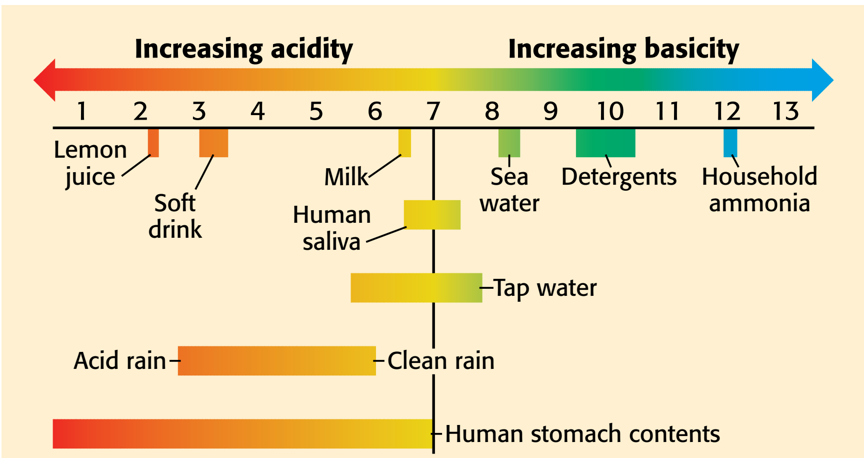
Acids, Bases, and pH

An ion is an atom or group of atoms that has an electric charge because it has lost or gained one or more electrons. When an acid, such as hydrochloric acid, HCl, is mixed with water, it separates into ions. An **acid** is a compound that produces hydrogen ions, H+, in water. The hydrogen ions then combine with a water molecule to form a hydronium ion, H_3O^+. A **base,** on the other hand, is a substance that produces hydroxide ions, OH^-, in water.

To determine whether a solution is acidic or basic, scientists use pH. The **pH** is a measure of the hydronium ion concentration in a solution. The pH scale ranges from 0 to 14. The middle point, pH = 7, is neutral, neither acidic nor basic. Acids have a pH less than 7; bases have a pH greater than 7. The lower the number is, the more acidic the solution. The higher the number is, the more basic the solution.

Chemical Equations

A chemical reaction occurs when a chemical change takes place. (In a chemical change, new substances with new properties are formed.) A chemical equation is a useful way of describing a chemical reaction by means of chemical formulas. The equation indicates what substances react and what the products are. For example, when carbon and oxygen combine, they can form carbon dioxide. The equation for the reaction is as follows: $C + O_2 \rightarrow CO_2$.



Physical Science Laws and Principles

Law of Conservation of Energy

The law of conservation of energy states that energy can be neither created nor destroyed.

The total amount of energy in a closed system is always the same. Energy can be changed from one form to another, but all of the different forms of energy in a system always add up to the same total amount of energy no matter how many energy conversions occur.

Law of Universal Gravitation

The law of universal gravitation states that all objects in the universe attract each other by a force called *gravity*. The size of the force depends on the masses of the objects and the distance between objects.

The first part of the law explains why a bowling ball is much harder to lift than a table-tennis ball. Because the bowling ball has a much larger mass than the table-tennis ball does, the amount of gravity between the Earth and the bowling ball is greater than the amount of gravity between the Earth and the table-tennis ball.

The second part of the law explains why a satellite can remain in orbit around the Earth. The satellite is carefully placed at a distance great enough to prevent the Earth's gravity from immediately pulling the satellite down but small enough to prevent the satellite from completely escaping the Earth's gravity and wandering off into space.

Newton's Laws of Motion

Newton's first law of motion states that an object at rest remains at rest and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force.

The first part of the law explains why a football will remain on a tee until it is kicked off or until a gust of wind blows it off.

The second part of the law explains why a bike rider will continue moving forward after the bike comes to an abrupt stop. Gravity and the friction of the sidewalk will eventually stop the rider.

Newton's second law of motion states that the acceleration of an object depends on the mass of the object and the amount of force applied.

The first part of the law explains why the acceleration of a 4 kg bowling ball will be greater than the acceleration of a 6 kg bowling ball if the same force is applied to both.

The second part of the law explains why the acceleration of a bowling ball will be larger if a larger force is applied to the bowling ball.

The relationship of acceleration (a) to mass (m) and force (F) can be expressed mathematically by the following equation:

$$acceleration = \frac{force}{mass}, \text{ or } a = \frac{F}{m}$$

This equation is often rearranged to the form

$$force = mass \times acceleration$$

or

$$F = m \times a$$

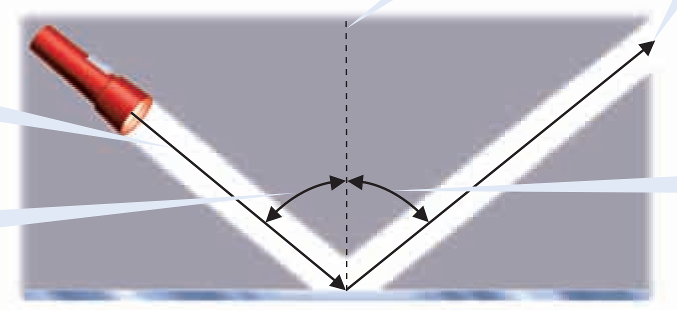
Newton's third law of motion states that whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

This law explains that a runner is able to move forward because of the equal and opposite force that the ground exerts on the runner's foot after each step.

Appendix

Law of Reflection

The law of reflection states that the angle of incidence is equal to the angle of reflection. This law explains why light reflects off a surface at the same angle that the light strikes the surface.



Charles's Law

Charles's law states that for a fixed amount of gas at a constant pressure, the volume of the gas increases as the temperature of the gas increases. Likewise, the volume of the gas decreases as the temperature of the gas decreases.

If a basketball that was inflated indoors is left outside on a cold winter day, the air particles inside the ball will move more slowly. They will hit the sides of the basketball less often and with less force. The ball will get smaller as the volume of the air decreases.

Boyle's Law

Boyle's law states that for a fixed amount of gas at a constant temperature, the volume of a gas increases as the pressure of the gas decreases. Likewise, the volume of a gas decreases as its pressure increases.

If an inflated balloon is pulled down to the bottom of a swimming pool, the pressure of the water on the balloon increases. The pressure of the air particles inside the balloon must increase to match that of the water outside, so the volume of the air inside the balloon decreases.

Pascal's Principle

Pascal's principle states that a change in pressure at any point in an enclosed fluid will be transmitted equally to all parts of that fluid.

When a mechanic uses a hydraulic jack to raise an automobile off the ground, he or she increases the pressure on the fluid in the jack by pushing on the jack handle. The pressure is transmitted equally to all parts of the fluid-filled jacking system. As fluid presses the jack plate against the frame of the car, the car is lifed off the ground.

Archimedes' Principle

Archimedes' principle states that the buoyant force on an object in a fluid is equal to the weight of the volume of fluid that the object displaces.

A person floating in a swimming pool displaces 20 L of water. The weight of that volume of water is about 200 N. Therefore, the buoyant force on the person is 200 N.

Bernoulli's Principle

Bernoulli's principle states that as the speed of a moving fluid increases, the fluid's pressure decreases.

The lift on an airplane wing or on a Frisbee® can be explained in part by using Bernoulli's principle. Because of the shape of the Frisbee, the air moving over the top of the Frisbee must travel farther than the air below the Frisbee in the same amount of time. In other words, the air above the Frisbee is moving faster than the air below it. This faster-moving air above the Frisbee exerts less pressure than the slower-moving air below it does. The resulting increased pressure below exerts an upward force and pushes the Frisbee up.

Useful Equations

Average speed

$$\textit{average speed} = \frac{\textit{total distance}}{\textit{total time}}$$

Example: A bicycle messenger traveled a distance of 136 km in 8 h. What was the messenger's average speed?

$$\frac{136\ \text{km}}{8\ \text{h}} = 17\ \text{km/h}$$

The messenger's average speed was **17 km/h.**

Average acceleration

$$\textit{average acceleration} = \frac{\textit{final velocity} - \textit{starting velocity}}{\textit{time it takes to change velocity}}$$

Example: Calculate the average acceleration of an Olympic 100 m dash sprinter who reaches a velocity of 20 m/s south at the finish line. The race was in a straight line and lasted 10 s.

$$\frac{20\ \text{m/s} - 0\ \text{m/s}}{10\text{s}} = 2\ \text{m/s/s}$$

The sprinter's average acceleration is **2 m/s/s south.**

Net force

Forces in the Same Direction

When forces are in the same direction, add the forces together to determine the net force.

Example: Calculate the net force on a stalled car that is being pushed by two people. One person is pushing with a force of 13 N northwest, and the other person is pushing with a force of 8 N in the same direction.

$$13\ \text{N} + 8\ \text{N} = 21\ \text{N}$$

The net force is **21 N northwest.**

Forces in Opposite Directions

When forces are in opposite directions, subtract the smaller force from the larger force to determine the net force. The net force will be in the direction of the larger force.

Example: Calculate the net force on a rope that is being pulled on each end. One person is pulling on one end of the rope with a force of 12 N south. Another person is pulling on the opposite end of the rope with a force of 7 N north.

$$12\ \text{N} - 7\ \text{N} = 5\ \text{N}$$

The net force is **5 N south.**

Appendix

Work

Work is done by exerting a force through a distance. Work has units of joules (J), which are equivalent to Newton-meters.

$$Work = F \times d$$

Example: Calculate the amount of work done by a man who lifts a 100 N toddler 1.5 m off the floor.

