interactive Student Edition

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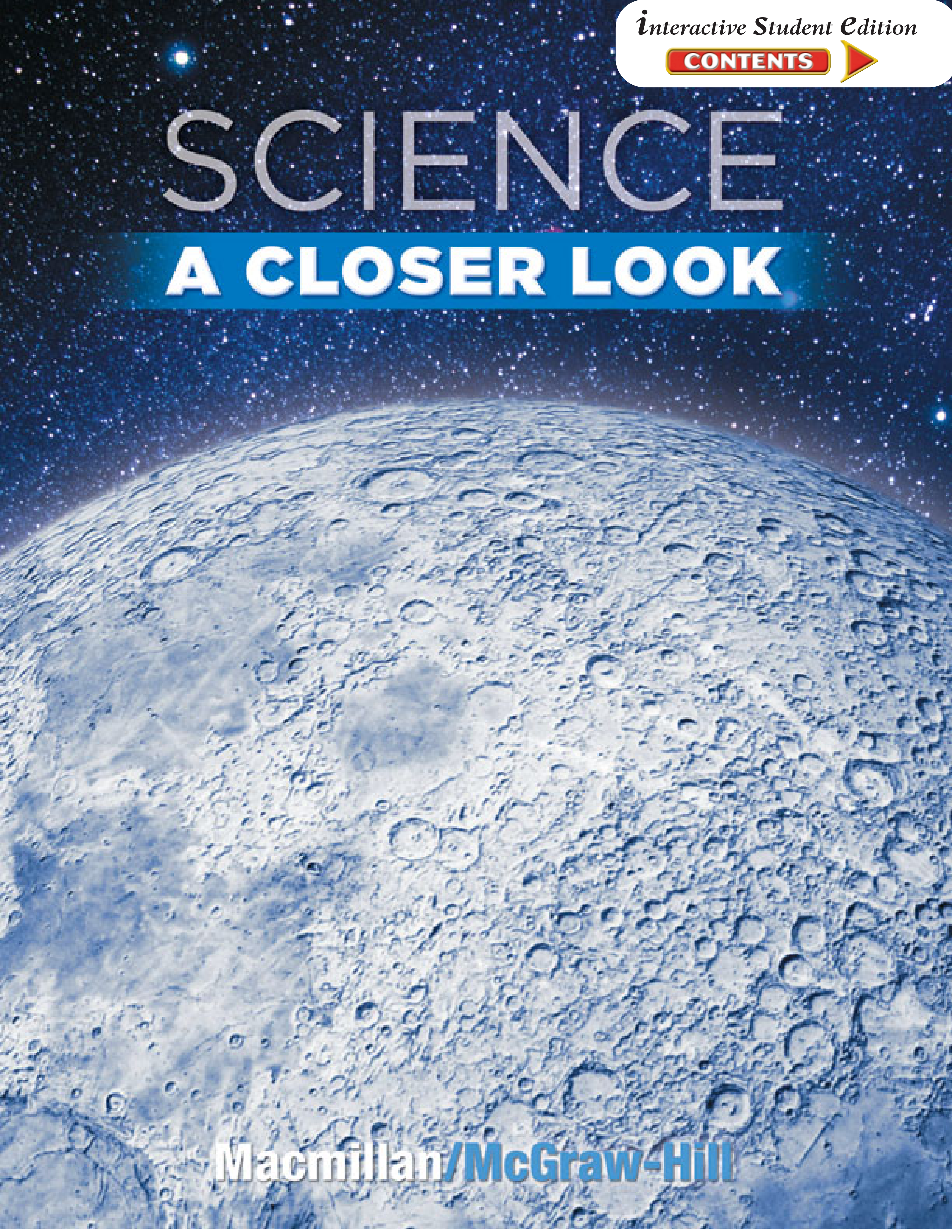
SCIENCE

A CLOSER LOOK



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SCIENCE

A CLOSER LOOK

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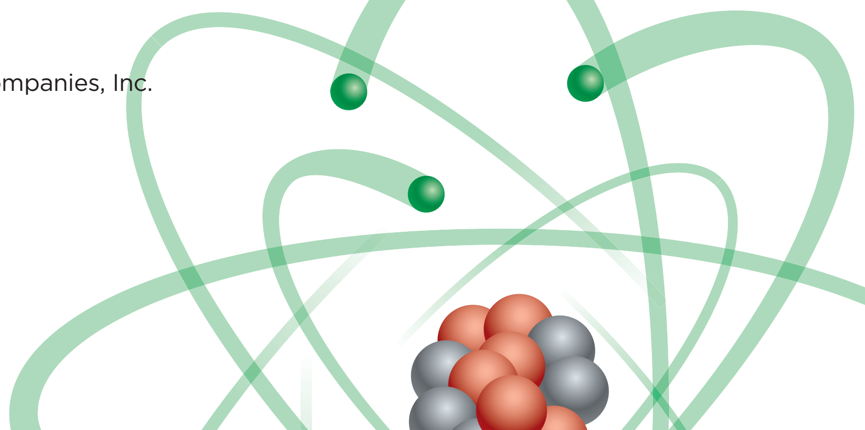

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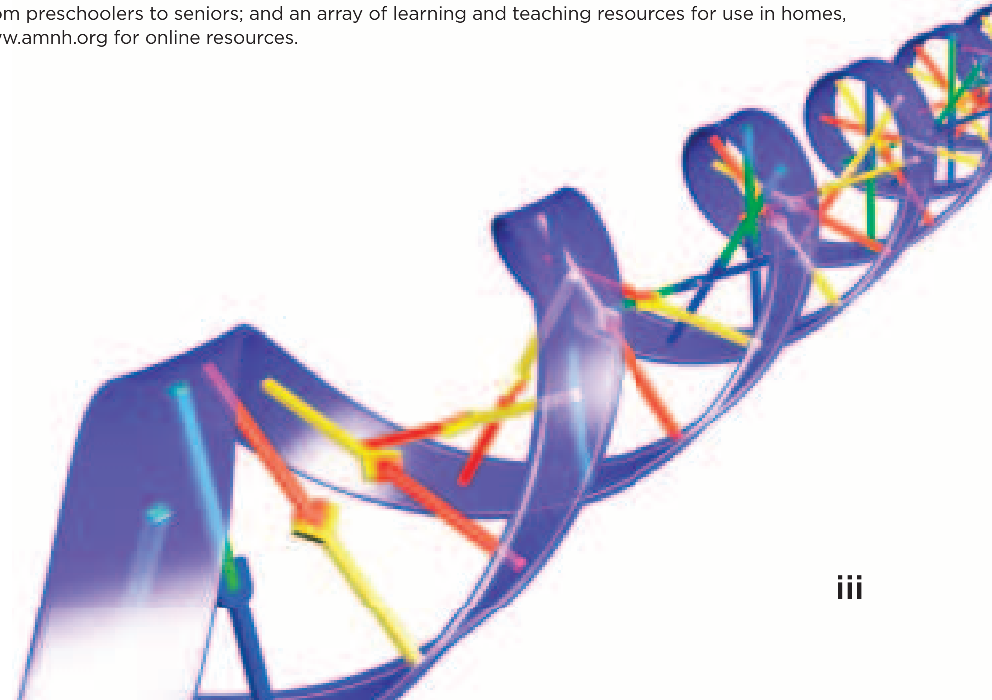
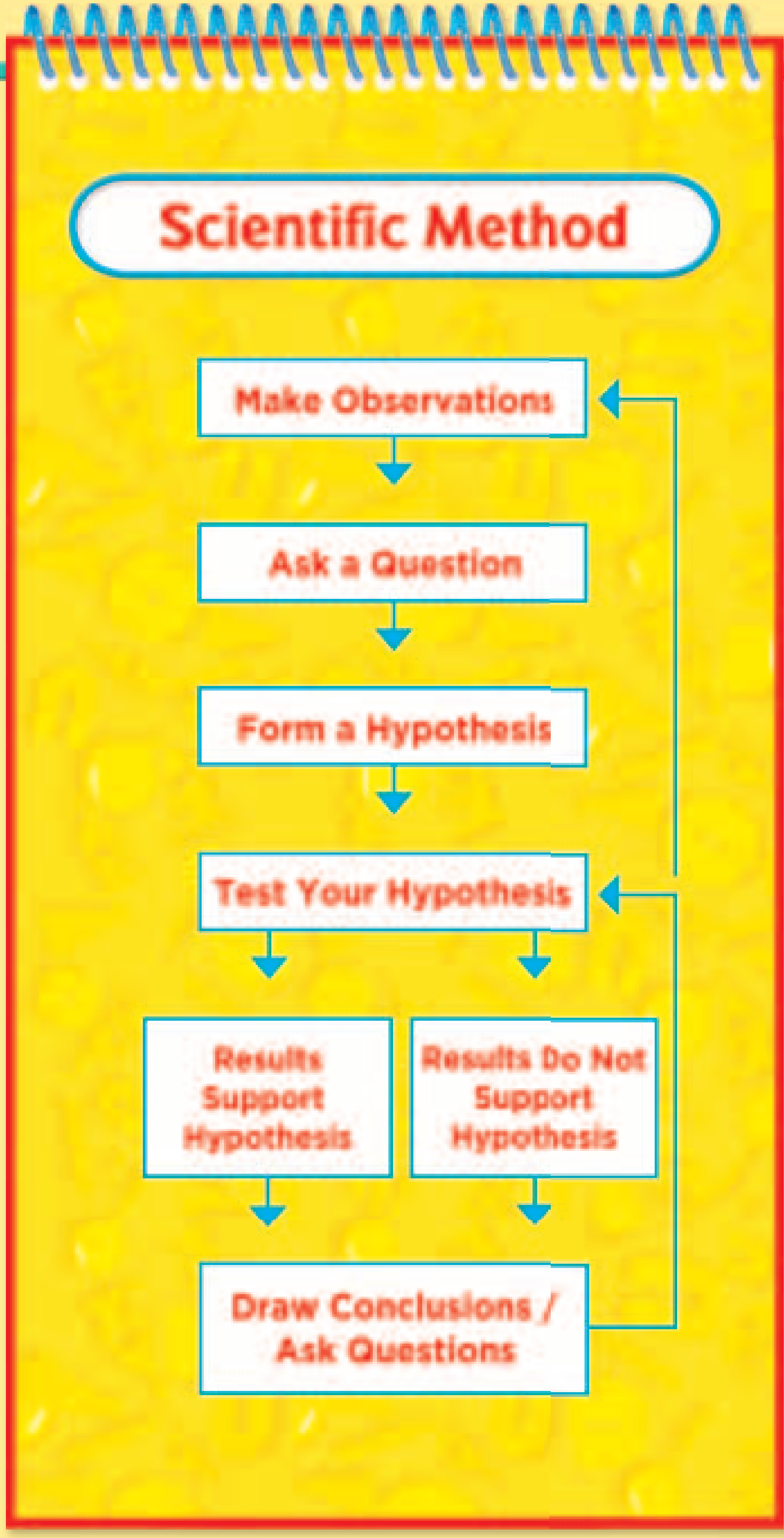
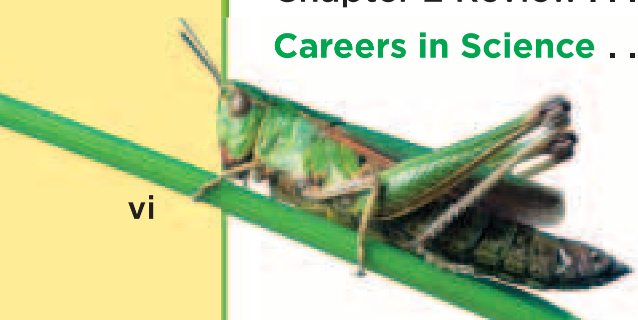


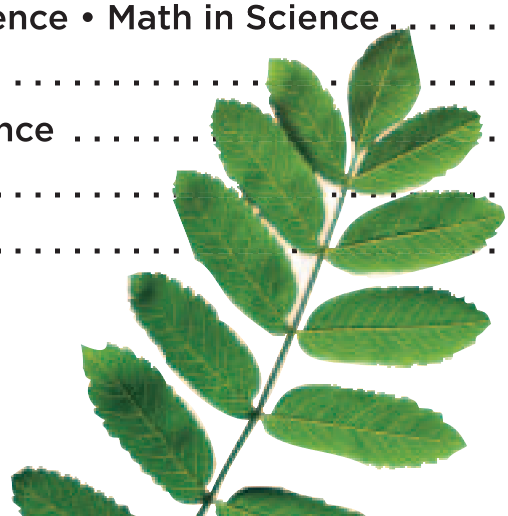
Be a Scientist

Students make measurements and record data.

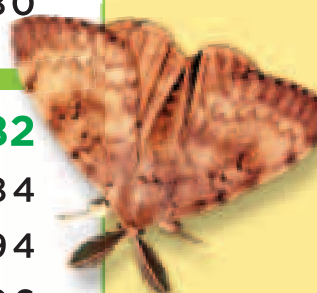

Scientific Method
Make Observations
Ask a Question
Form a Hypothesis
Test Your Hypothesis
Results Support Hypothesis
Results Do Not Support Hypothesis
Draw Conclusions / Ask Questions

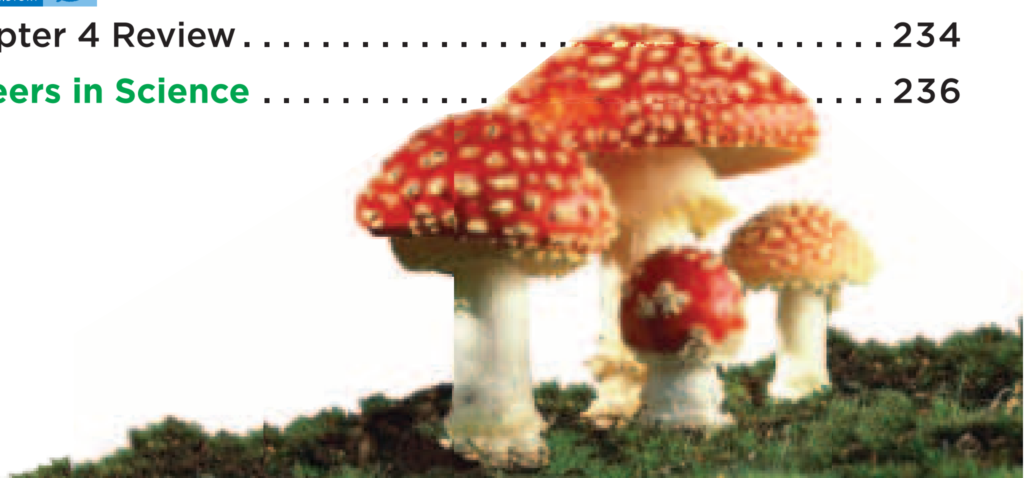
UNIT A Diversity of Life





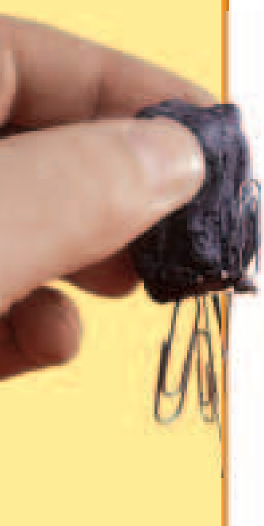
UNIT B Patterns of Life

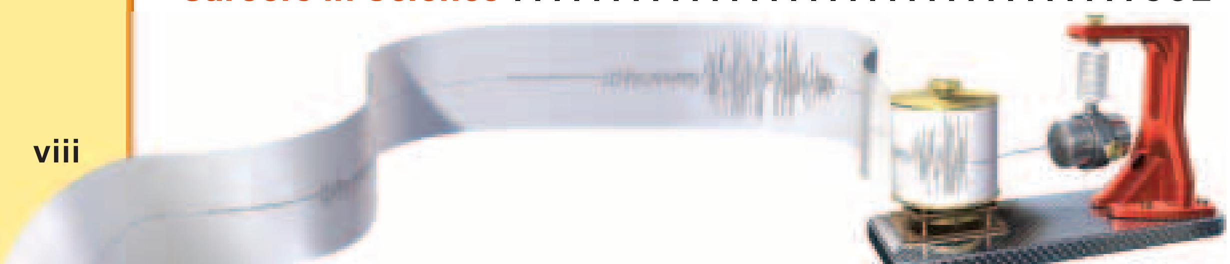


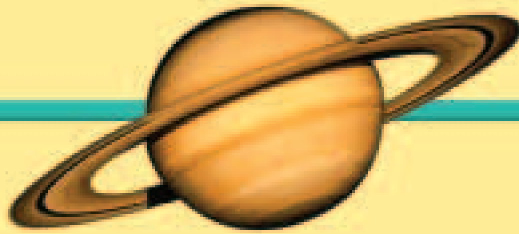


Earth Science

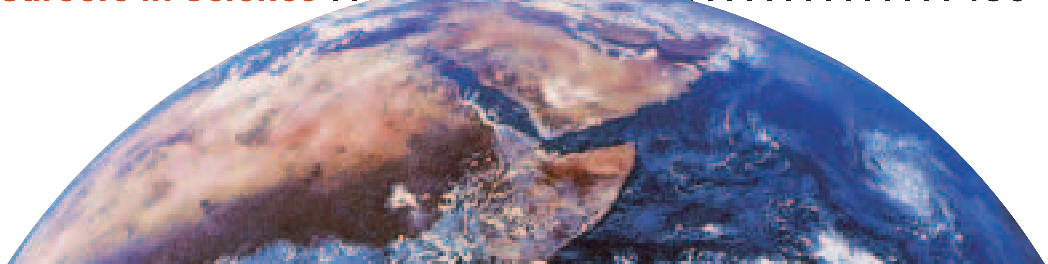
UNIT C Earth and Its Resources



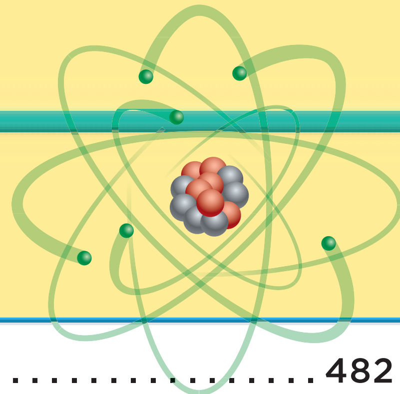




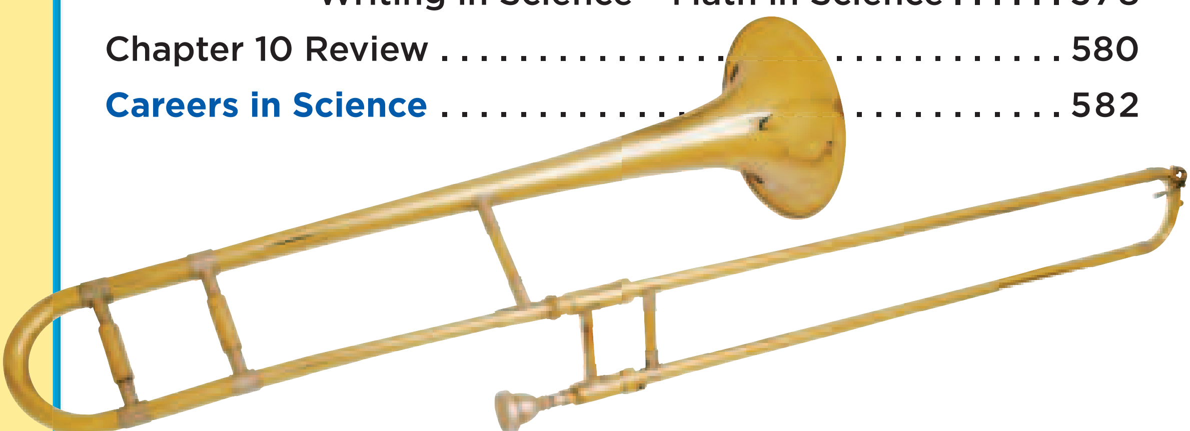
UNIT D Weather and Space



Physical Science



UNIT E Matter



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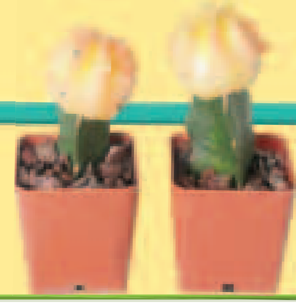
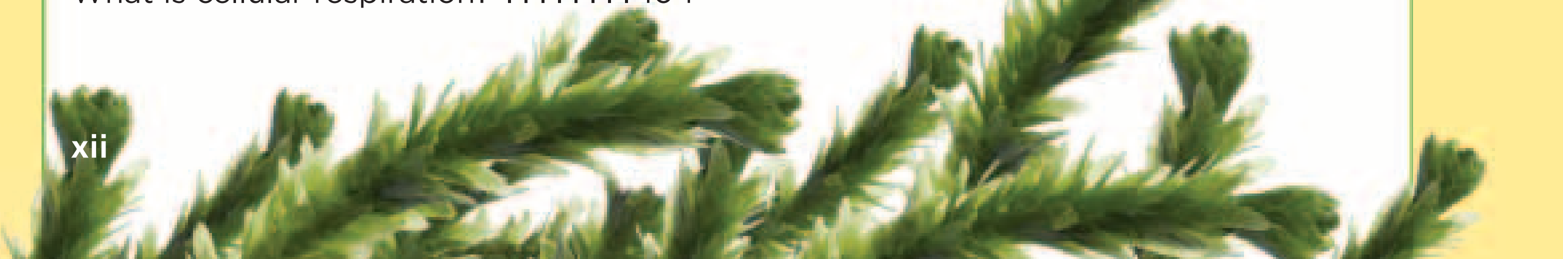
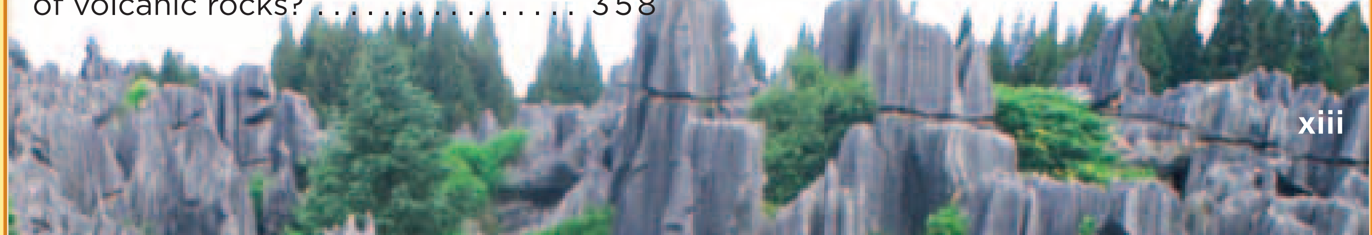
Activities and Investigations



Life Science



Earth Science

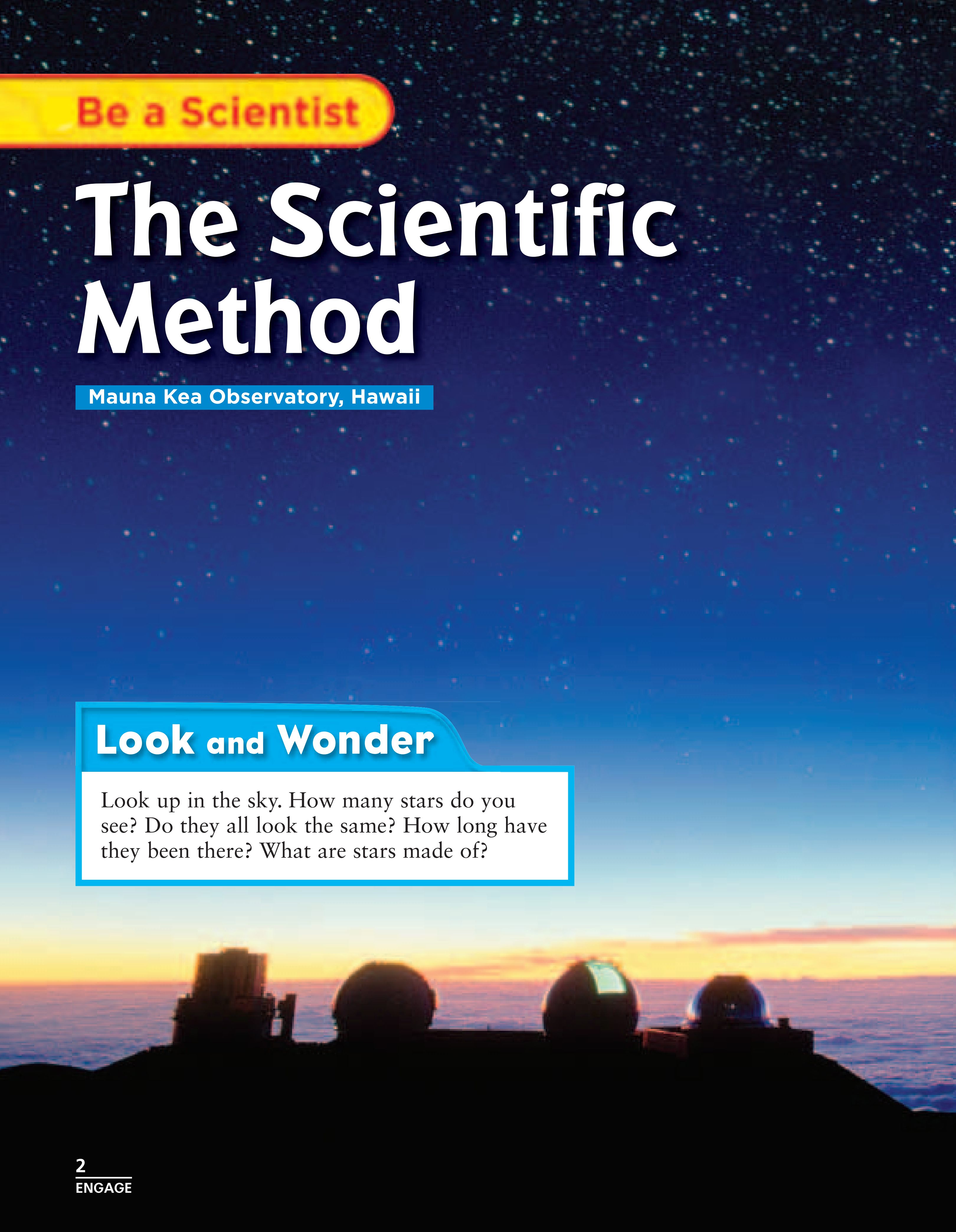


Activities and Investigations

Physical Science

Be a Scientist

A dying star formed the Ant Nebula.



Be a Scientist

The Scientific Method

Mauna Kea Observatory, Hawaii

Look and Wonder

Look up in the sky. How many stars do you see? Do they all look the same? How long have they been there? What are stars made of?

Explore

What do you know about stars?

Stars are born, shine brightly for millions or billions of years, then collapse and even explode. How do you think these changes happen? How do scientists study stars?

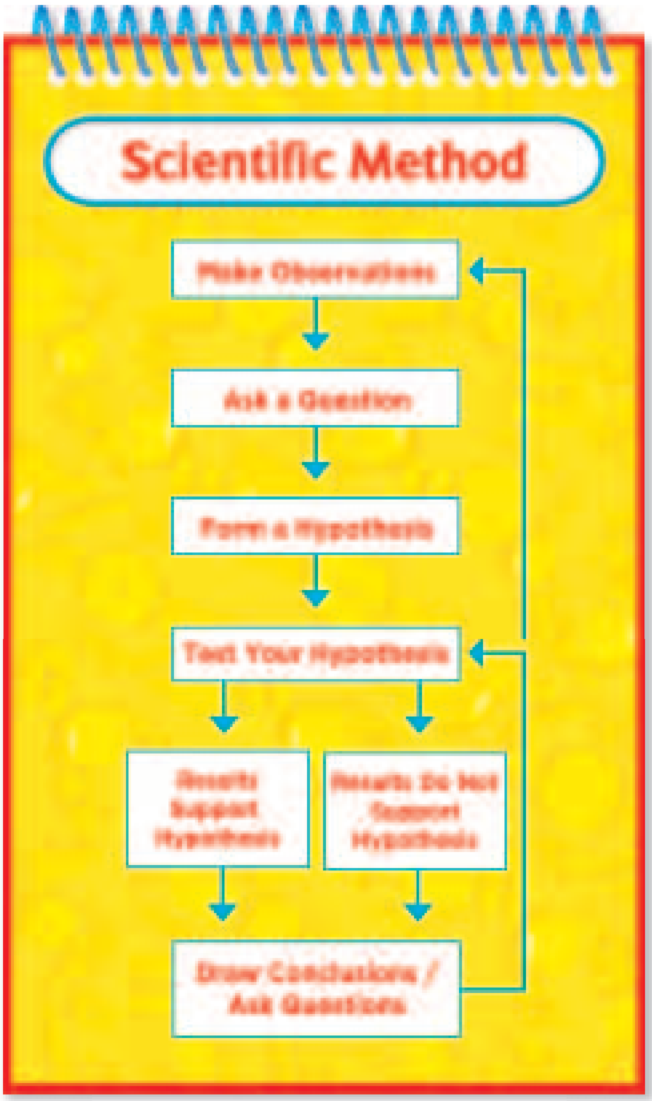
Orsola De Marco and Mordecai-Mark Mac Low are astrophysicists. They both work at the American Museum of Natural History in New York City. Astrophysicists are scientists who are curious about how the universe works.