Work = 100 N × 1.5 m = 150 N•m = 150 J

The man did **150 J** of work.

Power

Power is the rate at which work is done. Power is measured in watts (W), which are equivalent to joules per second.

$$P = \frac{Work}{t}$$

Example: Calculate the power of a weightlifter who raises a 300 N barbell 2.1 m off the floor in 1.25 s.

Work = 300 N × 2.1 m = 630 N•m = 630 J

$$P = \frac{630\text{ J}}{1.25\text{ s}} = \frac{504\text{ J}}{\text{s}} = 504\text{ W}$$

The weightlifter has **504 W** of power.

Pressure

Pressure is the force exerted over a given area. The SI unit for pressure is the pascal (Pa).

$$pressure = \frac{force}{area}$$

Example: Calculate the pressure of the air in a soccer ball if the air exerts a force of 25,000 N over an area of 0.15 m^2.

$$pressure = \frac{25{,}000\text{ N}}{0.15\text{ m}^2} = \frac{167{,}000\text{ N}}{\text{m}^2} = 167{,}000\text{ Pa}$$

The pressure of the air inside the soccer ball is **167,000 Pa.**

Density

$$density = \frac{mass}{volume}$$

Example: Calculate the density of a sponge that has a mass of 10 g and a volume of 40 cm^3.

$$\frac{10\text{ g}}{40\text{ cm}^3} = \frac{0.25\text{ g}}{\text{cm}^3}$$

The density of the sponge is $\mathbf{\frac{0.25\text{ g}}{\text{cm}^3}}$.

Concentration

$$concentration = \frac{mass\ of\ solute}{volume\ of\ solvent}$$

Example: Calculate the concentration of a solution in which 10 g of sugar is dissolved in 125 mL of water.

$$\frac{10\text{ g of sugar}}{125\text{ mL of water}} = \frac{0.08\text{ g}}{\text{mL}}$$

The concentration of this solution is $\mathbf{\frac{0.08\text{ g}}{\text{mL}}}$.

Appendix

Glossary

A

absolute dating any method of measuring the age of an event or object in years (442)

absolute zero the temperature at which molecular energy is at a minimum (0 K on the Kelvin scale or –273.16°C on the Celsius scale) (195)

abyssal plain a large, flat, almost level area of the deep-ocean basin (86)

activation energy the minimum amount of energy required to start a chemical reaction (310)

active transport the movement of substances across the cell membrane that requires the cell to use energy (530)

algae (AL JEE) eukaryotic organisms that convert the sun's energy into food through photosynthesis but that do not have roots, stems, or leaves (singular, *alga*) (582)

alkali metal (AL kuh LIE MET uhl) one of the elements of Group 1 of the periodic table (lithium, sodium, potassium, rubidium, cesium, and francium) (248)

alkaline-earth metal (AL kuh LIEN UHRTH MET uhl) one of the elements of Group 2 of the periodic table (beryllium, magnesium, calcium, strontium, barium, and radium) (249)

alluvial fan a fan-shaped mass of material deposited by a stream when the slope of the land decreases sharply (50)

analog signal (AN uh LAWG SIG nuhl) a signal whose properties can change continuously in a given range (373)

antibiotic medicine used to kill bacteria and other microorganisms (616)

aquifer a body of rock or sediment that stores groundwater and allows the flow of groundwater (53)

area a measure of the size of a surface or a region (24)

artesian spring a spring whose water flows from a crack in the cap rock over the aquifer (55)

azimuthal projection (az uh MYOOTH uhl proh JEK shuhn) a map projection that is made by moving the surface features of the globe onto a plane (409)

B

benthos the organisms that live at the bottom of the sea or ocean (90)

binary fission (BIE nuh ree FISH uhn) a form of asexual reproduction in single-celled organisms by which one cell divides into two cells of the same size (610)

bioremediation (BIE oh ri MEE dee AY shuhn) the biological treatment of hazardous waste by living organisms (615)

boiling the conversion of a liquid to a vapor when the vapor pressure of the liquid equals the atmospheric pressure (198)

C

carcinogen a cancer-causing substance (335)

cast a type of fossil that forms when sediments fill in the cavity left by a decomposed organism (448)

catalyst (KAT uh LIST) a substance that changes the rate of a chemical reaction without being used up or changed very much (313)

catastrophism a principle that states that geologic change occurs suddenly (433)

cell in biology, the smallest unit that can perform all life processes; cells are covered by a membrane and contain DNA and cytoplasm (498)

cell cycle the life cycle of a cell (536)

cell membrane a phospholipid layer that covers a cell's surface and acts as a barrier between the inside of a cell and the cell's environment (501)

cellular respiration the process by which cells use oxygen to produce energy from food (533)

cell wall a rigid structure that surrounds the cell membrane and provides support to the cell (506)

change of state the change of a substance from one physical state to another (196)

channel the path that a stream follows (43)

chemical any substance that has a defined composition (324)

chemical bond an interaction that holds atoms or ions together (268)

chemical bonding the combining of atoms to form molecules or ionic compounds (268)

chemical change a change that occurs when one or more substances change into entirely new substances with different properties (168)

chemical equation a representation of a chemical reaction that uses symbols to show the relationship between the reactants and the products (298)

chemical formula a combination of chemical symbols and numbers to represent a substance (296)

chemical property a property of matter that describes a substance's ability to participate in chemical reactions (166)

chemical reaction the process by which one or more substances change to produce one or more different substances (292)

chromosome in a eukaryotic cell, one of the structures in the nucleus that are made up of DNA and protein; in a prokaryotic cell, the main ring of DNA (536)

colloid (KAHL OYD) a mixture consisting of tiny particles that are intermediate in size between those in solutions and those in suspensions and that are suspended in a liquid, solid, or gas (228)

compound a substance made up of atoms of two or more different elements joined by chemical bonds (216)

compression stress that occurs when forces act to squeeze an object (478)

computer an electronic device that can accept data and instructions, follow the instructions, and output the results (380)

concentration the amount of a particular substance in a given quantity of a mixture, solution, or ore (226)

condensation the change of state from a gas to a liquid (199)

conic projection a map projection that is made by moving the surface features of the globe onto a cone (408)

continental drift the hypothesis that states that the continents once formed a single landmass, broke up, and drifted to their present locations (470)

continental rise the gently sloping section of the continental margin located between the continental slope and the abyssal plain (86)

continental shelf the gently sloping section of the continental margin located between the shoreline and the continental slope (86)

continental slope the steeply inclined section of the continental margin located between the continental rise and the continental shelf (86)

contour interval the difference in elevation between one contour line and the next (419)

contour line a line that connects points of equal elevation (418)

convergent boundary the boundary formed by the collision of two lithospheric plates (475)

Coriolis effect the apparent curving of the path of a moving object from an otherwise straight path due to the Earth's rotation (122)

covalent bond (koh VAY luhnt BAHND) a bond formed when atoms share one or more pairs of electrons (276)

crystal lattice (KRIS tuhl LAT is) the regular pattern in which a crystal is arranged (275)

cylindrical projection (suh LIN dri kuhl proh JEK shuhn) a map projection that is made by moving the surface features of the globe onto a cylinder (407)

cytokinesis the division of the cytoplasm of a cell (538)

D

data any pieces of information acquired through observation or experimentation (15)

decomposition reaction a reaction in which a single compound breaks down to form two or more simpler substances (305)

deep current a streamlike movement of ocean water far below the surface (123)

delta a fan-shaped mass of material deposited at the mouth of a stream (49)

density the ratio of the mass of a substance to the volume of the substance (25, 160)

deposition the process in which material is laid down (48)

desalination (DEE SAL uh NAY shuhn) a process of removing salt from ocean water (101)

diffusion (di FYOO zhuhn) the movement of particles from regions of higher density to regions of lower density (528)

digital signal a signal that can be represented as a sequence of discrete values (374)

divergent boundary the boundary between two tectonic plates that are moving away from each other (475)

divide the boundary between drainage areas that have streams that flow in opposite directions (42)

Glossary

DNA **d**eoxyribo**n**ucleic **a**cid, a molecule that is present in all living cells and that contains the information that determines the traits that a living thing inherits and needs to live (554)

dose the quantity of medicine that needs to be taken over a period of time (329)

double-displacement reaction a reaction in which a gas, a solid precipitate, or a molecular compound forms from the exchange of ions between two compounds (307)

E

electromagnetic spectrum all of the frequencies or wavelengths of electromagnetic radiation (414)

element a substance that cannot be separated or broken down into simpler substances by chemical means (212)

elevation the height of an object above sea level (418)

El Niño a change in the surface water temperature in the Pacific Ocean that produces a warm current (128)

endocytosis (EN doh sie TOH sis) the process by which a cell membrane surrounds a particle and encloses the particle in a vesicle to bring the particle into the cell (530)

endoplasmic reticulum (EN doh PLAZ mik ri TIK yuh luhm) a system of membranes that is found in a cell's cytoplasm and that assists in the production, processing, and transport of proteins and in the production of lipids (509)

endospore (EN doh SPAWR) a thick-walled protective spore that forms inside a bacterial cell and resists harsh conditions (611)

endothermic reaction a chemical reaction that requires heat (309)

eon (EE AHN) the largest division of geologic time (455)

epoch (EP uhk) a subdivision of a geologic period (455)

equator the imaginary circle halfway between the poles that divides the Earth into the Northern and Southern Hemispheres (403)

era a unit of geologic time that includes two or more periods (455)

erosion the process by which wind, water, ice, or gravity transports soil and sediment from one location to another (40)

estuary an area where fresh water from rivers mixes with salt water from the ocean (95)

eukaryote an organism made up of cells that have a nucleus enclosed by a membrane; eukaryotes include animals, plants, and fungi but not archaebacteria or eubacteria (504)

evaporation (ee vap uh RAY shuhn) the change of a substance from a liquid to a gas (198)

exocytosis (EK soh sie TOH sis) the process in which a cell releases a particle by enclosing the particle in a vesicle that then moves to the cell surface and fuses with the cell membrane (531)

exothermic reaction a chemical reaction in which heat is released to the surroundings (308)

extinction the death of every member of a species (455)