Astrophysicists use different methods to gather data. For example, Orsola studies light to investigate the history of the universe and the behavior of objects in space. Through a telescope, Orsola observes the light given off by distant stars. However, the length of time she can observe does not permit her to see events that may take many, many years to finish. Mordecai uses computer models to investigate how the universe works. Mordecai enters data into a computer. The data he enters are processed by the computer to make a model of an event in space. The model can show what happens in distant space over time.

Orsola studies stars by looking through a telescope.

By working together, their different skills increase our understanding of stars. What do scientists like Mordecai and Orsola learn about stars from their different methods of work?

Mordecai studies stars by making computer models.



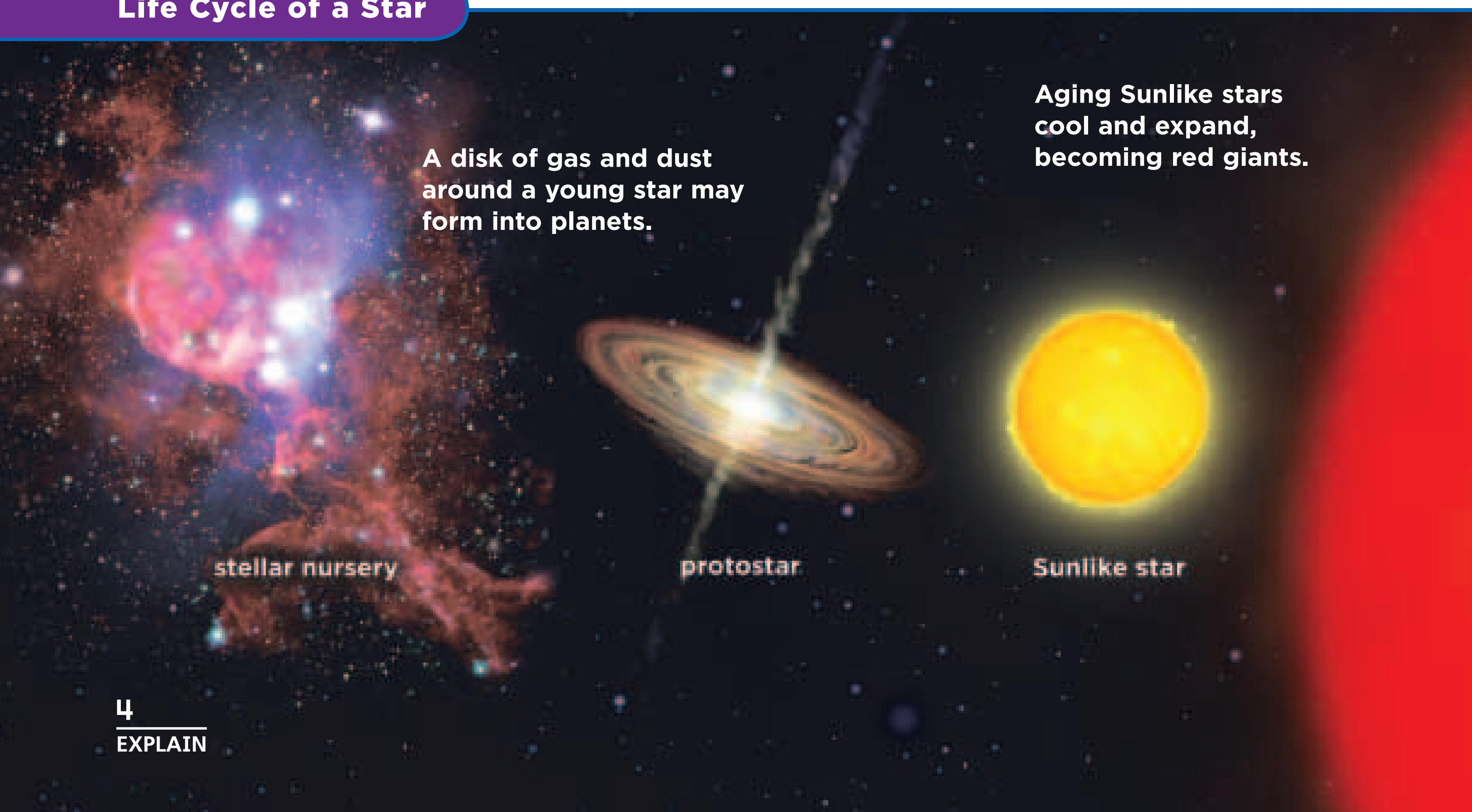
What do scientists do?

Astrophysicists know that, over billions of years, stars change. They call this the "life cycle" of stars. Stars form, mature, and eventually die. Orsola and Mordecai use the scientific method when they study this process. They and other scientists have observed large numbers of stars, formed hypotheses about stars, and tested these hypotheses with more observations.

The scientific method is used by all kinds of scientists to investigate and answer questions. This method helps them explain natural phenomena. It also makes it possible for others to reliably repeat their procedures. This way, the work can be independently checked. Scientists do not always follow all the steps of the scientific method in order. However, they always keep careful records of what they have done and observed.

Astrophysicists have observed that some stars have a companion star. The two stars

Life Cycle of a Star



orbit around each other, and are called a binary. In some binaries, the two stars can be a billion kilometers apart. In others, the two stars orbit so tightly that it is difficult to see that they are separate.

Orsola and Mordecai have been studying binaries for years. Sometimes Orsola observes tightly-orbiting binaries where one of the stars is a white dwarf. The distance between them is actually less than the size of the original red giant that became the white dwarf. Why does this happen?

Astrophysicists have been investigating this question for some time. They have a hypothesis, a statement they can test to answer a question. Their hypothesis is that the red giant "ate" its companion star.

The companion star spiraled in toward the core of the giant, driving away the giant's outer gas layers. The red giant became a white dwarf, and the companion star ended up in a tight orbit.

Forming a Hypothesis

1. Ask lots of "why" questions.
2. Look for connections between important variables.
3. Suggest possible explanations for these connections.

▶ **Make sure the explanations can be tested.**

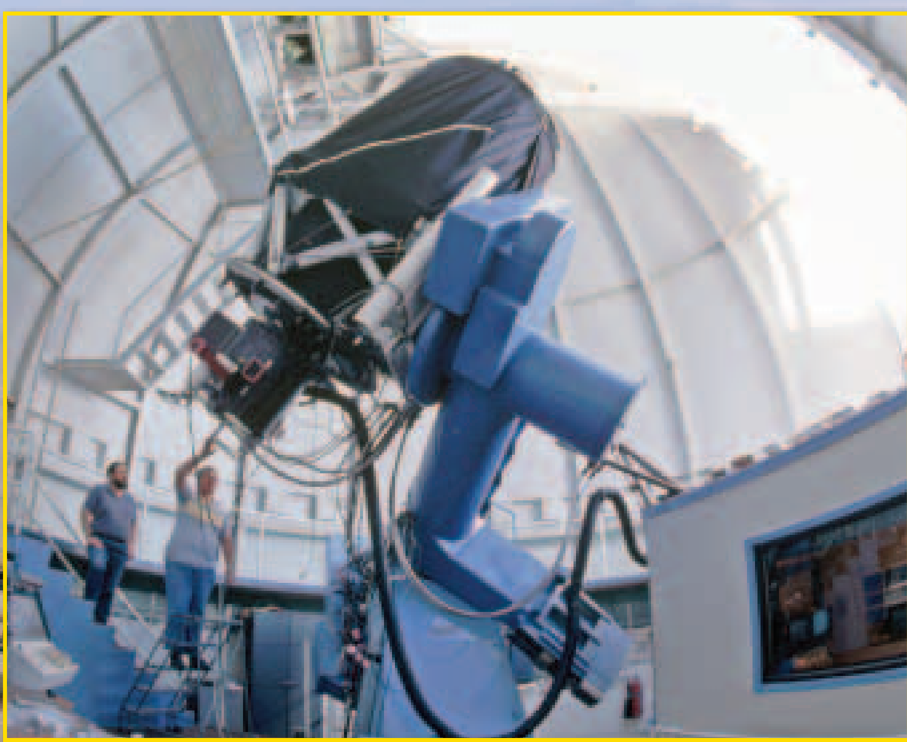
They die as white dwarfs—Earth-size stars with half the mass of the Sun.

How do scientists test their hypothesis?

▲ Orsola looks at the model to compare with her data gathered from a telescope.

Orsola and Mordecai want to test this hypothesis. To do this, they need to collect more data. Orsola spends weeks at a telescope. She measures distances between the two stars in binaries by observing how they move. She watches and records how long the two stars of a binary take to orbit each other. She uses this information to calculate the distances between the stars, and combines her data with data reported by other scientists.

Binary stars take five to ten years to form. This seems like a long time, but it is incredibly fast by astronomy standards. However, the universe is so vast that a scientist could spend a lifetime at a telescope and never find a star eating its companion. So, Orsola and Mordecai have to use a computer model to test their hypothesis. Mordecai's model can then be compared to Orsola's observations.



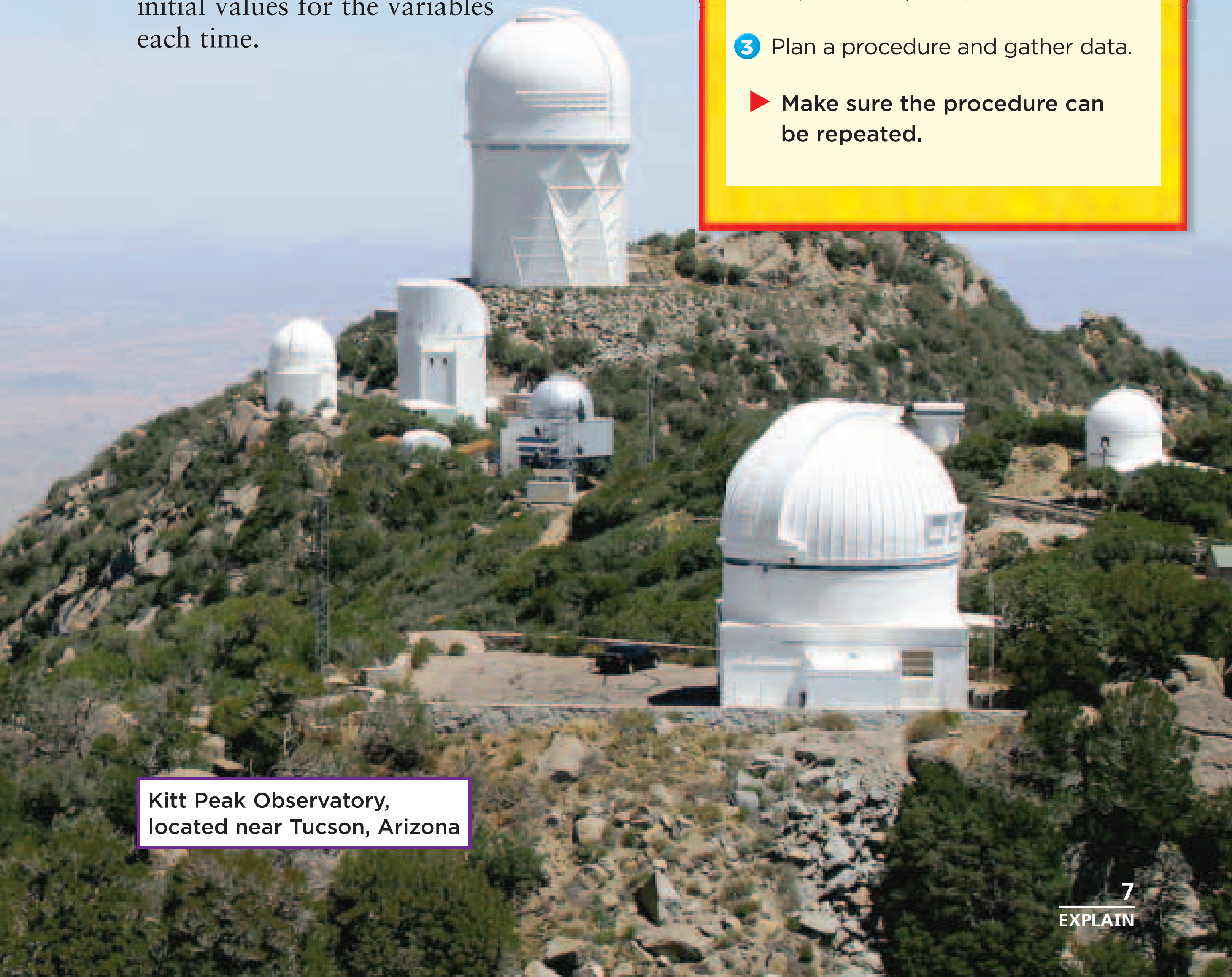
◄ interior of Kitt Peak Observatory

A model is a computer program that shows natural processes at work. “I need a model that uses the laws of physics to predict the orbits of the stars after they merge,” Mordecai explains. “Fortunately, fundamental processes such as gravity and pressure do not only apply on Earth. They apply across the universe.” These forces are an important part of the model. Mordecai also enters the initial values for the key variables of his model. For example, the masses of the stars that make up the binary and the distance between them. He runs the model many times, changing the initial values for the variables each time.