F

fault a break in a body of rock along which one block slides relative to another (480)

feedback mechanism a cycle of events in which information from one step controls or affects a previous step (540)

fermentation the breakdown of food without the use of oxygen (533)

floodplain an area along a river that forms from sediments deposited when the river overflows its banks (50)

folding the bending of rock layers due to stress (479)

fossil the remains or physical evidence of an organism preserved by geological processes (446)

function the special, normal, or proper activity of an organ or part (517)

fungus an organism whose cells have nuclei, rigid cell walls, and no chlorophyll and that belongs to the kingdom Fungi (590)

G

gas a form of matter that does not have a definite volume or shape (191)

geologic column an arrangement of rock layers in which the oldest rocks are at the bottom (437)

geologic time scale the standard method used to divide the Earth's long natural history into manageable parts (454)

global positioning system a network of satellites that orbit the Earth to measure positions on the Earth's surface (abbreviation, GPS) (412)

Golgi complex (GOHL jee KAHM PLEKS) cell organelle that helps make and package materials to be transported out of the cell (511)

group a vertical column of elements in the periodic table; elements in a group share chemical properties (246)

H

half-life the time needed for half of a sample of a radioactive substance to undergo radioactive decay (443)

halogen (HAL oh juhn) one of the elements of Group 17 of the periodic table (fluorine, chlorine, bromine, iodine, and astatine); halogens combine with most metals to form salts (253)

hardware the parts or pieces of equipment that make up a computer (382)

heat engine a machine that transforms heat into mechanical energy, or work (358)

heterotroph (HET uhr oh TROHF) an organism that gets food by eating other organisms or their byproducts and that cannot make organic compounds from inorganic materials (579)

homologous chromosomes (hoh MAHL uh guhs KROH muh SOHMZ) chromosomes that have the same sequence of genes and the same structure (537)

host an organism from which a parasite takes food or shelter (579, 618)

hypha (HIE fuh) a nonreproductive filament of a fungus (591)

hypothesis (hie PAHTH uh sis) an explanation that is based on prior scientific research or observations and that can be tested (13)

I

immunity the ability to resist an infectious disease (626)

index contour on a map, a darker, heavier contour line that is usually every fifth line and that indicates a change in elevation (419)

index fossil a fossil that is found in the rock layers of only one geologic age and that is used to establish the age of the rock layers (450)

inertia (in UHR shuh) the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction until an outside force acts on the object (156)

infectious disease a disease that is caused by a pathogen and that can be spread from one individual to another (622)

inhibitor a substance that slows down or stops a chemical reaction (312)

insulation a substance that reduces the transfer of electricity, heat, or sound (353)

Internet a large computer network that connects many local and smaller networks all over the world (386)

ion a charged particle that forms when an atom or group of atoms gains or loses one or more electrons (272)

ionic bond (ie AHN ik BAHND) a bond that forms when electrons are transferred from one atom to another, which results in a positive ion and a negative ion (272)

isotope an atom that has the same number of protons (or the same atomic number) as other atoms of the same element do but that has a different number of neutrons (and thus a different atomic mass) (442)

L

La Niña a change in the eastern Pacific Ocean in which the surface water temperature becomes unusually cool (128)

latitude the distance north or south from the equator; expressed in degrees (403)

law a summary of many experimental results and observations; a law tells how things work (21)

law of conservation of energy the law that states that energy cannot be created or destroyed but can be changed from one form to another (309)

law of conservation of mass the law that states that mass cannot be created or destroyed in ordinary chemical and physical changes (301)

lichen (LIE kuhn) a mass of fungal and algal cells that grow together in a symbiotic relationship and that are usually found on rocks or trees (596)

liquid the state of matter that has a definite volume but not a definite shape (190)

load the materials carried by a stream (44)

longitude the distance east and west from the prime meridian; expressed in degrees (404)

longshore current a water current that travels near and parallel to the shoreline (133)

lysosome (LIE suh SOHM) a cell organelle that contains digestive enzymes (512)

M

magnetic declination the difference between the magnetic north and the true north (402)

map a representation of the features of a physical body such as Earth (400)

mass a measure of the amount of matter in an object (24, 155)

matter anything that has mass and takes up space (152)

medicine any drug that is used to cure, prevent, or treat illness or discomfort (328)

melting the change of state in which a solid becomes a liquid by adding heat (197)

meniscus (muh NIS kuhs) the curve at a liquid's surface by which one measures the volume of the liquid (153)

metal an element that is shiny and that conducts heat and electricity well (214)

metallic bond a bond formed by the attraction between positively charged metal ions and the electrons around them (279)

metalloid an element that has properties of both metals and nonmetals (214)

meter the basic unit of length in the SI (symbol, m) (24)

microprocessor a single semiconductor chip that controls and executes a microcomputer's instructions (381)

mid-ocean ridge a long, undersea mountain chain that forms along the floor of the major oceans (87)

mitochondrion (MIET oh KAHN dree uhn) in eukaryotic cells, the cell organelle that is surrounded by two membranes and that is the site of cellular respiration (510)

mitosis in eukaryotic cells, a process of cell division that forms two new nuclei, each of which has the same number of chromosomes (537)

mixture a combination of two or more substances that are not chemically combined (222)

model a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept (18)

mold a mark or cavity made in a sedimentary surface by a shell or other body (448); *also* in biology, a fungus that looks like wool or cotton (592)

molecule (MAHL i KYOOL) the smallest unit of a substance that keeps all of the physical and chemical properties of that substance (277)

mutation a change in the nucleotide-base sequence of a gene or DNA molecule (562)

mycelium (mie SEE lee uhm) the mass of fungal filaments, or hyphae, that forms the body of a fungus (591)

N

neap tide a tide of minimum range that occurs during the first and third quarters of the moon (138)

nekton all organisms that swim actively in open water, independent of currents (90)

noble gas one of the elements of Group 18 of the periodic table (helium, neon, argon, krypton, xenon, and radon); noble gases are unreactive (254)

noninfectious disease a disease that cannot spread from one individual to another (622)

nonmetal an element that conducts heat and electricity poorly (214)

nonpoint-source pollution pollution that comes from many sources rather than from a single, specific site (58, 104)

nucleotide in a nucleic-acid chain, a subunit that consists of a sugar, a phosphate, and a nitrogenous base (554)

nucleus in a eukaryotic cell, a membrane-bound organelle that contains the cell's DNA and that has a role in processes such as growth, metabolism, and reproduction (501)

O

observation the process of obtaining information by using the senses (11)

ocean current a movement of ocean water that follows a regular pattern (120)

ocean trench a steep and long depression in the deep-sea floor that runs parallel to a chain of volcanic islands or a continental margin (87)

organ a collection of tissues that carry out a specialized function of the body (515)

organelle one of the small bodies in a cell's cytoplasm that are specialized to perform a specific function (501)

organism a living thing; anything that can carry out life processes independently (516)

organ system a group of organs that work together to perform body functions (516)

osmosis (ahs MOH sis) the diffusion of water through a semipermeable membrane (529)

P

paleontology the scientific study of fossils (435)

parasite an organism that feeds on an organism of another species (the host) and that usually harms the host; the host never benefits from the presence of the parasite (579)

passive transport the movement of substances across a cell membrane without the use of energy by the cell (530)

pathogen a virus, microorganism, or other organism that causes disease (622)

pathogenic bacteria (PATH uh JEN ik bak TIR ee uh) bacteria that cause disease (616)

period in chemistry, a horizontal row of elements in the periodic table (246); *also* a unit of geologic time into which eras are divided (455)

periodic describes something that occurs or repeats at regular intervals (241)

periodic law the law that states that the repeating chemical and physical properties of elements change periodically with the atomic numbers of the elements (241)

permeability the ability of a rock or sediment to let fluids pass through its open spaces, or pores (53)

photosynthesis (FOHT oh SIN thuh sis) the process by which plants, algae, and some bacteria use sunlight, carbon dioxide, and water to make food (532)

physical change a change of matter from one form to another without a change in chemical properties (164)

physical property a characteristic of a substance that does not involve a chemical change, such as density, color, or hardness (158)

phytoplankton (FIET oh PLANGK tuhn) the microscopic, photosynthetic organisms that float near the surface of marine or fresh water (582)

plankton the mass of mostly microscopic organisms that float or drift freely in freshwater and marine environments (90)

plate tectonics the theory that explains how large pieces of the Earth's outermost layer, called *tectonic plates,* move and change shape (474)

point-source pollution pollution that comes from a specific site (58, 105)

porosity the percentage of the total volume of a rock or sediment that consists of open spaces (53)

potency the power of a medicine to produce a desired effect (329)

precipitate (pree SIP uh TAYT) a solid that is produced as a result of a chemical reaction in solution (293)

prime meridian the meridian, or line of longitude, that is designated as 0° longitude (404)

product a substance that forms in a chemical reaction (298)

prokaryote (pro KAR ee OHT) an organism that consists of a single cell that does not have a nucleus (502, 609)

protist an organism that belongs to the kingdom Protista (578)

pure substance a sample of matter, either a single element or a single compound, that has definite chemical and physical properties (212)