Testing a Hypothesis

1. Think about the different kinds of data that could be used to test the hypothesis.
2. Choose the best method to collect this data:
   - **Perform an experiment** (in the lab)
   - **Observe the natural world** (in the field)
   - **Make a model** (on a computer)
3. Plan a procedure and gather data.

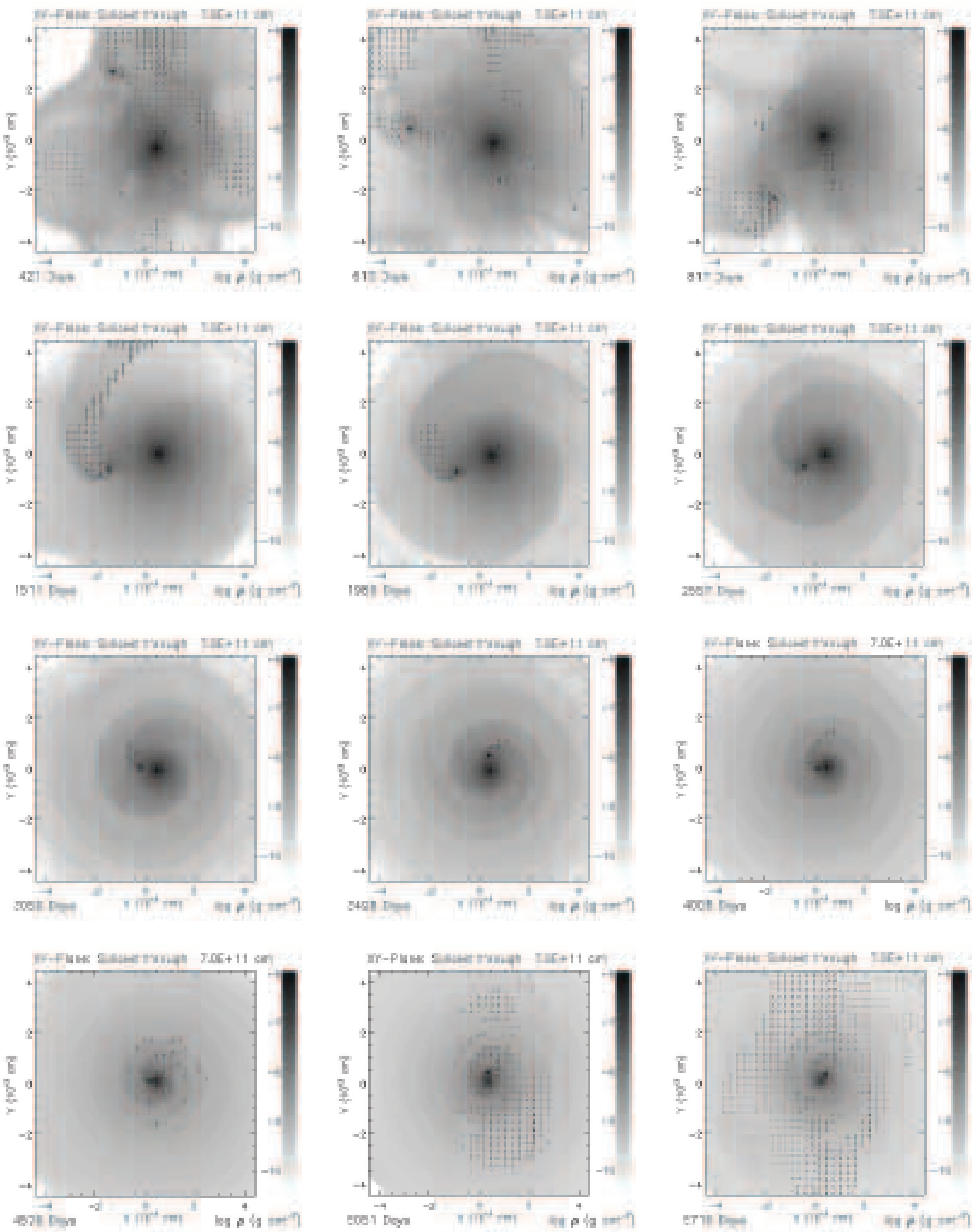
▶ **Make sure the procedure can be repeated.**



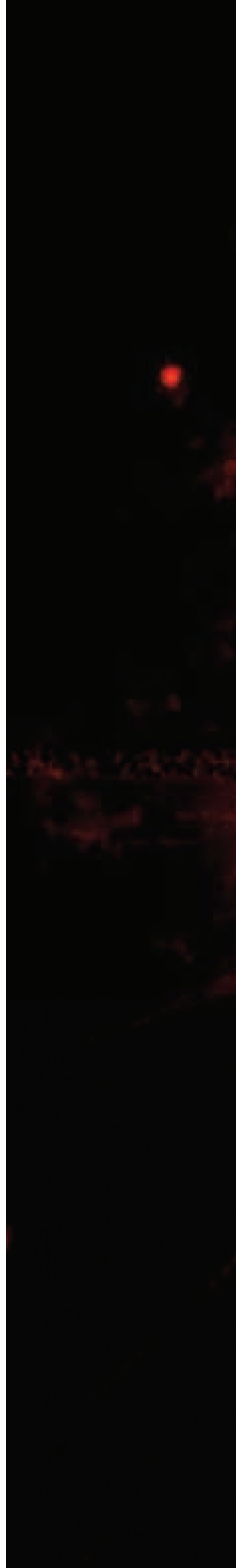
Kitt Peak Observatory, located near Tucson, Arizona

How do scientists analyze data?

Each run of the model takes approximately a week on a supercomputer to finish. Each run predicts a final distance between the two stars. After all the models are run, Mordecai has a range of outcomes that reflect the different sets of initial values for the key variables (mass and distance between two stars prior to run).



▲ This is a series of still images taken from one of Orsola and Mordecai's visualizations.



Part of testing a hypothesis is arranging the data to look for patterns. Orsola and Mordecai organize their data so they can compare Mordecai's predictions to Orsola's observations.

Mordecai does this by creating visualizations of the data that his model generated. Visualizations are images or movies that represent complex sets of data. Visualizations of Mordecai's runs show what happens as stars of different masses and initial distances swirl into the center of a red giant.

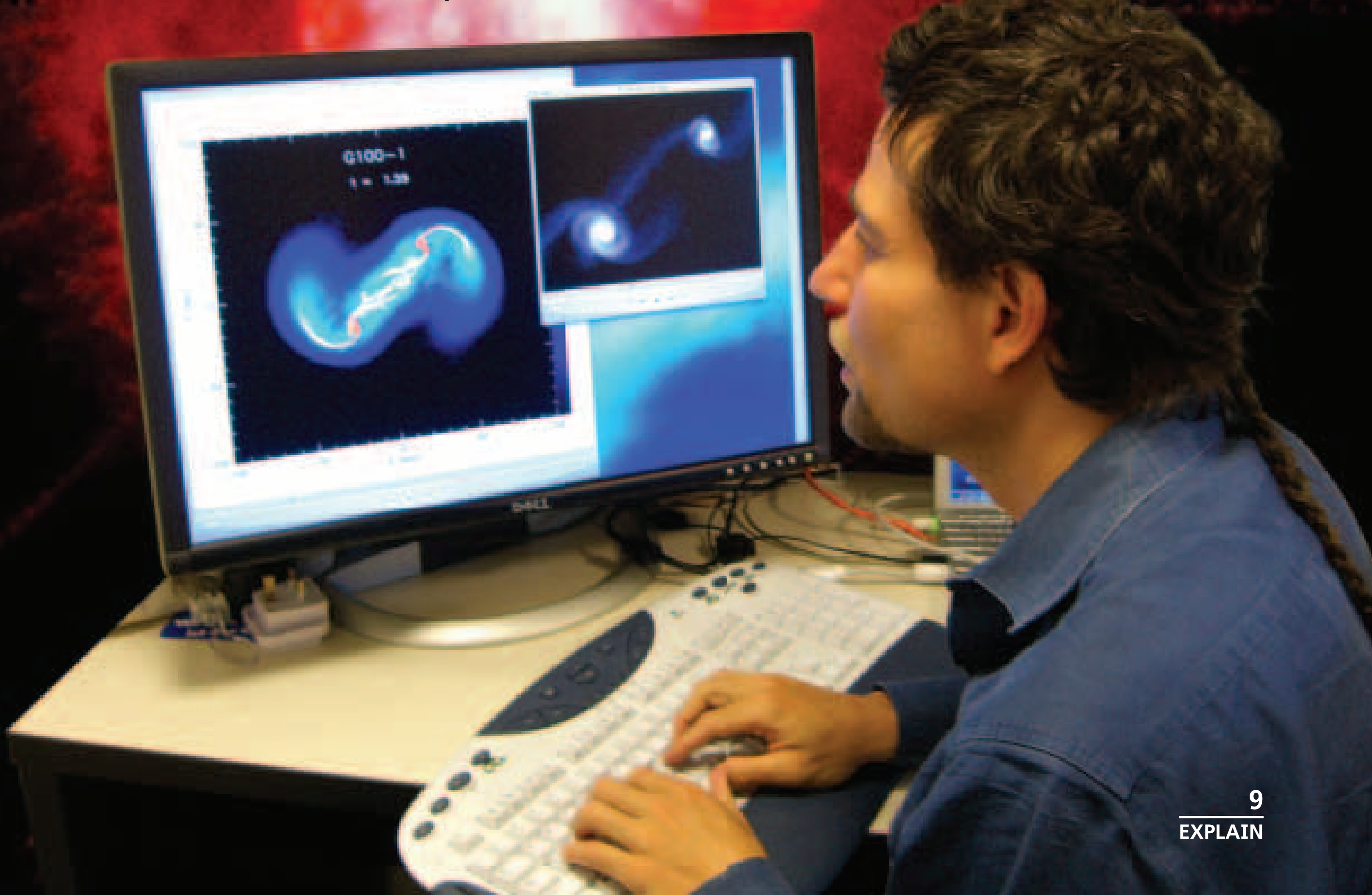
Analyzing the Data

1. Organize the data as a chart such as a table, graph, diagram, map or group of pictures.

2. Look for patterns in the chart that show connections between important variables in the hypothesis being tested.

- **Make sure to check the data by comparing it to data from other sources.**

Mordecai compares his computer model runs.



How do scientists draw conclusions?

Now it is time for Orsola and Mordecai to compare the model predictions to the observations. They compare the distances between the two stars in binaries produced by the model to the distances that Orsola and other astrophysicists observed in space. If the results from the model and the observations agree, that is evidence in favor of the hypothesis. If the results disagree, either the hypothesis is flawed or the model is incomplete. “So far, we have found some preliminary predictions in the model that match observed data!” says Orsola, “which is very exciting.”

However, some of the models also predict that when a red giant eats a companion star, the two stars combine into one. “The model shows us that the process can produce another kind of object in the universe: a single star formed when two stars combine,” she explains. “This is really fascinating!”

Mordecai and Orsola discuss their conclusions. ▶

The Great Nebula in the constellation Orion has many stellar nurseries where stars and solar systems are forming. On a clear, dark winter night, the nebula can be seen as a fuzzy patch in Orion's sword.

Drawing Conclusions

1. Decide if the data clearly support or do not support the hypothesis.
2. If the results are not clear rethink how the hypothesis was tested and make a new plan.
3. Write up the results to share with others.

▶ **Make sure to ask new questions.**

Orsola and Mordecai's results lead them to ask more questions. Can they find stars that are evidence of this second outcome? What can Orsola learn from Mordecai's model about where and how to look for these stars? New questions, like these, are important because they lead to new hypotheses and new discoveries.

Focus on Skills

Scientists use many skills as they work through the scientific method. Skills help them gather information and answer questions they have about the world around us. Here are some skills they use:

Observe Use your senses to learn about an object or event.

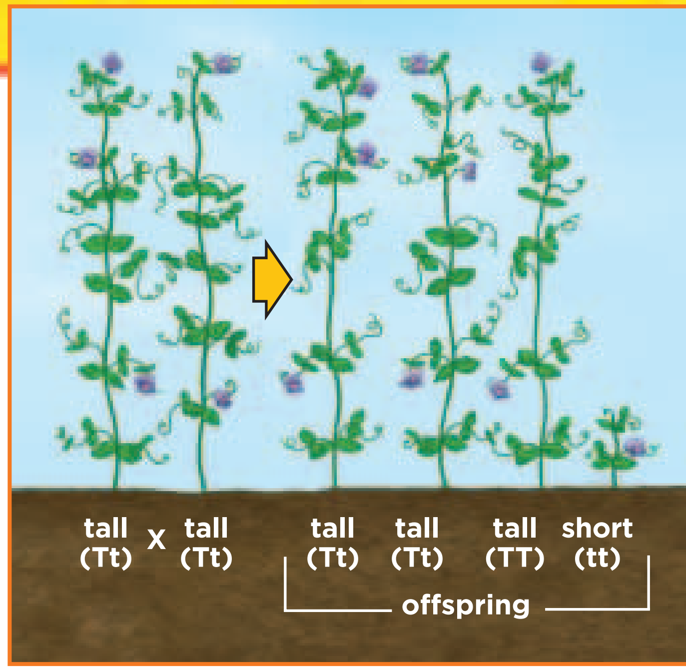
Form a Hypothesis Make a statement that can be tested to answer a question.

Communicate Share information with others.

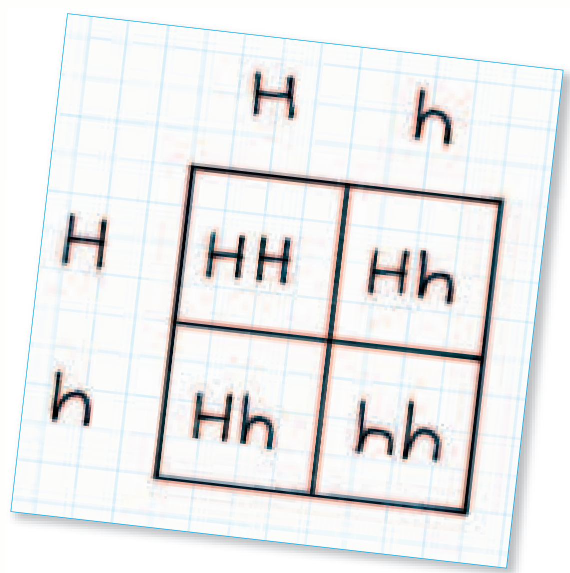
Classify Place things with similar properties into groups.

Use Numbers Order, count, add, subtract, multiply, or divide to explain data.

Make a Model Make something to represent an object or event.



▲ Use diagrams and drawings to help classify living and nonliving things.



▲ A Punnett square is used to predict the possible outcomes of a genetic cross.

Use a calculator to perform long or complex calculations or to verify your work.

Use Variables Identify things that can control or change the outcome of an experiment.

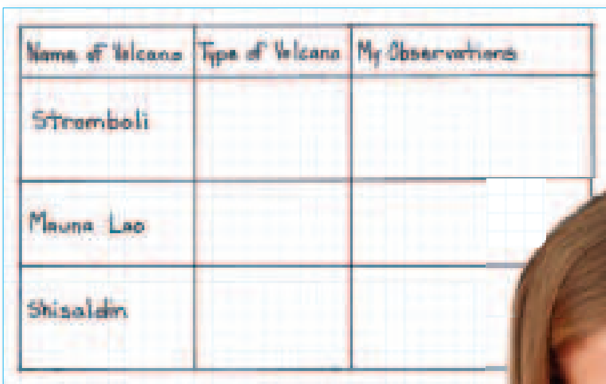
Interpret Data Use information that has been gathered to answer questions or solve a problem.

Measure Find the size, distance, time, volume, area, mass, weight, or temperature of an object or event.

Predict State possible results of an event or experiment.

Infer Form an idea or opinion from facts or observations.

Experiment Perform a test to support or disprove a hypothesis.



Name of Volcano	Type of Volcano	My Observations
Stromboli		
Mauna Loa		
Shisaldin		

Use a table to help organize and interpret data.

Inquiry Skill Builder

In each chapter of this book, you will find an Inquiry Skill Builder. These features will help you build the skills you need to be a scientist.

Safety Tips

In the Classroom

- Read all of the directions. Make sure you understand them. When you see "**Be Careful,**" follow the safety rules.
- Listen to your teacher for safety directions. If you do not understand, ask for help.

- Wash your hands with soap and water before an activity.
- Be careful around a hot plate. Know when it is on and when it is off. Remember that the plate stays hot for a few minutes after it is turned off.
- Wear a safety apron if you work with anything messy or that might spill.

- Clean up a spill right away, or ask your teacher for help.
- Tell your teacher if something breaks. If glass breaks, do not clean it up yourself.
- Do not eat or drink anything during an experiment.
- Wear safety goggles when your teacher tells you to wear them. Wear them when working with anything that can fly into your eyes or when working with liquids.

- Be careful around a hot plate. Know when it is on and when it is off. Remember that the plate stays hot for a few minutes after it is turned off.
- Keep your hair and clothes away from open flames. Tie back long hair, and roll up long sleeves.
- Keep your hands dry around electrical equipment.
- Put equipment back the way your teacher tells you to.
- Clean up your work area after an activity, and wash your hands with soap and water.

In the Field

- Go with a trusted adult—such as your teacher, or a parent or guardian.
- Do not touch animals or plants without an adult's approval. The animal might bite. The plant might be poison ivy or another dangerous plant.

Responsibility

Treat living things, the environment, and one another with respect.

Diversity of Life

Although it is called a firefly, this insect is actually a beetle and not a fly at all!

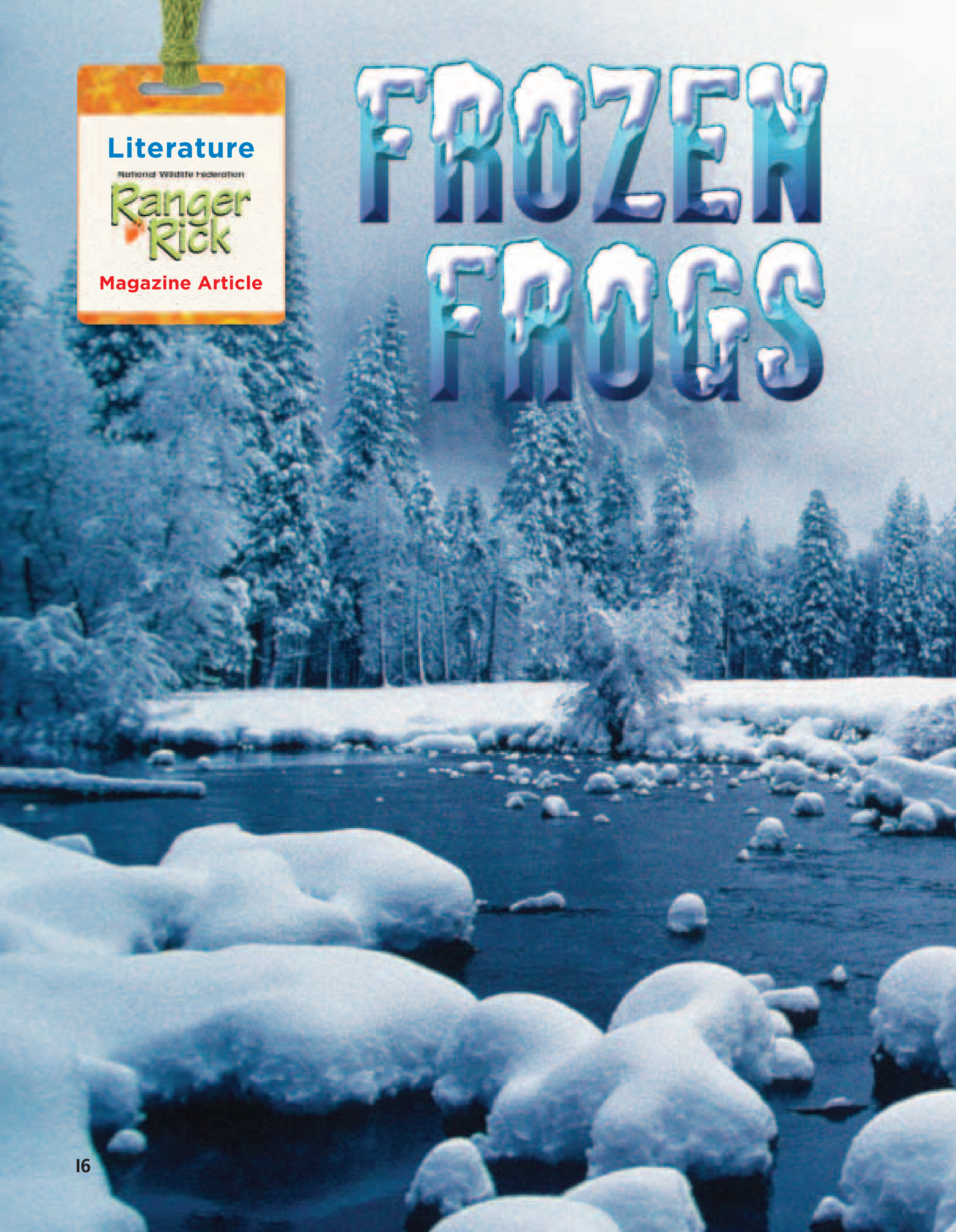
Literature

National Wildlife Federation

Ranger Rick

Magazine Article

FROZEN FROGS



On a cold winter day, a wood frog lies in a shallow burrow beneath fallen leaves on the forest floor. The frog is not moving. It is not breathing. Its heart is not beating. In fact, it is frozen solid. Yet this frog is alive!

Staying Warm

Amphibians and reptiles have no fur or feathers to keep them warm. In cold climates they need to have other survival strategies. Most avoid freezing by burrowing deep underground or by burying themselves at the bottom of a pond or a lake. A few simply freeze. Wood frogs, which live as far north as the Arctic Circle, survive the winter as frozen "frog-sicles."

Sugar and Ice

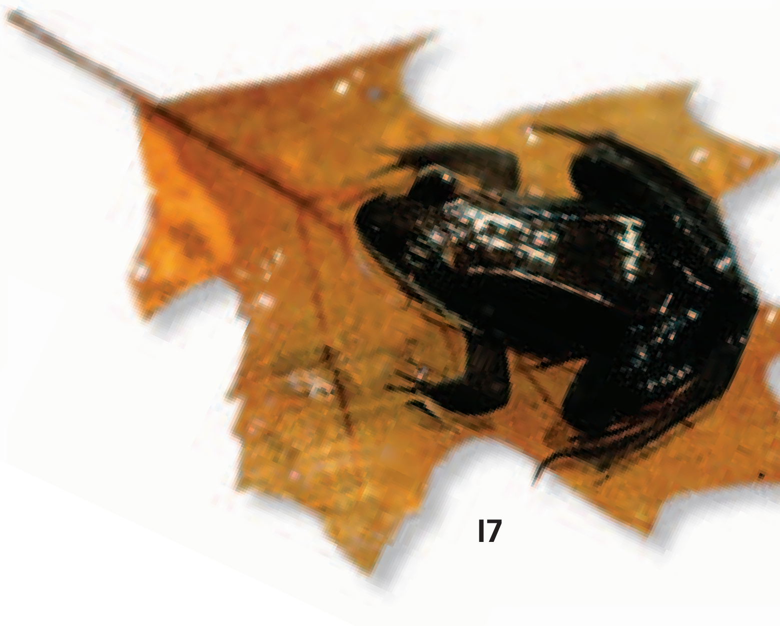
If you or most other animals tried this trick, you would not be nearly as successful. Sharp ice crystals that form inside your body's cells would damage your cells beyond repair. (That is why we get frostbite.) Wood frogs solve this problem in an interesting way. Freezing temperatures trigger the frog's body to produce large amounts of glucose, or blood sugar. This works as an antifreeze. It is like the antifreeze people put in car engines to keep them running in winter. Glucose inside the wood frog's cells prevents the cells from freezing. Instead, ice forms outside the cells. It fills the cavities around the frog's organs and forms thin sheets between layers of skin and muscle. As the frog's blood freezes, its heart stops beating, its other organs shut down, and its breathing stops. As much as 65 to 70 percent of the water in its body turns to ice. The wood frog enters a state of suspended animation.

As temperatures climb above freezing in spring, the wood frog begins to thaw. Soon it is ready to hop to a nearby puddle or pond and begin looking for a mate. Although snow may still cover the ground, the calls of this incredible winter survivor loudly proclaim that spring is on the way.

Write About It

Response to Literature This article describes a wood frog during winter. What happens to the frog? Choose a different animal to write about. Write an essay describing the process that this animal goes through to survive severe weather conditions, such as cold winters or dry, hot summers.

LOG ON e-Journal Write about it online at www.macmillanmh.com



CHAPTER 1

Classifying Living Things

The Big Idea

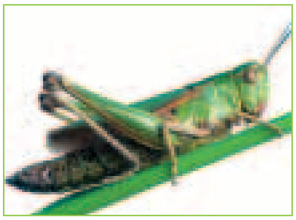
How do scientists classify Earth's living things?

Polar bears and glaucous gulls in Alaska.

Key Vocabulary

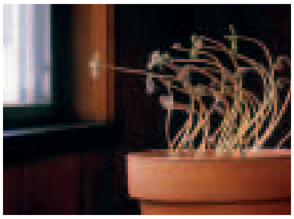
photosynthesis
The process in which plants and some other organisms use sunlight to make food in the form of glucose. (p. 37)

pollination
The transfer of pollen from an anther to the female part of a stigma. (p. 38)

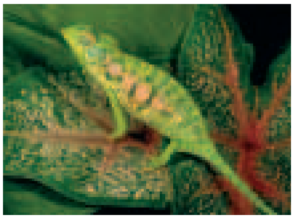


exoskeleton
A hard covering that protects an invertebrate's body. (p. 52)

respiration The process of releasing energy from food molecules such as glucose, which takes place in the mitochondria of a cell. (p. 60)



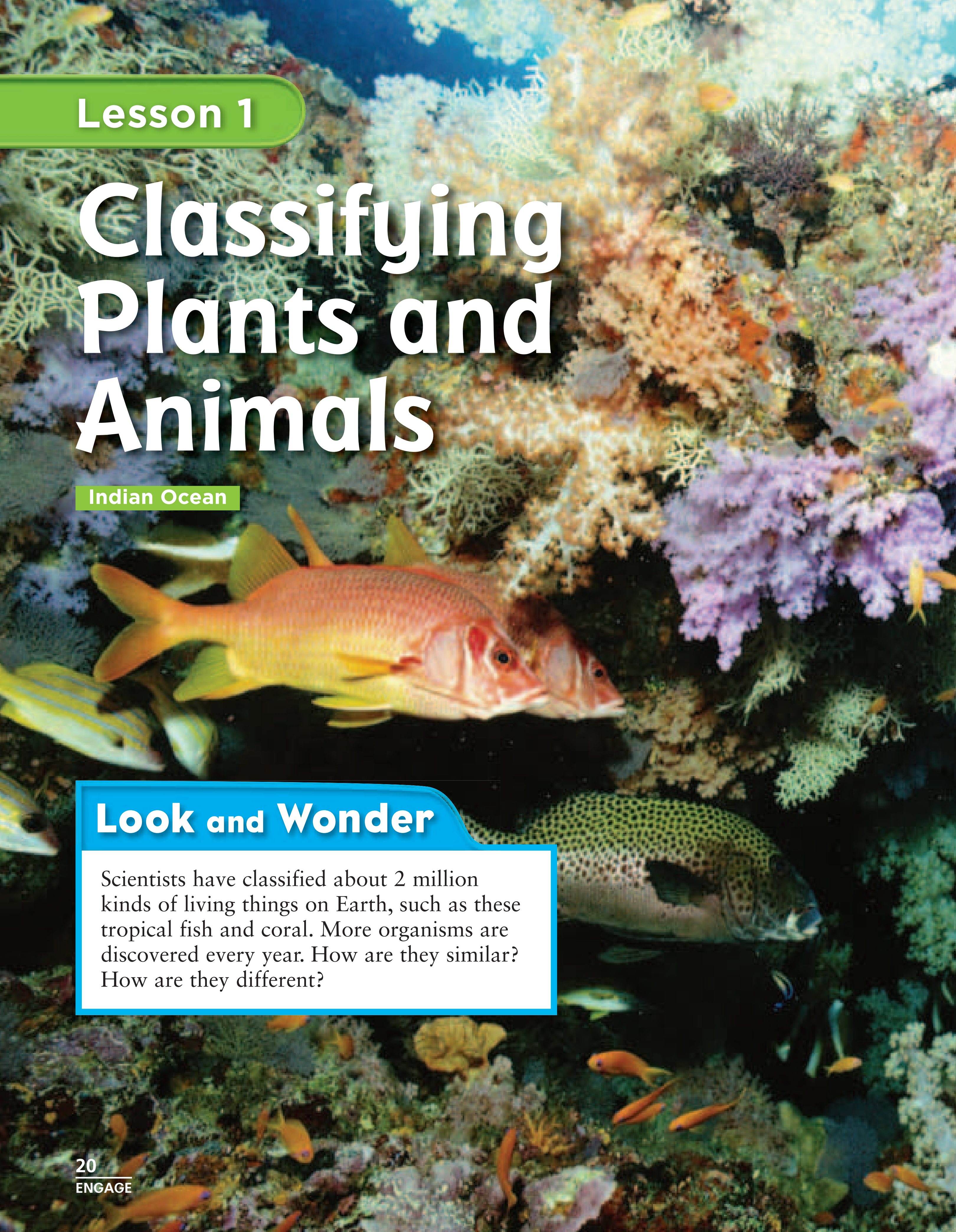
tropism
The response of an organism toward or away from a stimulus. (p. 70)



camouflage
A disguise used to make something look like its surroundings. (p. 72)

More Vocabulary

organism, p. 22
species, p. 24
phylum, p. 24
kingdom, p. 24
vascular, p. 26
nonvascular, p. 26
reproduction, p. 38
seed, p. 38
vertebrate, p. 48
chordate, p. 49
endoskeleton, p. 49
invertebrate, p. 50
digestion, p. 58
excretion, p. 58
diffusion, p. 60
circulation, p. 62
adaptation, p. 70
mimicry, p. 72
instinct, p. 74
migrate, p. 76



Lesson 1

Classifying Plants and Animals

Indian Ocean

Look and Wonder

Scientists have classified about 2 million kinds of living things on Earth, such as these tropical fish and coral. More organisms are discovered every year. How are they similar? How are they different?