R

radioactive decay the process in which a radioactive isotope tends to break down into a stable isotope of the same element or another element (442)

radiometric dating a method of determining the age of an object by estimating the relative percentages of a radioactive (parent) isotope and a stable (daughter) (443)

reactant (ree AK tuhnt) a substance or molecule that participates in a chemical reaction (298)

recharge zone an area in which water travels downward to become part of an aquifer (54)

relative dating any method of determining whether an event or object is older or younger than other events or objects (436)

relief the variations in elevation of a land surface (419)

remote sensing the process of gathering and analyzing information about an object without physically being in touch with the object (412)

ribosome a cell organelle composed of RNA and protein; the site of protein synthesis (509, 561)

rift valley a long, narrow valley that forms as tectonic plates separate (87)

RNA **r**ibo**n**ucleic **a**cid, a molecule that is present in all living cells and that plays a role in protein production (560)

S

salinity a measure of the amount of dissolved salts in a given amount of liquid (78)

science the knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested (4)

scientific methods a series of steps followed to solve problems (10)

sea-floor spreading the process by which new oceanic lithosphere forms as magma rises toward the surface and solidifies (472)

seamount a submerged mountain on the ocean floor that is at least 1,000 m high and that has a volcanic origin (87)

sewage treatment plant a facility that cleans the waste materials found in water that comes from sewers or drains (62)

single-displacement reaction a reaction in which one element takes the place of another element in a compound (305)

software a set of instructions or commands that tells a computer what to do; a computer program (385)

solid the state of matter in which the volume and shape of a substance are fixed (189)

solubility the ability of one substance to dissolve in another at a given temperature and pressure (226)

solute in a solution, the substance that dissolves in the solvent (224)

solution a homogeneous mixture of two or more substances uniformly dispersed throughout a single phase (224)

solvent in a solution, the substance in which the solute dissolves (224)

specific heat the quantity of heat required to raise a unit mass of homogeneous material 1 K or 1°C in a specified way given constant pressure and volume (163)

spore a reproductive cell or multicellular structure that is resistant to stressful environmental conditions and that can develop into an adult without fusing with another cell (591)

spring tide a tide of increased range that occurs two times a month, at the new and full moons (138)

states of matter the physical forms of matter, which include solid, liquid, and gas (188)

storm surge a local rise in sea level near the shore that is caused by strong winds from a storm, such as those from a hurricane (135)

structure the arrangement of parts in an organism (517)

sublimation (SUHB luh MAY shuhn) the process in which a solid changes directly into a gas (200)

subsidence (suhb SIED'ns) the sinking of regions of the Earth's crust to lower elevations (484)

superposition a principle that states that younger rocks lie above older rocks if the layers have not been disturbed (436)

surface current a horizontal movement of ocean water that is caused by wind and that occurs at or near the ocean's surface (121)

surface tension the force that acts on the surface of a liquid and that tends to minimize the area of the surface (190)

suspension a mixture in which particles of a material are more or less evenly dispersed throughout a liquid or gas (228)

swell one of a group of long ocean waves that have steadily traveled a great distance from their point of generation (134)

synthesis reaction (SIN thuh sis ree AK shuhn) a reaction in which two or more substances combine to form a new compound (304)

T

technology the application of science for practical purposes; the use of tools, machines, materials, and processes to meet human needs (11)

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object (26, 192)

tension stress that occurs when forces act to stretch an object (478)

theory an explanation that ties together many hypotheses and observations (20)

thermal expansion an increase in the size of a substance in response to an increase in the temperature of the substance (194)

tidal range the difference in levels of ocean water at high tide and low tide (138)

tide the periodic rise and fall of the water level in the oceans and other large bodies of water (136)

tissue a group of similar cells that perform a common function (515)

topographic map (TAHP uh GRAF ik MAP) a map that shows the surface features of Earth (418)

trace fossil a fossilized mark that is formed in soft sediment by the movement of an animal (448)

transform boundary the boundary between tectonic plates that are sliding past each other horizontally (475)

tributary a stream that flows into a lake or into a larger stream (42)

true north the direction to the geographic North Pole (402)

tsunami a giant ocean wave that forms after a volcanic eruption, submarine earthquake, or landslide (134)

U

unconformity a break in the geologic record created when rock layers are eroded or when sediment is not deposited for a long period of time (439)

undertow a subsurface current that is near shore and that pulls objects out to sea (133)

uniformitarianism a principle that states that geologic processes that occurred in the past can be explained by current geologic processes (432)

uplift the rising of regions of the Earth's crust to higher elevations (484)

upwelling the movement of deep, cold, and nutrient-rich water to the surface (127)

V

valence electron (VAY luhns ee LEK TRAHN) an electron that is found in the outermost shell of an atom and that determines the atom's chemical properties (269)

vesicle (VES i kuhl) a small cavity or sac that contains materials in a eukaryotic cell; forms when part of the cell membrane surrounds the materials to be taken into the cell or transported within the cell (511)

virus a microscopic particle that gets inside a cell and often destroys the cell (618)

viscosity the resistance of a gas or liquid to flow (190)

volume a measure of the size of a body or region in three-dimensional space (25, 152)

W

water cycle the continuous movement of water from the ocean to the atmosphere to the land and back to the ocean (41, 81)

watershed the area of land that is drained by a water system (42)

water table the upper surface of underground water; the upper boundary of the zone of saturation (52)

weight a measure of the gravitational force exerted on an object; its value can change with the location of the object in the universe (155)

whitecap the bubbles in the crest of a breaking wave (134)

Spanish Glossary

A

absolute dating/datación absoluta cualquier método que sirve para determinar la edad de un suceso u objeto en años (442)

absolute zero/cero absoluto la temperatura a la que la energía molecular es mínima (0 K en la escala de Kelvin ó –273.16°C en la escala de Celsius) (195)

abyssal plain/llanura abisal un área amplia, llana y casi plana de la cuenca oceánica profunda (86)

activation energy/energía de activación la cantidad mínima de energía que se requiere para iniciar una reacción química (310)

active transport/transporte activo el movimiento de substancias a través de la membrana celular que requiere que la célula gaste energía (530)

algae/algas organismos eucarióticos que transforman la energía del Sol en alimento por medio de la fotosíntesis, pero que no tienen raíces, tallos ni hojas (582)

alkali metal/metal alcalino uno de los elementos del Grupo 1 de la tabla periódica (litio, sodio, potasio, rubidio, cesio y francio) (248)

alkaline-earth metal/metal alcalinotérreo uno de los elementos del Grupo 2 de la tabla periódica (berilio, magnesio, calcio, estroncio, bario y radio) (249)

alluvial fan/abanico aluvial masa de materiales rocosos en forma de abanico, depositados por un arroyo cuando la pendiente del terreno disminuye bruscamente (50)

analog signal/señal análoga una señal cuyas propiedades cambian continuamente en un rango determinado (373)

antibiotic/antibiótico medicina utilizada para matar bacterias y otros microorganismos (616)

aquifer/acuífero un cuerpo rocoso o sedimento que almacena agua subterránea y permite que fluya (53)

area/área una medida del tamaño de una superficie o región (24)

artesian spring/manantial artesiano un manantial en el que el agua fluye a partir de una grieta en la capa de rocas que se encuentra sobre el acuífero (55)

azimuthal projection/proyección azimutal una proyección cartográfica que se hace al transferir las características de la superficie del globo a un plano (409)

B

benthos/benthos los organismos que viven en el fondo del mar o del océano (90)

binary fission/fisión binaria una forma de reproducción asexual de los organismos unicelulares, por medio de la cual la célula se divide en dos células del mismo tamaño (610)

bioremediation/bioremediación el tratamiento biológico de desechos peligrosos por medio de organismos vivos (615)

boiling/ebullición la conversión de un líquido en vapor cuando la presión de vapor del líquido es igual a la presión atmosférica (198)