Explore

Inquiry Activity

How can living things be classified?

Purpose

What characteristics can you use to classify different living things? Observe living things in a drop of water, and group those with similar characteristics.

Procedure

1. **Observe** Place 1 drop of the water sample on a clean microscope slide. Gently lower a coverslip onto the slide so it touches the drop as shown. Lower and release the coverslip so it flattens the drop. Place the slide on the stage of the microscope, and observe it under low power.
2. **Record Data** Work with a partner to look for living things in the drop. What characteristics do they have? Record your observations.
3. **Classify** Find different ways to group organisms with similar characteristics.
4. **Communicate** Make a data table of the different kinds of characteristics you observed (motion, shape, color, size, structure, and so on).

Draw Conclusions

5. **Interpret Data** What characteristics did you use to place the living things in separate groups? What do the members of each group have in common? What differences do they have?
6. **Compare** Did you find more than one way to classify an organism? If so, why did you decide on one particular way rather than another?

Explore More

Add other living things to your classification system. Study living specimens around you. You might observe animals at a local zoo. How does the addition of new living things change your classification system?

Materials

- dropper
- sample of aquarium, pond, or ocean water
- slide
- coverslip
- microscope

Read and Learn

Main Idea

Living things are classified based on various characteristics.

Vocabulary

organism, p. 22
species, p. 24
phylum, p. 24
kingdom, p. 24
scientific name, p. 25
vascular, p. 26
nonvascular, p. 26

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Reading Skill

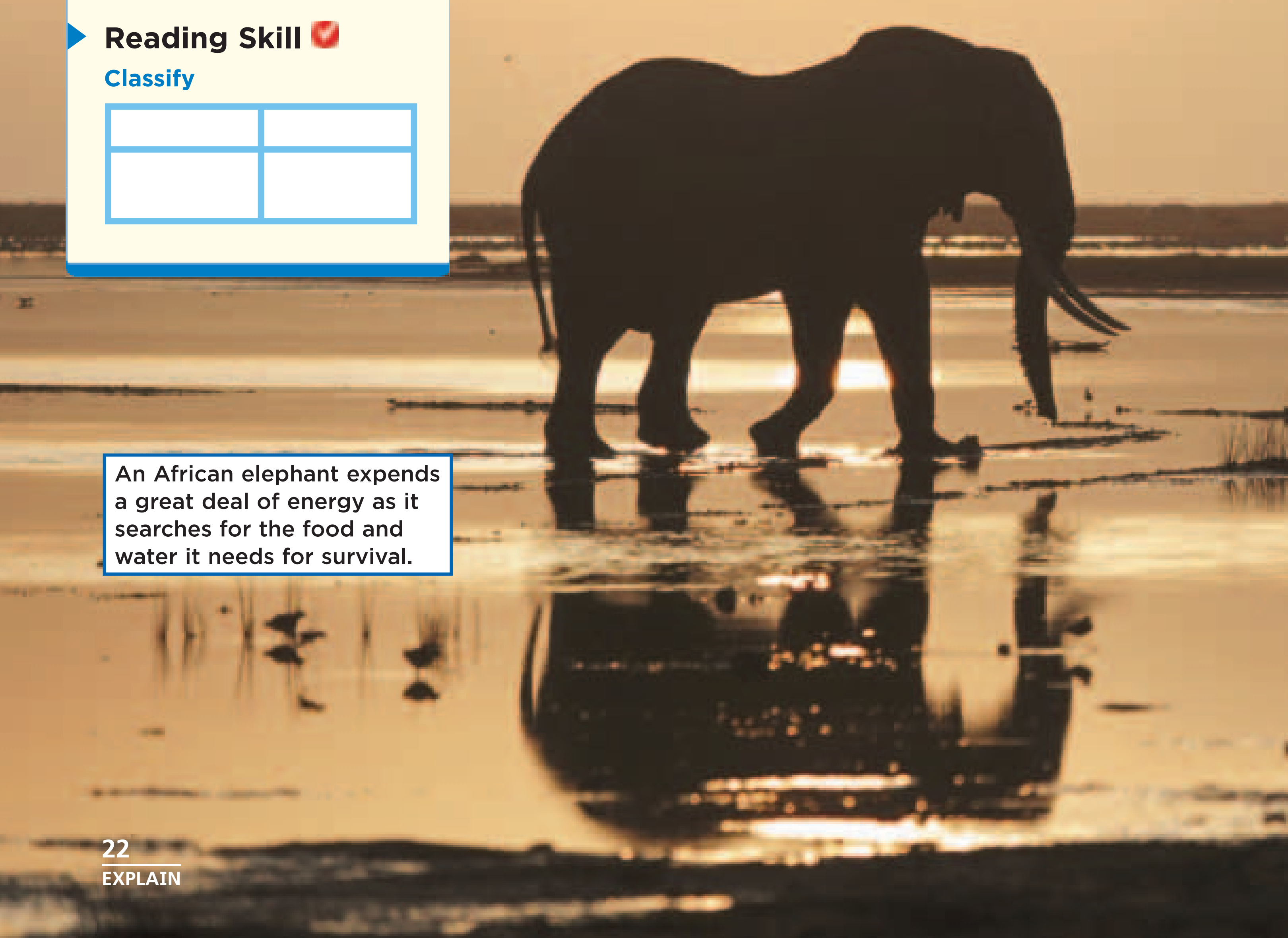
Classify

What are living things?

What do scientists look for when they search for new life? What tells a scientist that something is alive? One way to define *life* is to use examples. For instance, a deer, a raccoon, and a heron are all **organisms**, or living things. What common characteristics do they share? All three organisms can grow and move from place to place. However, scientists require more evidence than this to state that something is living. After all, clouds can grow and move as well, but they are not alive.

Characteristics of Living Things

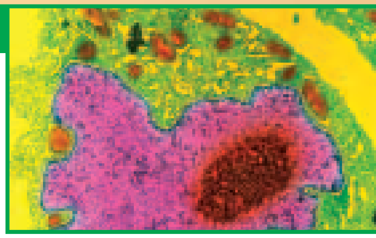
Scientists consider five basic functions when they define living things. Living organisms fulfill all five life functions.



An African elephant expends a great deal of energy as it searches for the food and water it needs for survival.

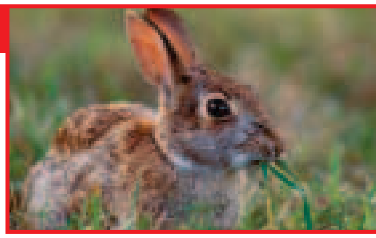
Are Made of Cells

Cells, such as these animal cells, are the building blocks of life. Cells carry out all basic life processes, such as converting food molecules into energy and getting rid of waste materials. An organism can be one cell or can be made up of many cells.



Obtain and Use Energy

All living things, such as this cottontail rabbit, require energy to carry out their life functions. Plants capture the Sun's energy and convert it into food. Animals take in energy by consuming plants and other organisms.

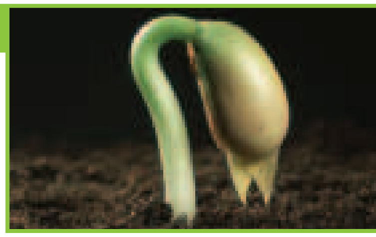


Reproduce

Living things are able to make more of their own kind. Many multicellular organisms, such as these golden orioles, require two parents to reproduce. Each parent contributes one special cell. The two cells combine to form a single cell. This cell becomes a new organism with characteristics from both parents.

Grow and Develop

Seeds germinate, grow, and develop into adult plants, as seen in this green bean. Each organism has a life cycle that involves changes in its size, shape, ability to move, and feeding behavior.



Respond to the Environment

Even simple organisms respond to the environment. A paramecium quickly acts to defend itself when a drop of vinegar drips into its water. Plants such as these sunflowers turn toward the Sun to absorb as much sunlight as possible.

Quick Check

Classify What are the five characteristics of living things?

Critical Thinking Cars move, age, and use energy. Why are they not living things?

How are organisms classified?

Carolus Linnaeus (li•NEE•uhs), a Swedish botanist, developed a system to name and classify living things. He grouped organisms by their common characteristics. His system is still in use today.

Organisms with the most characteristics in common are grouped into the smallest unit of classification, the species. A **species** is a group of similar organisms that reproduce more of their own kind. Similar species are combined into *genuses*.

Organisms in similar genuses are combined into *families*. For example, the genus that includes dogs and wolves is part of a family that also includes foxes. In the larger group, the family, organisms have less in common than members of the same genus do.

Families that share characteristics are grouped into *orders*. The order that includes dogs is called Carnivora. Dogs, wolves, and foxes—members of the same family—are grouped into an order that includes animals such as cats, weasels, and bears.

Similar orders are grouped into *classes*. The order Carnivora is part of a class that includes bats, chimpanzees, and even whales. Several classes make up a **phylum** (FIGH•luhm). At the phylum level, dogs are grouped with birds, snakes, frogs, and even fish.

Phyla (singular, *phylum*) combine into **kingdoms**. The kingdom is the largest and most general grouping.

Evidence has led modern scientists to conclude that there are enough differences among some organisms that they should be in separate kingdoms. The most commonly used classification system now includes six kingdoms: eubacteria (yew•bak•TEER•ee•uh), archaebacteria (ahr•kee•bak•TEER•ee•uh), protists, fungi, plants, and animals. You will learn more about organisms in these kingdoms later in this lesson.

▼ Dogs often look quite different, but they all belong to the same species, *Canis familiaris*.

Classification of *Canis familiaris*

Naming Species

Linnaeus used the genus and the species together to form a **scientific name** for known organisms. Many of the names used are derived from Latin. For example, the name for the order Carnivora comes from two Latin word parts. *Carn* means "meat" or "flesh." The ending *-vorus* means "devouring or feeding upon." Certainly you can guess what all carnivores have in common!

The name *Canis familiaris* describes all domestic dogs. *Canis* is the genus, and *familiaris* is the species. Do you recognize that *familiaris* sounds like the word *familiar*? *Familiaris* is Latin for "closely acquainted." There are species in many different genuses that also have the name *familiaris*. This is one of the reasons that a species is always properly identified by both its genus and its species name.

Quick Check

Classify List the seven classification groups in order, beginning with the largest, or most general.

Critical Thinking Which have more in common: organisms in the same family or organisms in the same order? Explain.

Read a Diagram

What characteristics do dogs share with others in their class? What are the characteristics they share with others in their phylum?

Clue: Look for common characteristics at each classification level.

FACT Linnaeus recognized only two kingdoms: plants and animals.

What are some other kingdoms?

When people think of living things, they often think of animals. However, the other kingdoms include fascinating organisms that are vital to life on Earth.

Plants

Plants use sunlight to make their own food. Most plants have roots that anchor them in the ground and absorb water and nutrients. There are over 260,000 species in the plant kingdom, organized into divisions. (The term *phylum* is not used for plants.) The first division of plants is based on the presence or absence of *vascular tissue*, veins or tubes in roots, stems, and leaves. Plants that have them are called **vascular** plants, and plants that do not have them are called **nonvascular** plants. Nonvascular plants do not grow very tall, because they are unable to transport nutrients up to their top structures or carry wastes back down.