C

carcinogen/carcinógeno una substancia que causa cáncer (335)

cast/molde un tipo de fósil que se forma cuando un organismo descompuesto deja una cavidad que es llenada por sedimentos (448)

catalyst/catalizador una substancia que cambia la tasa de una reacción química sin consumirse ni cambiar demasiado (313)

catastrophism/catastrofismo un principio que establece que los cambios geológicos ocurren súbitamente (433)

cell/célula en biología, la unidad más pequeña que puede realizar todos los procesos vitales; las células están cubiertas por una membrana y tienen ADN y citoplasma (498)

cell cycle/ciclo celular el ciclo de vida de una célula (536)

cell membrane/membrana celular una capa de fosfolípidos que cubre la superficie de la célula y funciona como una barrera entre el interior de la célula y el ambiente de la célula (501)

cellular respiration/respiración celular el proceso por medio del cual las células utilizan oxígeno para producir energía a partir de los alimentos (533)

cell wall/pared celular una estructura rígida que rodea la membrana celular y le brinda soporte a la célula (506)

change of state/cambio de estado el cambio de una substancia de un estado físico a otro (196)

channel/canal el camino que sigue un arroyo (43)

chemical/substancia química cualquier substancia que tiene una composición definida (324)

chemical bond/enlace químico una interacción que mantiene unidos los átomos o los iones (268)

chemical bonding/formación de un enlace químico la combinación de átomos para formar moléculas o compuestos iónicos (268)

chemical change/cambio químico un cambio que ocurre cuando una o más substancias se transforman en substancias totalmente nuevas con propiedades diferentes (168)

chemical equation/ecuación química una representación de una reacción química que usa símbolos para mostrar la relación entre los reactivos y los productos (298)

chemical formula/fórmula química una combinación de símbolos químicos y números que se usan para representar una substancia (296)

chemical property/propiedad química una propiedad de la materia que describe la capacidad de una substancia de participar en reacciones químicas (166)

chemical reaction/reacción química el proceso por medio del cual una o más substancia cambian para producir una o más substancias distintas (292)

chromosome/cromosoma en una célula eucariótica, una de las estructuras del núcleo que está hecha de ADN y proteína; en una célula procariótica, el anillo principal de ADN (536)

colloid/coloide una mezcla formada por partículas diminutas que son de tamaño intermedio entre las partículas de las soluciones y las de las suspensiones y que se encuentran suspendidas en un líquido, sólido o gas (228)

compound/compuesto una substancia formada por átomos de dos o más elementos diferentes unidos por enlaces químicos (216)

compression/compresión estrés que se produce cuando distintas fuerzas actúan para estrechar un objeto (478)

computer/computadora un aparato electrónico que acepta información e instrucciones, sigue instrucciones y produce una salida para los resultados (380)

concentration/concentración la cantidad de una cierta substancia en una cantidad determinada de mezcla, solución o mena (226)

condensation/condensación el cambio de estado de gas a líquido (199)

conic projection/proyección cónica una proyección cartográfica que se hace al transferir las características de la superficie del globo a un cono (408)

continental drift/deriva continental la hipótesis que establece que alguna vez los continentes formaron una sola masa de tierra, se dividieron y se fueron a la deriva hasta terminar en sus ubicaciones actuales (470)

continental rise/elevación continental la sección del margen continental que tiene un ligero declive, ubicada entre el talud continental y la llanura abisal (86)

continental shelf/plataforma continental la sección del margen continental que tiene un ligero declive, ubicada entre la costa y el talud continental (86)

continental slope/talud continental la sección del margen continental que tiene una gran inclinación, ubicada entre la elevación continental y la plataforma continental (86)

contour interval/distancia entre las curvas de nivel la diferencia en elevación entre una curva de nivel y la siguiente (419)

contour line/curva de nivel una línea que une puntos que tienen la misma elevación (418)

convergent boundary/límite convergente el límite que se forma debido al choque de dos placas de la litosfera (475)

Coriolis effect/efecto de Coriolis la desviación aparente de la trayectoria recta que experimentan los objetos en movimiento debido a la rotación de la Tierra (122)

covalent bond/enlace covalente un enlace formado cuando los átomos comparten uno más pares de electrones (276)

crystal lattice/red cristalina el patrón regular en el que un cristal está ordenado (275)

cylindrical projection/proyección cilíndrica una proyección cartográfica que se hace al transferir las características de la superficie del globo a un cilindro (407)

cytokinesis/citoquinesis la división del citoplasma de una célula (538)

D

data/datos cualquier parte de la información que se adquiere por medio de la observación o experimentación (15)

decomposition reaction/reacción de descomposición una reacción en la que un solo compuesto se descompone para formar dos o más substancias más simples (305)

deep current/corriente profunda un movimiento del agua del océano que es similar a una corriente y ocurre debajo de la superficie (123)

delta/delta un depósito de materiales rocosos en forma de abanico ubicado en la desembocadura de un río (317)

density/densidad la relación entre la masa de una substancia y su volumen (25, 160)

deposition/deposición el proceso por medio del cual un material se deposita (48)

desalination/desalación (o desalinización) un proceso de remoción de sal del agua del océano (101)

diffusion/difusión el movimiento de partículas de regiones de mayor densidad a regiones de menor densidad (528)

digital signal/señal digital una señal que se puede representar como una secuencia de valores discretos (374)

divergent boundary/límite divergente el límite entre dos placas tectónicas que se están separando una de la otra (475)

divide/división el límite entre áreas de drenaje que tienen corrientes que fluyen en direcciones opuestas (42)

DNA/ADN **á**cido **d**esoxirribo**n**ucleico, una molécula que está presente en todas las células vivas y que contiene la información que determina los caracteres que un ser vivo hereda y necesita para vivir (554)

dose/dosis la cantidad de medicina que es necesario tomar durante un período de tiempo (329)

double-displacement reaction/reacción de doble desplazamiento una reacción en la que se forma un gas, un precipitado sólido o un compuesto molecular a partir del intercambio de iones entre dos compuestos (307)

E

electromagnetic spectrum/espectro electromagnético todas las frecuencias o longitudes de onda de la radiación electromagnética (414)

element/elemento una substancia que no se puede separar o descomponer en substancias más simples por medio de métodos químicos (212)

elevation/elevación la altura de un objeto sobre el nivel del mar (418)

El Niño/El Niño un cambio en la temperatura del agua superficial del océano Pacífico que produce una corriente caliente (128)

endocytosis/endocitosis el proceso por medio del cual la membrana celular rodea una partícula y la encierra en una vesícula para llevarla al interior de la célula (530)

endoplasmic reticulum/retículo endoplásmico un sistema de membranas que se encuentra en el citoplasma de la célula y que tiene una función en la producción, procesamiento y transporte de proteínas y en la producción de lípidos (509)

endospore/endospora una espora protectiva que tiene una pared gruesa, se forma dentro de una célula bacteriana y resiste condiciones adversas (611)

endothermic reaction/reacción endotérmica una reacción química que necesita calor (309)

eon/eón la mayor división del tiempo geológico (455)

epoch/época una subdivisión de un período geológico (455)

equator/ecuador el círculo imaginario que se encuentra a la mitad entre los polos y divide a la Tierra en los hemisferios norte y sur (403)

era/era una unidad de tiempo geológico que incluye dos o más períodos (455)

erosion/erosión el proceso por medio del cual el viento, el agua, el hielo o la gravedad transporta tierra y sedimentos de un lugar a otro (40)

estuary/estuario un área donde el agua dulce de los ríos se mezcla con el agua salada del océano (95)

eukaryote/eucariote un organismo cuyas células tienen un núcleo rodeado por una membrana; entre los eucariotes se encuentran los animales, las plantas y los hongos, pero no las arqueobacterias (504)

evaporation/evaporación el cambio de una substancia de líquido a gas (198)

exocytosis/exocitosis el proceso por medio del cual una célula libera una partícula encerrándola en una vesícula que luego se traslada a la superficie de la célula y se fusiona con la membrana celular (531)

exothermic reaction/reacción exotérmica una reacción química en la que se libera calor a los alrededores (308)

extinction/extinción la muerte de todos los miembros de una especie (455)

F

fault/falla una grieta en un cuerpo rocoso a lo largo de la cual un bloque se desliza respecto a otro (480)

feedback mechanism/mecanismo de retroalimentación un ciclo de sucesos en el que la información de una etapa controla o afecta a una etapa anterior (540)

fermentation/fermentación la descomposición de los alimentos sin utilizar oxígeno (533)

floodplain/llanura de inundación un área a lo largo de un río formada por sedimentos que se depositan cuando el río se desborda (50)

folding/plegamiento fenómeno que ocurre cuando las capas de roca se doblan debido a la compresión (479)

fossil/fósil los restos o las pruebas físicas de un organismo preservados por los procesos geológicos (446)

function/función la actividad especial, normal o adecuada de un órgano o parte (517)

fungus/hongo un organismo que tiene células con núcleos y pared celular rígida, pero carece de clorofila, perteneciente al reino Fungi (590)

G

gas/gas un estado de la materia que no tiene volumen ni forma definidos (191)

geologic column/columna geológica un arreglo de las capas de roca en el que las rocas más antiguas están al fondo (437)

geologic time scale/escala de tiempo geológico el método estándar que se usa para dividir la larga historia natural de la Tierra en partes razonables (454)

global positioning system/sistema de posicionamiento global una red de satélites que orbita la Tierra para medir posiciones en la superficie terrestre (abreviature: GPS, por sus siglas en inglés) (412)

Golgi complex/aparato de Golgi un organelo celular que ayuda a hacer y a empacar los materiales que serán transportados al exterior de la célula (511)

group/grupo una columna vertical de elementos de la tabla periódica; los elementos de un grupo comparten propiedades químicas (246)

H

half-life/vida media el tiempo que tarda la mitad de la muestra de una substancia radiactiva en desintegrarse por desintegración radiactiva (443)

halogen/halógeno uno de los elementos del Grupo 17 de la tabla periódica (flúor, cloro, bromo, yodo y ástato); los halógenos se combinan con la mayoría de los metales para formar sales (253)

hardware/hardware las partes o piezas de equipo que forman una computadora (382)

heat engine/motor térmico una máquina que transforma el calor en energía mecánica, o trabajo (358)

heterotroph/heterótrofo un organismo que se alimenta comiendo otros organismos o sus productos secundarios y que no puede producir compuestos orgánicos a partir de materiales inorgánicos (579)

homologous chromosomes/cromosomas homólogos cromosomas con la misma secuencia de genes y la misma estructura (537)

host/huésped el organismo del cual un parásito obtiene alimento y refugio (579, 618)

hypha/hifa un filamento no-reproductor de un hongo (591)

hypothesis/hipótesis una explicación que se basa en observaciones o investigaciones científicas previas y que se puede probar (13)

I

immunity/inmunidad la capacidad de resistir una enfermedad infecciosa (626)

index contour/índice de las curvas de nivel en un mapa, la curva de nivel que es más gruesa y oscura, la cual normalmente se encuentra cada quinta línea e indica un cambio en la elevación (419)

index fossil/fósil guía un fósil que se encuentra en las capas de roca de una sola era geológica y que se usa para establecer la edad de las capas de roca (450)

inertia/inercia la tendencia de un objeto a no moverse o, si el objeto se está moviendo, la tendencia a resistir un cambio en su rapidez o dirección hasta que una fuerza externa actúe en el objeto (156)

infectious disease/enfermedad infecciosa una enfermedad que es causada por un patógeno y que puede transmitirse de un individuo a otro (622)

inhibitor/inhibidor una substancia que desacelera o detiene una reacción química (312)

insulation/aislante una substancia que reduce la transferencia de electricidad, calor o sonido (353)

Internet/Internet una amplia red de computadoras que conecta muchas redes locales y redes más pequeñas por todo el mundo (386)

ion/ion una partícula cargada que se forma cuando un átomo o grupo de átomos gana o pierde uno o más electrones (272)

ionic bond/enlace iónico un enlace que se forma cuando los electrones se transfieren de un átomo a otro, y que produce un ion positivo y uno negativo (272)

isotope/isótopo un átomo que tiene el mismo número de protones (o el mismo número atómico) que otros átomos del mismo elemento, pero que tiene un número diferente de neutrones (y, por lo tanto, otra masa atómica) (442)

L

La Niña/La Niña un cambio en el océano Pacífico oriental por el cual el agua superficial se vuelve más fría que de costumbre (128)

latitude/latitud la distancia hacia el norte o hacia el sur del ecuador; se expresa en grados (403)

law/ley un resumen de muchos resultados y observaciones experimentales; una ley dice cómo funcionan las cosas (21)

law of conservation of energy/ley de la conservación de la energía la ley que establece que la energía ni se crea ni se destruye, sólo se transforma de una forma a otra (309)

law of conservation of mass/ley de la conservación de la masa la ley que establece que la masa no se crea ni se destruye por cambios químicos o físicos comunes (301)

lichen/liquen una masa de células de hongos y de algas que crecen juntas en una relación simbiótica y que normalmente se encuentran en rocas o árboles (596)

liquid/líquido el estado de la materia que tiene un volumen definido, pero no una forma definida (190)

load/carga los materiales que lleva un arroyo; también, la masa de rocas que recubre una estructura geológica (44)

longitude/longitud la distancia hacia el este y hacia el oeste del primer meridiano; se expresa en grados (404)

longshore current/corriente de ribera una corriente de agua que se desplaza cerca de la costa y paralela a ella (133)

lysosome/lisosoma un organelo celular que contiene enzimas digestivas (512)

M

magnetic declination/declinación magnética la diferencia entre el norte magnético y el norte verdadero (402)

map/mapa una representación de las características de un cuerpo físico, tal como la Tierra (400)

mass/masa una medida de la cantidad de materia que tiene un objeto (24, 155)

matter/materia cualquier cosa que tiene masa y ocupa un lugar en el espacio (152)

medicine/medicina cualquier droga usada para curar, prevenir o tratar una enfermedad o malestar (328)

melting/fusión el cambio de estado en el que un sólido se convierte en líquido al añadirse calor (197)

meniscus/menisco la curva que se forma en la superficie de un líquido, la cual sirve para medir el volumen de un líquido (153)

metal/metal un elemento que es brillante y conduce bien el calor y la electricidad (214)

metallic bond/enlace metálico un enlace formado por la atracción entre iones metálicos cargados positivamente y los electrones que los rodean (279)

metalloid/metaloides elementos que tienen propiedades tanto de metales como de no metales (214)

meter/metro la unidad fundamental de longitud en el sistema internacional de unidades (símbolo: m) (24)

microprocessor/microprocesador un chip único de un semiconductor, el cual controla y ejecuta las instrucciones de una microcomputadora (381)

mid-ocean ridge/dorsal oceánica una larga cadena submarina de montañas que se forma en el suelo de los principales océanos (87)

mitochondrion/mitocondria en las células eucarióticas, el organelo celular rodeado por dos membranas que es el lugar donde se lleva a cabo la respiración celular (510)

mitosis/mitosis en las células eucarióticas, un proceso de división celular que forma dos núcleos nuevos, cada uno de los cuales posee el mismo número de cromosomas (537)

mixture/mezcla una combinación de dos o más substancias que no están combinadas químicamente (222)

model/modelo un diseño, plan, representación o descripción cuyo objetivo es mostrar la estructura o funcionamiento de un objeto, sistema o concepto (18)

mold/molde una marca o cavidad hecha en una superficie sedimentaria por una concha u otro cuerpo (448)

mold/moho en biología, un hongo que tiene la apariencia de lana o algodón (592)

molecule/molécula la unidad más pequeña de una substancia que conserva todas las propiedades físicas y químicas de esa substancia (277)

mutation/mutación un cambio en la secuencia de la base de nucleótidos de un gene o de una molécula de ADN (562)

mycelium/micelio una masa de filamentos de hongos, o hifas, que forma el cuerpo de un hongo (591)

N

neap tide/marea muerta una marea que tiene un rango mínimo, la cual ocurre durante el primer y el tercer cuartos de la Luna (138)

nekton/necton todos los organismos que nadan activamente en las aguas abiertas, de manera independiente de las corrientes (90)

noble gas/gas noble uno de los elementos del Grupo 18 de la tabla periódica (helio, neón, argón, criptón, xenón y radón); los gases nobles son no reactivos (254)

noninfectious disease/enfermedad no infecciosa una enfermedad que no se contagia de una persona a otra (622)

nonmetal/no metal un elemento que es mal conductor del calor y la electricidad (214)

nonpoint-source pollution/contaminación no puntual contaminación que proviene de muchas fuentes, en lugar de provenir de un solo sitio específico (58, 104)

nucleotide/nucleótido en una cadena de ácidos nucleicos, una subunidad formada por un azúcar, un fosfato y una base nitrogenada (554)

nucleus/núcleo en una célula eucariótica, un organelo cubierto por una membrana, el cual contiene el ADN de la célula y participa en procesos tales como el crecimiento, metabolismo y reproducción (501)

O

observation/observación el proceso de obtener información por medio de los sentidos (11)

ocean current/corriente oceánica un movimiento del agua del océano que sigue un patrón regular (120)

ocean trench/fosa oceánica una depresión empinada y larga del suelo marino profundo, paralela a una cadena de islas volcánicas o al margen continental (87)

organ/órgano un conjunto de tejidos que desempeñan una función especializada en el cuerpo (515)

organelle/organelo uno de los cuerpos pequeños del citoplasma de una célula que están especializados para llevar a cabo una función específica (501)

organism/organismo un ser vivo; cualquier cosa que pueda llevar a cabo procesos vitales independientemente (516)

organ system/aparato (o sistema) de órganos un grupo de órganos que trabajan en conjunto para desempeñar funciones corporales (516)

osmosis/ósmosis la difusión del agua a través de una membrana semipermeable (529)

P

paleontology/paleontología el estudio científico de los fósiles (435)

parasite/parásito un organismo que se alimenta de un organismo de otra especie (el huésped) y que normalmente lo daña; el huésped nunca se beneficia de la presencia del parásito (579)

passive transport/transporte pasivo el movimiento de substancias a través de una membrana celular sin que la célula tenga que usar energía (530)

pathogen/patógeno un virus, microorganismo u otra substancia que causa enfermedades (622)

pathogenic bacteria/bacteria patogénica bacteria que causa una enfermedad (616)

period/período en química, una hilera horizontal de elementos en la tabla periódica (246); *también* una unidad de tiempo geológico en la que se dividen las eras (455)

periodic/periódico término que describe algo que ocurre o que se repite a intervalos regulares (241)

periodic law/ley periódica la ley que establece que las propiedades químicas y físicas repetitivas de un elemento cambian periódicamente en función del número atómico de los elementos (241)

permeability/permeabilidad la capacidad de una roca o sedimento de permitir que los fluidos pasen a través de sus espacios abiertos o poros (53)

photosynthesis/fotosíntesis el proceso por medio del cual las plantas, las algas y algunas bacterias utilizan la luz solar, el dióxido de carbono y el agua para producir alimento (532)

physical change/cambio físico un cambio de materia de una forma a otra sin que ocurra un cambio en sus propiedades químicas (164)

physical property/propiedad física una característica de una substancia que no implica un cambio químico, tal como la densidad, el color o la dureza (158)

phytoplankton/fitoplancton los organismos microscópicos fotosintéticos que flotan cerca de la superficie del agua dulce o marina (582)

plankton/plancton la masa de organismos en su mayoría microscópicos que flotan o se encuentran a la deriva en ambientes de agua dulce o marina (90)

plate tectonics/tectónica de placas la teoría que explica cómo se mueven y cambian de forma las placas tectónicas, que son grandes porciones de la capa más externa de la Tierra (474)

point-source pollution/contaminación puntual contaminación que proviene de un lugar específico (58, 105)

porosity/porosidad el porcentaje del volumen total de una roca o sedimento que está formado por espacios abiertos (53)

potency/potencia el poder de una medicina para producir el efecto deseado (329)

precipitate/precipitado un sólido que se produce como resultado de una reacción química en una solución (293)

prime meridian/meridiano de Greenwich el meridiano, o línea de longitud, que se designa como longitud 0° (404)

product/producto una substancia que se forma en una reacción química (298)

prokaryote/procariote un organismo que está formado por una sola célula y que no tiene núcleo (502, 609)

protist/protista un organismo que pertenece al reino Protista (578)

pure substance/substancia pura una muestra de materia, ya sea un solo elemento o un solo compuesto, que tiene propiedades químicas y físicas definidas (212)