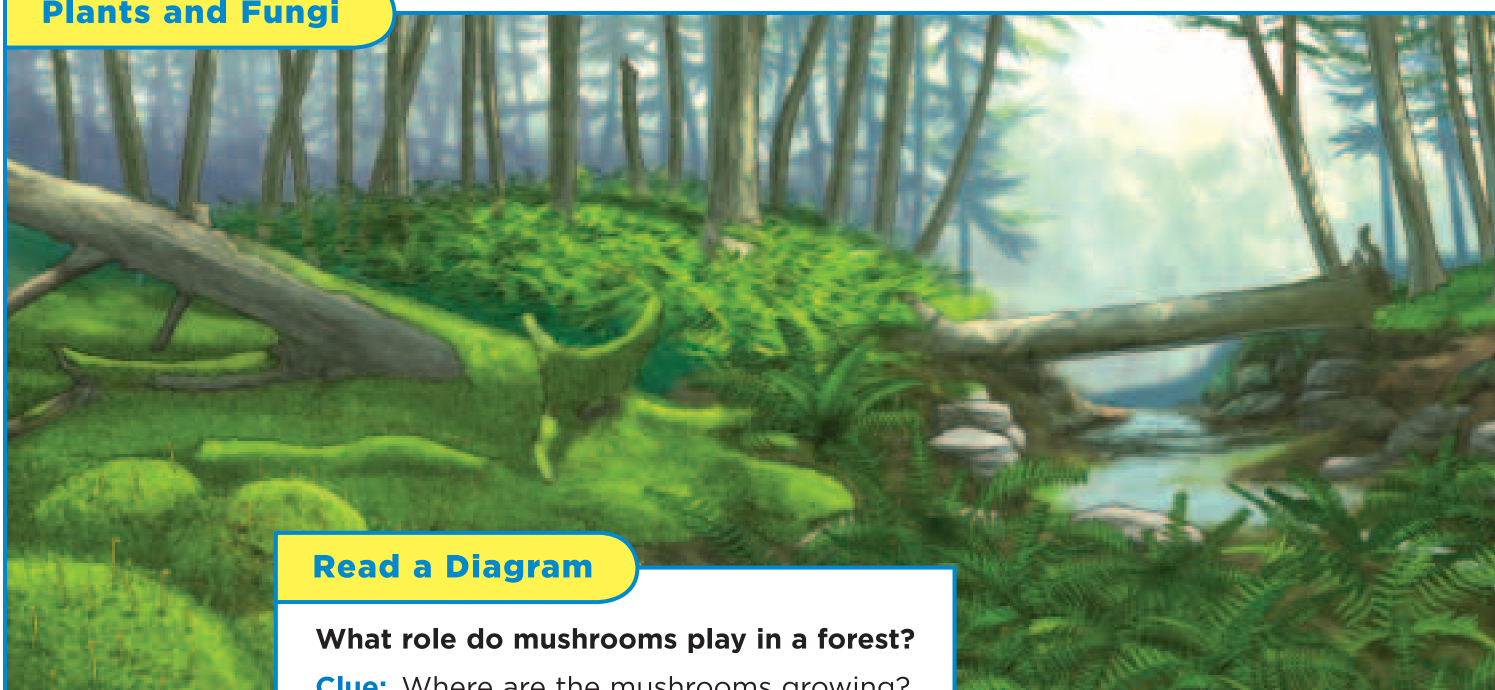
Vascular plants are further classified by how they reproduce. Flowering plants reproduce by seeds that develop inside a protective organ called an *ovary*. The ovary forms fruits or seed pods. Another group of plants produces seeds that are carried in cones rather than in pods or fruits.

Fungi

Fungi (singular, *fungus*) include organisms such as yeast, mushrooms, and molds. Some members of the fungi kingdom cause diseases, but others play a vital role in the environment by breaking down dead organisms. These natural recyclers return useful materials to the soil, where these materials can then be used by other living things.

One important fungus is *Penicillium notatum*. This fungus species makes penicillin, an antibiotic that can save lives by killing many types of bacteria.

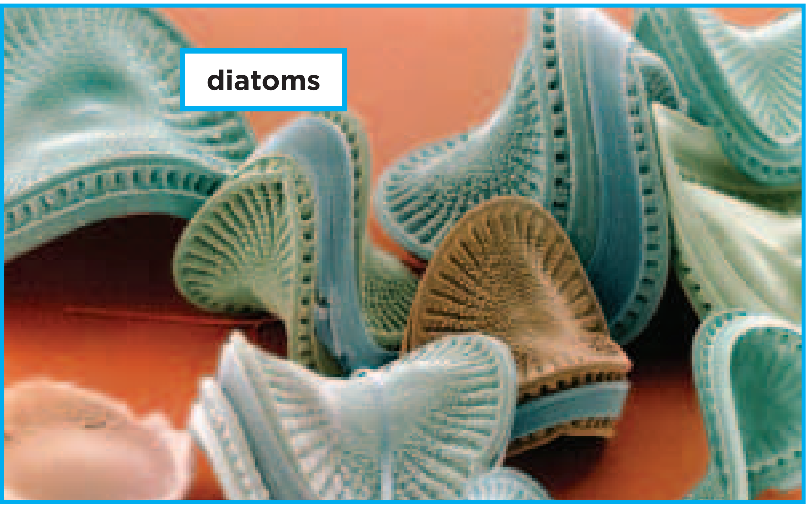
Plants and Fungi



Read a Diagram

What role do mushrooms play in a forest?

Clue: Where are the mushrooms growing?



Protists

The protist kingdom contains some organisms that resemble plants and others that resemble animals. This kingdom includes mostly unicellular microbes, or microscopic organisms, as well as some multicellular organisms. Plantlike protists make their own food, and animal-like protists obtain food from the environment. Diatoms, which are unicellular plantlike protists, are often yellow-brown instead of the characteristic green of other organisms that make their own food.

Quick Lab

Measuring Protists

1. **Measure** Slide a thin, transparent metric ruler onto the stage of your microscope. Focus on it under low power. Measure and record the field of view in millimeters.
2. Obtain a water sample from your teacher. Put 1 drop of the water in the center of a microscope slide. Gently place a coverslip over it.
3. **Observe** Using low power, focus the microscope until you find a protist. Draw what you see.
4. **Use Numbers** Estimate the fraction of the field of view that the protist takes up. Multiply that fraction by the size of your field of view to estimate the length of the organism in millimeters. For example, if the field of view is 10 mm in diameter and the microbe takes up one fourth of the field of view, then $10 \text{ mm} \times 0.25 = 2.5 \text{ mm}$.

Quick Check

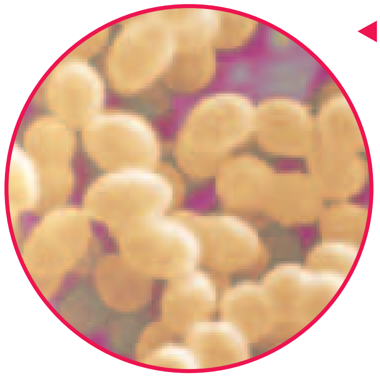
Classify What features distinguish each of these kingdoms: plants, fungi, and protists?

Critical Thinking How are fungi and protists similar to plants and animals? How are they different?

What are bacteria and viruses?

Bacteria are divided into two kingdoms: eubacteria and archaebacteria. Eubacteria, or "true bacteria," can live almost anywhere, including soil, air, water, and even your own body. Archaebacteria, or "ancient bacteria," live in extreme conditions such as hot springs, volcanic vents on the ocean floor, and very salty environments. Some archaebacteria are classified by where they are found. Eubacteria are classified by their shapes, such as rods, spheres, or spirals. They are often found growing together. For example, sphere-shaped eubacteria may grow in clusters or in long chains.

Viruses are not alive. They are not made of cells and do not have a source of energy. A *virus* is a set of instructions that takes over and controls a cell of another organism. Cells invaded by viruses are called host cells. Once inside a host cell, a virus instructs the cell to reproduce copies of the virus. Then, the cell bursts open and releases the viruses. Each new virus can then take over a new host cell. Host cells can make up to 10 billion copies of the virus in a single day. Think about what it would be like if a virus were the size of a penny. In one day, 10 billion penny-sized viruses would cover a football field to a depth of more than 1 meters (3 feet).

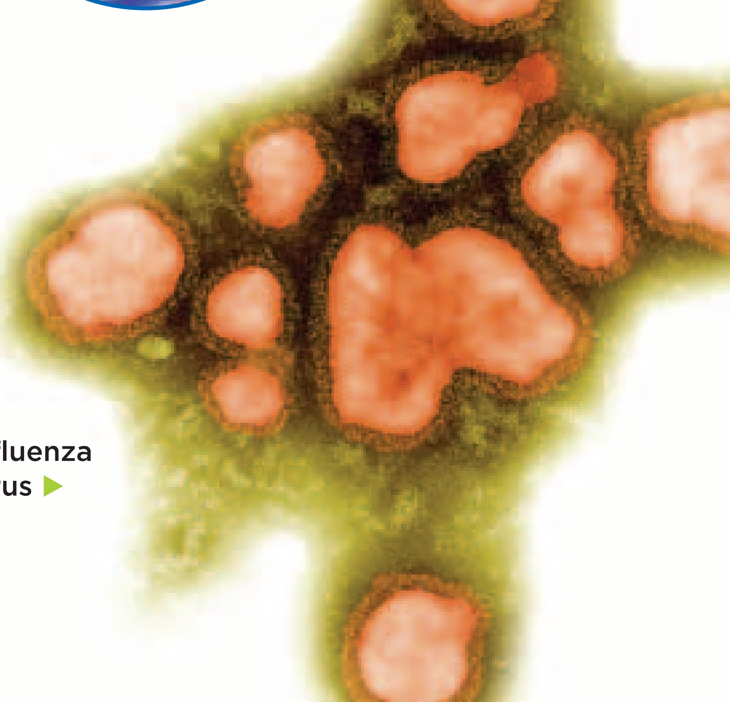


◀ Sphere-shaped eubacteria are called cocci.

Spiral-shaped eubacteria are called spirilla. ▶

◀ Rod-shaped eubacteria are called bacilli.

influenza virus ▶



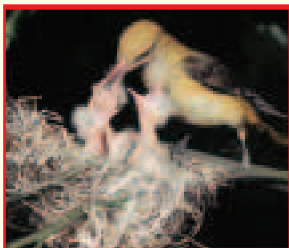
Quick Check

Classify How are eubacteria and archaebacteria classified?

Critical Thinking If viruses can reproduce inside host cells, why are they not considered living things?

Lesson Review

Visual Summary



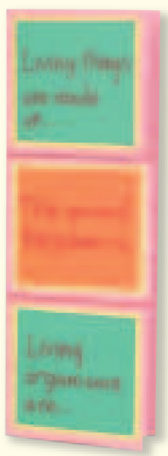
Living **organisms** are made of cells, grow and develop, obtain and use energy, reproduce, and respond to the environment.

The animal **kingdom** is divided into phyla, classes, orders, families, genuses, and species.

Vascular plants have veins or tubes in their roots, stems, and leaves, and **nonvascular** plants do not have veins or tubes.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide supporting details.



Think, Talk, and Write

1. **Main Idea** How are living things classified?
2. **Vocabulary** A group of similar organisms that reproduce more of their own kind is a(n) ________.
3. **Classify** An organism is shaped like a plant, does not move, and cannot make its own food. How might you classify it?

4. **Critical Thinking** How have advances in technology affected the classification of living things?
5. **Test Prep** **If you observed a very tall tree growing in a forest, how might you BEST describe it?**
   - **A** nonvascular
   - **B** unicellular
   - **C** vascular
   - **D** herbaceous
6. **Test Prep** **Unicellular organisms living in hot springs could be classified as**
   - **A** eubacteria.
   - **B** protists.
   - **C** bacilli.
   - **D** archaebacteria

Writing Link

Explanatory Writing

Write a paragraph explaining why the Linnaeus system of classification is useful. Remember to include a strong topic sentence and supporting details.

Music Link

Organize Music

Your job is to organize a CD library for a radio station, so that each CD is easy to locate. Make a diagram of how you would classify and label each CD.

LOG ON e-Review Summaries and quizzes online at www.macmillanmh.com

Focus on Skills

Inquiry Skill: Classify

When scientists **classify**, they place things that share characteristics in groups. In order to do that, scientists need to compare and contrast things to find out what characteristics they share. Remember, to compare you look for how things are alike. To contrast you look for how they are different.

palmate leaf

▶ Learn It

Classifying is a useful tool for organizing and analyzing things. When you **classify**, you can learn about characteristics of millions of things without actually having to learn about each one. For example, you may not know all the different kinds of bicycles there are in the world, but you know that all bicycles have two wheels.

It is a good idea to keep notes of the criteria, or rules, you use to classify things. An example of a criterion is the number of wheels something has. If you decide to classify things by the number of wheels they have, then cars, pickup trucks, and carts would be in the group of things that have four wheels. Motorcycles and bicycles would be together in the group of things that have two wheels. Your notes can help you figure out how to classify other things if you want to add to your classification.

You can classify leaves by their shapes and edges. Here are some examples of different types of leaves.

smooth leaf

lobed leaf

toothed leaf

pinnate leaf

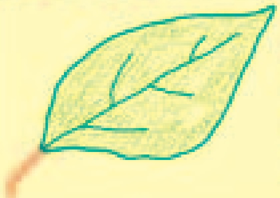
Try It

1. Find ten leaves of different kinds, shapes, and sizes.
2. Examine each of your ten leaves, one at a time.
3. Draw your leaves on a chart similar to the one below.
4. Write a description of each leaf next to its picture.
5. **Classify** your leaves according to the type of edge each has. As a guideline, use the leaves shown. Record the type of edge on your chart.

Apply It

1. Now that you know how to classify objects, look around you for more things to classify.
2. Think of things you see every day, such as plants, rocks, or animals. What similarities and differences do you see among them?
3. Keep a list of each of those things that you see, and **classify** them by size, shape, color, or any other characteristic they have in common. Share your findings with the class.

Leaf Classification

Leaf	What It Looks Like	Description	Classification
1.		veins smooth edges	smooth
2.			

Lesson 2

Plants

Look and Wonder

Like other organisms, plants need food to survive. Where do plants such as this orchid get their food? How do they get their energy?

Explore

Inquiry Activity

How does light affect plants?

Form a Hypothesis

Plants need light to grow. What do you think will happen to a plant's leaves if you cover parts of them so that no light reaches those parts? Write your answer in the form of a hypothesis: "If parts of a plant's leaves do not receive any light, then . . ."

Test Your Hypothesis

1. Wrap small pieces of aluminum foil over parts of several leaves of a growing plant. Secure the foil with paper clips. Wash your hands after handling the plant.
2. **Use Variables** Cover at least four different leaves of the plant in the same way.
3. Place the plant in a window where it will have lots of light. Water the plant as needed.
4. **Experiment** After one day, carefully lift the foil and check each leaf. Write down your observations. Gently replace the foil in the same position. Continue your observations each day for one week, placing the foil back in the same position each time. How do the areas covered by the foil differ from the other parts of the leaves?

Draw Conclusions

5. **Interpret Data** What changes did you observe after 1 day? After 2 days? After 1 week? How do light and darkness seem to affect the growth of leaves?