R

radioactive decay/desintegración radiactiva el proceso por medio del cual un isótopo radiactivo tiende a desintegrarse y formar un isótopo estable del mismo elemento o de otro elemento (442)

radiometric dating/datación radiométrica un método para determinar la edad de un objeto estimando los porcentajes relativos de un isótopo radiactivo (precursor) y un isótopo estable (hijo) (443)

reactant/reactivo una substancia o molécula que participa en una reacción química (298)

recharge zone/zona de recarga un área en la que el agua se desplaza hacia abajo para convertirse en parte de un acuífero (54)

relative dating/datación relativa cualquier método que se utiliza para determinar si un acontecimiento u objeto es más viejo o más joven que otros acontecimientos u objetos (436)

relief/relieve las variaciones en elevación de una superficie de terreno (419)

remote sensing/teledetección el proceso de recopilar y analizar información acerca de un objeto sin estar en contacto físico con el objeto (412)

ribosome/ribosoma un organelo celular compuesto de ARN y proteína; el sitio donde ocurre la síntesis de proteínas (509, 561)

rift valley/fosa tectónica un valle largo y estrecho que se forma cuando se separan las placas tectónicas (87)

RNA/ARN **á**cido **r**ibo**n**ucleico, una molécula que está presente en todas las células vivas y que juega un papel en la producción de proteínas (560)

S

salinity/salinidad una medida de la cantidad de sales disueltas en una cantidad determinada de líquido (78)

science/ciencia el conocimiento que se obtiene por medio de la observación natural de acontecimientos y condiciones con el fin de descubrir hechos y formular leyes o principios que puedan ser verificados o probados (4)

scientific methods/métodos científicos una serie de pasos que se siguen para solucionar problemas (10)

sea-floor spreading/expansión del suelo marino el proceso por medio del cual se forma nueva litosfera oceánica a medida que el magma se eleva hacia la superficie y se solidifica (472)

seamount/montaña submarina una montaña sumergida que se encuentra en el fondo del océano, la cual tiene por lo menos 1,000 m de altura y cuyo origen es volcánico (87)

sewage treatment plant/planta de tratamiento de residuos una instalación que limpia los materiales de desecho que se encuentran en el agua procedente de cloacas o alcantarillas (62)

single-displacement reaction/reacción de sustitución simple una reacción en la que un elemento toma el lugar de otro elemento en un compuesto (305)

software/software un conjunto de instrucciones o comandos que le dicen qué hacer a una computadora; un programa de computadora (385)

solid/sólido el estado de la materia en el cual el volumen y la forma de una sustancia están fijos (189)

solubility/solubilidad la capacidad de una substancia de disolverse en otra a una temperatura y una presión dadas (226)

solute/soluto en una solución, la sustancia que se disuelve en el solvente (224)

solution/solución una mezcla homogénea de dos o más sustancias dispersas de manera uniforme en una sola fase (224)

solvent/solvente en una solución, la sustancia en la que se disuelve el soluto (224)

specific heat/calor específico la cantidad de calor que se requiere para aumentar una unidad de masa de un material homogéneo 1 K ó 1°C de una manera especificada, dados un volumen y una presión constantes (163)

spore/espora una célula reproductora o estructura pluricelular que resiste las condiciones ambientales adversas y que se puede desarrollar hasta convertirse en un adulto sin necesidad de fusionarse con otra célula (591)

spring tide/marea muerta una marea de mayor rango que ocurre dos veces al mes, durante la luna nueva y la luna llena (138)

states of matter/estados de la material las formas físicas de la materia, que son sólida, líquida y gaseosa (188)

storm surge/marea de tempestad un levantamiento local del nivel del mar cerca de la costa, el cual es resultado de los fuertes vientos de una tormenta, como por ejemplo, los vientos de un huracán (135)

structure/estructura el orden y distribución de las partes de un organismo (517)

sublimation/sublimación el proceso por medio del cual un sólido se transforma directamente en un gas (200)

subsidence/hundimiento del terreno el hundimiento de regiones de la corteza terrestre a elevaciones más bajas (484)

superposition/superposición un principio que establece que las rocas más jóvenes se encontrarán sobre las rocas más viejas si las capas no han sido alteradas (436)

surface current/corriente superficial un movimiento horizontal del agua del océano que es producido por el viento y que ocurre en la superficie del océano o cerca de ella (121)

surface tension/tensión superficial la fuerza que actúa en la superficie de un líquido y que tiende a minimizar el área de la superficie (190)

suspension/suspensión una mezcla en la que las partículas de un material se encuentran dispersas de manera más o menos uniforme a través de un líquido o de un gas (228)

swell/mar de leva un grupo de olas oceánicas grandes que se han desplazado una gran distancia desde el punto en el que se originaron (134)

synthesis reaction/reacción de síntesis una reacción en la que dos o más sustancias se combinan para formar un compuesto nuevo (304)

T

technology/tecnología la aplicación de la ciencia con fines prácticos; el uso de herramientas, máquinas, materiales y procesos para satisfacer las necesidades de los seres humanos (11)

temperature/temperatura una medida de qué tan caliente (o frío) está algo; específicamente, una medida de la energía cinética promedio de las partículas de un objeto (26, 192)

tension/tensión estrés que se produce cuando distintas fuerzas actúan para estirar un objeto (478)

theory/teoría una explicación que relaciona muchas hipótesis y observaciones (20)

thermal expansion/expansión térmica un aumento en el tamaño de una sustancia en respuesta a un aumento en la temperatura de la sustancia (194)

tidal range/rango de marea la diferencia en los niveles del agua del océano entre la marea alta y la marea baja (138)

tide/marea el ascenso y descenso periódico del nivel del agua en los océanos y otras masas grandes de agua (136)

tissue/tejido un grupo de células similares que llevan a cabo una función común (515)

topographic map/mapa topográfico un mapa que muestra las características superficiales de la Tierra (418)

trace fossil/fósil traza una marca fosilizada que se forma en un sedimento blando debido al movimiento de un animal (448)

transform boundary/límite de transformación el límite entre placas tectónicas que se están deslizando horizontalmente una sobre otra (475)

tributary/afluente un arroyo que fluye a un lago o a otro arroyo más grande (42)

true north/norte verdadero la dirección al Polo Norte geográfico (402)

tsunami/tsunami una ola gigante del océano que se forma después de una erupción volcánica, terremoto submarino o desprendimiento de tierras (134)

U

unconformity/disconformidad una ruptura en el registro geológico, creada cuando las capas de roca se erosionan o cuando el sedimento no se deposita durante un largo período de tiempo (439)

undertow/resaca un corriente subsuperficial que está cerca de la orilla y que arrastra los objetos hacia el mar (133)

uniformitarianism/uniformitarianismo un principio que establece que es posible explicar los procesos geológicos que ocurrieron en el pasado en función de los procesos geológicos actuales (432)

uplift/levantamiento la elevación de regiones de la corteza terrestre a elevaciones más altas (484)

upwelling/surgencia el movimiento de las aguas profundas, frías y ricas en nutrientes hacia la superficie (127)

V

valence electron/electrón de valencia un electrón que se encuentra en el orbital más externo de un átomo y que determina las propiedades químicas del átomo (269)

vesicle/vesícula una cavidad o bolsa pequeña que contiene materiales en una célula eucariótica; se forma cuando parte de la membrana celular rodea los materiales que van a ser llevados al interior la célula o transportados dentro de ella (511)

virus/virus una partícula microscópica que se introduce en una célula y a menudo la destruye (618)

viscosity/viscosidad la resistencia de un gas o un líquido a fluir (190)

volume/volumen una medida del tamaño de un cuerpo o región en un espacio de tres dimensiones (25, 152)

W

water cycle/ciclo del agua el movimiento continuo del agua: del océano a la atmósfera, de la atmósfera a la tierra y de la tierra al océano (41, 81)

watershed/cuenca hidrográfica el área del terreno que es drenada por un sistema de agua (42)

water table/capa freática el nivel más alto del agua subterránea; el límite superior de la zona de saturación (52)

weight/peso una medida de la fuerza gravitacional ejercida sobre un objeto; su valor puede cambiar en función de la ubicación del objeto en el universo (155)

whitecap/cabrillas las burbujas de la cresta de una ola rompiente (134)

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Academic Reviewers
continued

John Brockhaus, Ph.D.
Professor of Geospatial Information Science and Director of Geospatial Information Science Program
Department of Geography and Environmental Engineering
United States Military Academy
West Point, New York

Joe W. Crim, Ph.D.
Professor and Head of Cellular Biology
Department of Cellular Biology
University of Georgia
Athens, Georgia

Roger J. Cuffey, Ph.D.
Professor of Paleontology
Department of Geosciences
Pennsylvania State University
University Park, Pennsylvania

Scott Darveau, Ph.D.
Associate Professor of Chemistry
Chemistry Department
University of Nebraska at Kearney
Kearney, Nebraska

William E. Dunscombe
Chairman
Biology Department
Union County College
Cranford, New Jersey

Cassandra Eagle
Professor
Chemistry Department
Appalachian State University
Boone, North Carolina

Linda K. Gaul
Epidemiologist
Texas Department of Health
Austin, Texas

David Haig, Ph.D.
Professor of Biology
Organismic and Evolutionary Biology
Harvard University
Cambridge, Massachusetts

David S. Hall, Ph.D.
Assistant Professor of Physics
Department of Physics
Amherst College
Amherst, Massachusetts

David Hershey, Ph.D.
Education Consultant
Hyattsville, Maryland

Richard N. Hey, Ph.D.
Professor of Geophysics
Department of Geophysics and Planetology
University of Hawaii at Manoa
Honolulu, Hawaii

Steven A. Jennings, Ph.D.
Associate Professor
Geography and Environmental Studies
University of Colorado at Colorado Springs
Colorado Springs, Colorado

Ping H. Johnson, M.D., Ph.D., CHES
Assistant Professor of Health Education
Department of Health, Physical Education and Sport Science
Kennesaw State University
Kennesaw, Georgia

Linda Jones
Program Manager
Texas Department of Public Health
Austin, Texas

Jamie Kneitel, Ph.D.
Postdoctoral Associate
Department of Biology
Washington University
St. Louis, Missouri

Mark N. Kobrak, Ph.D.
Assistant Professor of Chemistry
Chemistry Department
Brooklyn College of the City University of New York
Brooklyn, New York

Daniela Kohen
Assistant Professor of Chemistry
Chemistry Department
Carleton College
North Field, Minnesota

David Lamp, Ph.D.
Associate Professor of Physics
Physics Department
Texas Tech University
Lubbock, Texas

Joel S. Leventhal, Ph.D.
Emeritus Scientist
United States Geological Survey (USGS)
Lakewood, Colorado

Mark Mattson, Ph.D.
Assistant Professor
Physics Department
James Madison University
Harrisonburg, Virginia

Nancy L. McQueen, Ph.D.
Professor of Microbiology
Department of Biological Sciences
California State University, Los Angeles
Los Angeles, California

Madeline Micceri Mignone, Ph.D.
Assistant Professor
Natural Science
Dominican College
Orangeburg, New York

Nancy Moreno, Ph.D.
Associate Professor, Department of Family and Community Medicine
Baylor College of Medicine
Houston, Texas

Enrique Peacock-López
Professor of Chemistry
Department of Chemistry
Williams College
Wiliamstown, Massachusetts

Kate Queeney, Ph.D.
Assistant Professor of Chemistry
Chemistry Department
Smith College
Northampton, Massachusetts

Kenneth H. Rubin, Ph.D.
Associate Professor
Department of Geology and Geophysics
University of Hawaii at Manoa
Honolulu, Hawaii

Patrick K. Schoff, Ph.D.
Research Associate
Natural Resources Research Institute
University of Minnesota—Duluth
Duluth, Minnesota

Fred Seaman, Ph.D.
Retired Research Associate
College of Pharmacy
The University of Texas at Austin
Austin, Texas

H. Michael Sommermann, Ph.D.
Professor of Physics
Physics Department
Westmont College
Santa Barbara, California

Daniel Z. Sui, Ph.D.
Professor
Department of Geography
Texas A&M University
College Station, Texas

Colin D. Sumrall, Ph.D.
Lecturer of Paleontology
Earth and Planetary Sciences
The University of Tennessee
Knoxville, Tennessee

Richard S. Treptow, Ph.D.
Professor of Chemistry
Department of Chemistry and Physics
Chicago State University
Chicago, Illinois

Dale Wheeler
Assistant Professor of Chemistry
A. R. Smith Department of Chemistry
Appalachian State University
Boone, North Carolina

Dwight L. Whitaker, Ph.D.
Assistant Professor of Physics
Department of Physics
Williams College
Williamstown, Massachusetts

Ross Whitwam, Ph.D.
Assistant Professor of Biology
Division of Science and Mathematics
Mississippi University for Women
Columbus, Mississippi

Lab Testing

Paul Boyle
Science Teacher
Perry Heights Middle School
Evansville, Indiana

Daniel Bugenhagen
Science Teacher and Department Chair
Yutan Juniot–Senior High
Yutan, Nebraska

Kenneth Creese
Science Teacher
White Mountain Junior High
Rock Springs, Wyoming

Rebecca Ferguson
Science Teacher
North Ridge Middle School
North Richland Hills, Texas

Laura Fleet
Science Teacher
Alice B. Landrum Middle School
Ponte Verde Beach, Florida

Susan Gorman
Science Teacher
North Ridge Middle School
North Richland Hills, Texas

C. John Graves
Science Teacher
Monforton Middle School
Bozeman, Montana

Dennis Hanson
Science Teacher and Department Chair
Big Bear Middle School
Big Bear Lake, California

Norman E. Holcomb
Science Teacher
Marion Local Schools
Maria Stein, Ohio

Kenneth J. Horn
Science Teacher and Department Chair
Fallston Middle School
Fallston, Maryland

Tracy Jahn
Science Teacher
Berkshire Junior-Senior High School
Canaan, New York

David Jones
Science Teacher
Andrew Jackson Middle School
Cross Lanes, West Virginia

Michael E. Kral
Science Teacher
West Hardin Middle School
Cecilia, Kentucky

Kathy LaRoe
Science Teacher
East Valley Middle School
East Helena, Montana

Jason P. Marsh
Biology Teacher
Montevideo High School and Montevideo Country School
Montevideo, Minnesota

Alyson Mike
Science Teacher
East Valley Middle School
East Helena, Montana

Jan Nelson
Science Teacher
East Valley Middle School
East Helena, Montana

Dwight Patton
Science Teacher
Carrol T. Welch Middle School
Horizon City, Texas

Joseph W. Price
Science Teacher and Dept. Chair
H.M. Browne Junior High School
Washington, D.C.

Terry J. Rakes
Science Teacher
Elmwood Junior High School
Rogers, Arkansas

Elizabeth Rustad
Science Teacher
Rigley School District
Gilbert, Arizona

Debra A. Sampson
Science Teacher
Booker T. Washington Middle School
Elgin, Texas

Rodney A. Sandefur
Science Teacher
Naturita Middle School
Naturita, Colorado

David M. Sparks
Science Teacher
Redwater Junior High School
Redwater, Texas

Sharon L. Woolf
Science Teacher
Langston Hughes Middle School
Reston, Virginia

Lee Yassinski
Science Teacher
Sun Valley Middle School
Sun Valley, California

John Zambo
Science Teacher
Elizabeth Ustach Middle School
Modesto, California

Gordon Zibelman
Science Teacher
Drexel Hill Middle School
Drexel Hill, Pennsylvania

Teacher Reviewers

Diedre S. Adams
Physical Science Instructor
Science Department
West Vigo Middle School
West Terre Haute, Indiana

Barbara Gavin Akre
Teacher of Biology, Anatomy-Physiology, and Life Science
Duluth Independent School District
Duluth, Minnesota

Sarah Carver
Science Teacher
Jackson Creek Middle School
Bloomington, Indiana

Robin K. Clanton
Science Department Head
Berrien Middle School
Nashville, Georgia

Hilary Cochran
Science Teacher
Indian Crest Junior High School
Souderton, Pennsylvania

Karen Dietrich, S.S.J., Ph.D.
Principal and Biology Instructor
Mount Saint Joseph Academy
Flourtown, Pennsylvania

Randy Dye, M.S.
Middle School Science Department Head
Earth Science
Wood Middle School
Waynesville School District #6, Missouri

Trisha Elliott
Science and Mathematics Teacher
Chain of Lakes Middle School
Orlando, Florida

Liza M. Guasp
Science Teacher
Celebration K–8 School
Celebration, Florida

Brian Herndon
Instructional Specialist
Gaston County Schools
Gastonia, North Carolina

Ronald W. Hudson
Science Teacher
Batchelor Middle School
Bloomington, Indiana

Denise Hulette
Teacher
Conway Middle School
Orlando, Florida

James Kerr
Oklahoma Teacher of the Year 2002–2003
Oklahoma State Department of Education
Union Public Schools
Tulsa, Oklahoma

Laura Kitselman
Science Teacher and Coordinator
Loudoun Country Day School
Leesburg, Virginia

Tiffany Kracht
Science Teacher
Chain of Lakes Middle School
Orlando, Florida

Deborah L. Kronsteiner
Teacher
Science Department
Spring Grove Area Middle School
Spring Grove, Pennsylvania

Jennifer L. Lamkie
Science Teacher
Thomas Jefferson Middle School
Edison, New Jersey

Sally M. Lesley
ESL Science Teacher
Burnet Middle School
Austin, Texas

Beverly Lyons
Science Teacher and Department Chair
Hanes Middle School
Winston-Salem, North Carolina

Augie Maldonado
Science Teacher
Grisham Middle School
Round Rock, Texas

Bill Martin
Science Teacher
Southeast Middle School
Kernersville, North Carolina

Maureen Martin
Science Teacher
Jackson Creek Middle School
Bloomington, Indiana

Alyson Mike
Science Teacher
East Valley Middle School
East Helena, Montana

Jean Pletchette
Health Educator
Winterset Community Schools
Winterset, Iowa

Thomas Lee Reed
Science Teacher
Rising Starr Middle School
Fayetteville, Georgia

Shannon Ripple
Science Teacher
Science Department
Canyon Vista Middle School
Round Rock, Texas

Susan H. Robinson
Science Teacher
Oglethorpe County Middle School
Lexington, Georgia

Elizabeth Rustad
Science Teacher
Higley School District
Gilbert, Arizona

Helen Schiller
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