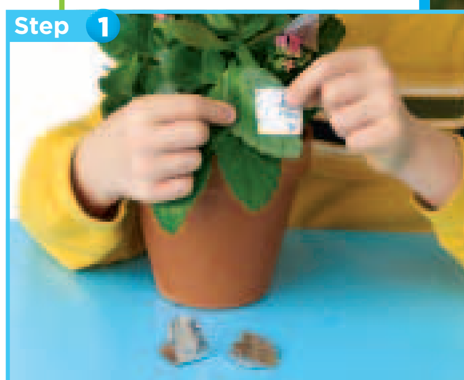
Explore More

What will happen if the leaves are no longer covered? Remove the foil from the leaves, and continue to water and observe the plant for another week. Share your findings with the rest of your class.

Materials

- aluminum foil
- growing plant (a large-leafed plant will work best)
- paper clips
- water

Step 1



Step 3

Read and Learn

Main Idea

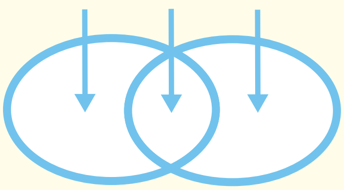
Plants have structures that carry out specific functions. They use sunlight to make their own food.

Vocabulary

stem, p. 34
root, p. 35
photosynthesis, p. 37
reproduction, p. 38
seed, p. 38
sperm, p. 38
egg, p. 38
pollination, p. 38

Reading Skill

Compare and Contrast



Technology

SCIENCE QUEST

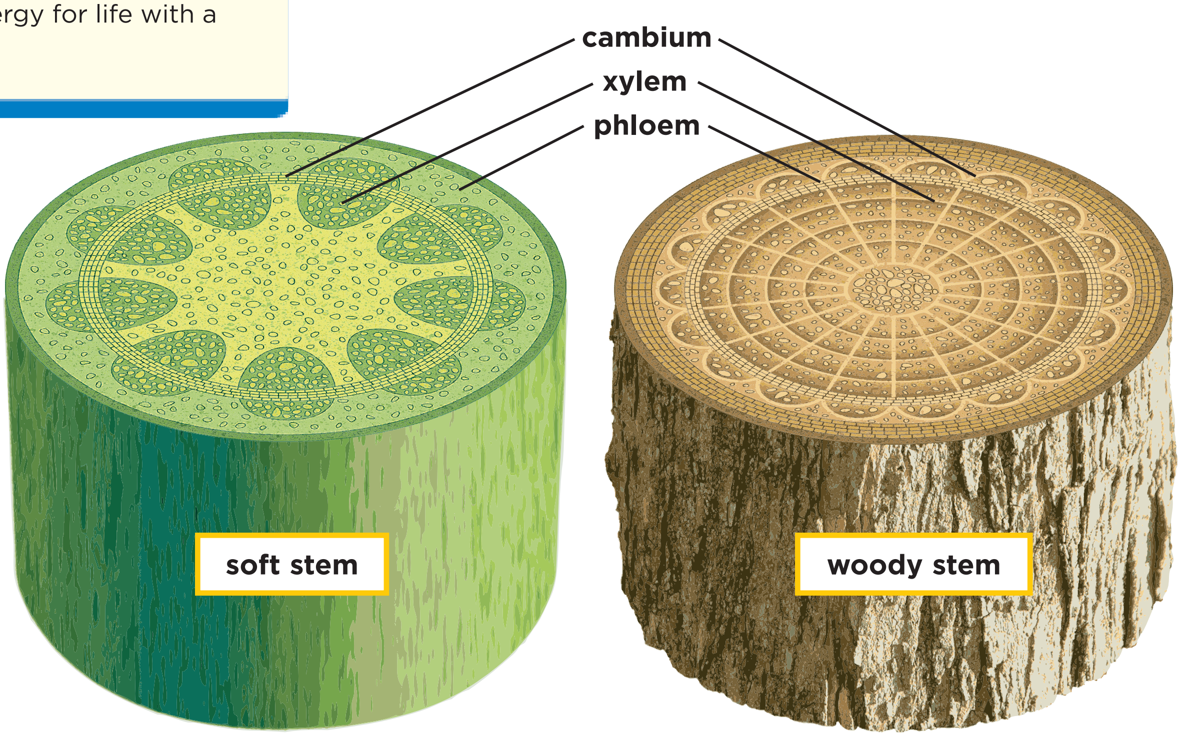
Explore energy for life with a farmer.

What are roots and stems for?

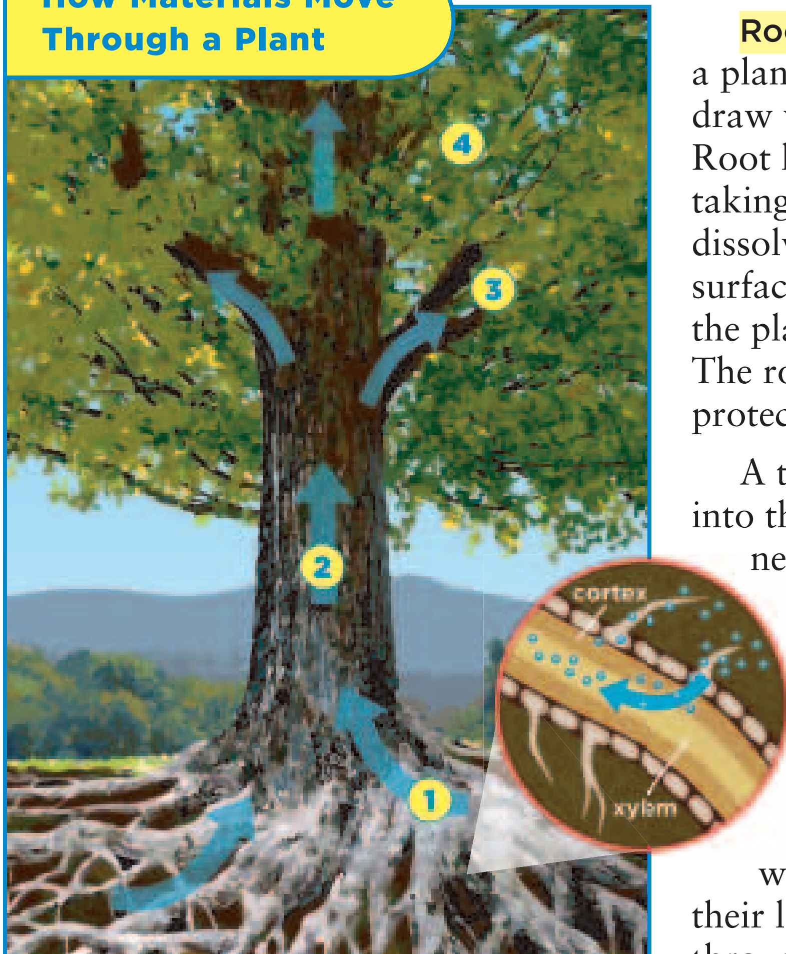
Think about the water supply in a tall apartment building. The water comes in at the basement level and flows through pipes to every floor. Water moves through vascular plants in a similar way. Vascular plants draw water from the soil into their roots and up through their stems to their top branches. They use a system of "pipes" called xylem (ZIGH•luhm) to move water and minerals from the soil upward. The "pipes" that move food back down through plants are called phloem (FLOH•em). The xylem and phloem are separated by a layer of cells called the cambium (CAM•bee•uhm). The layer of tissue just beneath the surface of a plant's roots and stems is the cortex.

Stems are structures that hold a plant up and support its leaves. Some stems, such as those of many flowers, are soft stems. Woody stems are tough and strong, with protective bark. Some plants, such as sugar cane, store food in their stems. Other plants, such as cactuses, use their stems to store water.

Parts of a Stem



How Materials Move Through a Plant



1 Water and minerals from the soil enter root hairs, pass through the cortex, and then enter the xylem.

2 Transpiration draws water and minerals up the stem and into the leaves.

3 The materials enter the leaves and are carried to each leaf cell.

4 Leaf cells use the water, along with carbon dioxide from the air, to make sugars.

Read a Diagram

How does water travel from a plant's roots to its stem?

Clue: Follow the path of the blue arrows.

LOG ON *Science in Motion* Watch how plants transport water at **www.macmillanmh.com**

Roots

Roots are plant parts that anchor a plant in the ground, store food, and draw water and nutrients from the soil. Root hairs are designed for absorption, taking up most of the water and dissolved minerals. They increase the surface area of the root, allowing the plant to absorb greater quantities. The root cap, a tough layer of cells, protects the tip of each root.

A taproot is a root that grows deep into the ground. Fibrous roots grow near the surface of the soil. They collect water and can form huge networks.

As roots absorb water, pressure pushes water through the stem and toward the leaves. In transpiration, plants release water into the atmosphere through their leaves. As a plant loses water through transpiration, water enters the xylem from the roots.

Quick Check

Compare and Contrast How do roots and stems help move water and nutrients through a plant?

Critical Thinking Daffodils have soft stems, and oak trees have woody stems. What do these two stems have in common?

How do leaves function?

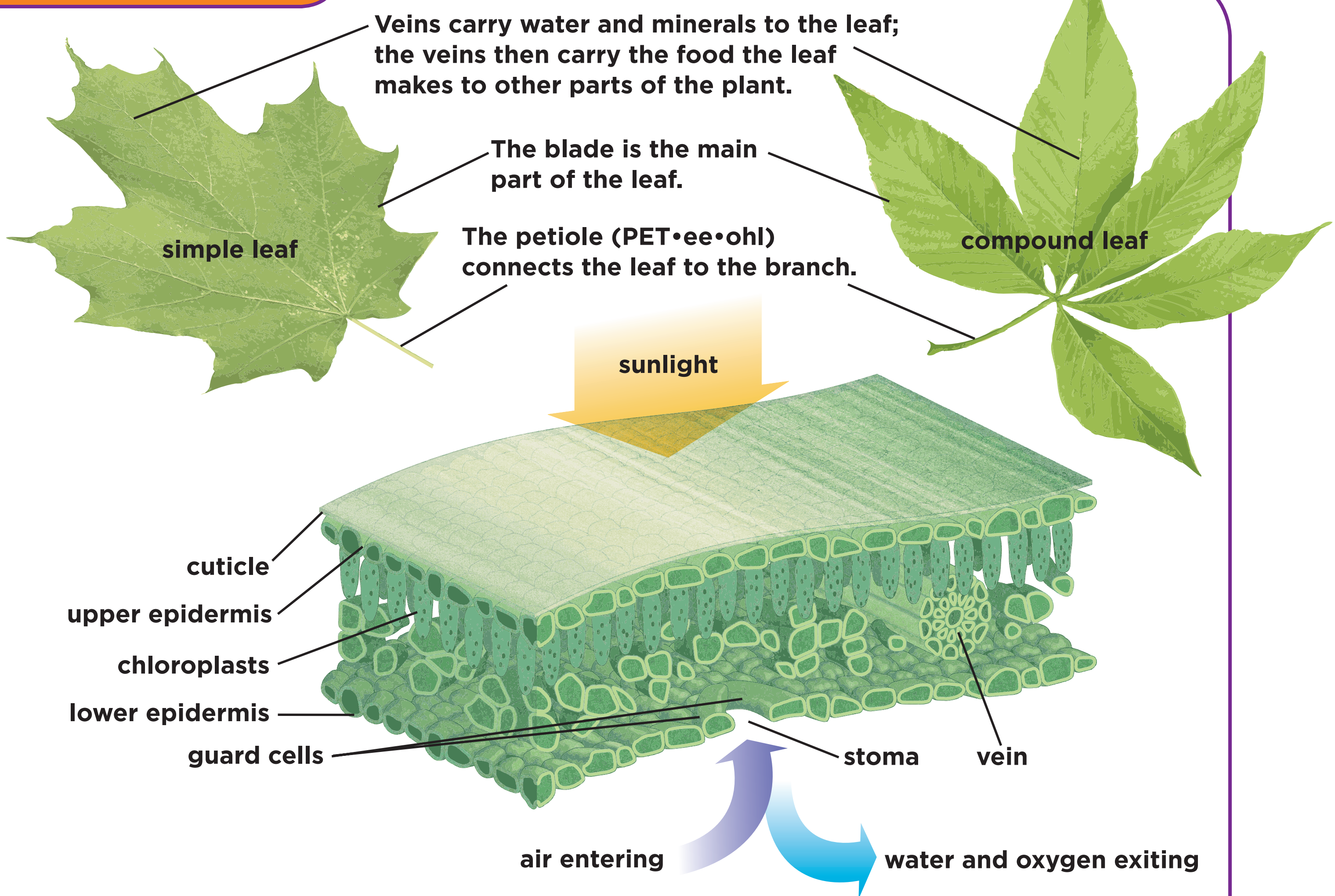
There are many shapes and sizes of leaves. Maple and oak trees have single leaves, or simple leaves. Some plants, such as horse-chestnut and locust trees, have leaves that grow in clusters. These are compound leaves. Other plants have leaves shaped like needles or spines.

The outermost layer of a leaf is the epidermis. It is covered by a waxy coating called the cuticle. On plants that stay green year-round, such as pine trees, the cuticle prevents the leaves or needles from losing too much water, especially during cold or dry weather.

The epidermis on the lower surface of a leaf contains tiny pores called stomata (STOH•muh•tuh) (singular, *stoma*). Guard cells that surround the stomata control the amount of air entering the plant and the amount of water exiting the plant. When the plant has plenty of water, the guard cells swell and pull the stomata open. The stomata close when the temperature is high, in order to minimize water loss.

Plants can lose large amounts of water through transpiration. Almost 99 percent of the water that enters a plant through its roots is given off into the air through transpiration.

Parts of a Leaf



Photosynthesis

Many plants have leaves with broad, flat surfaces that capture sunlight. Plants use sunlight to make their own food in a process called **photosynthesis** (foh•tuh•SIN•thuh•sis). Photosynthesis occurs within the leaves of the plant. In addition to sunlight, plants also use water, minerals, and carbon dioxide. The roots and stems of plants take in water and minerals. Plants obtain carbon dioxide from the air through their stomata.

Photosynthesis occurs in structures called chloroplasts, which are found mainly in plant cells. Chloroplasts use carbon dioxide, water, and solar energy to produce food in the form of glucose. Oxygen is also produced as a waste product of photosynthesis, and it is released into the atmosphere by the plant.

Some of the glucose produced by plants remains in the plants' leaves. However, most of the glucose is transported through the phloem to the stems and roots, where it is stored. When animals eat plants, this stored energy is then available to them.

Quick Check

Compare and Contrast How are simple and compound leaves alike? How are they different?

Critical Thinking How would transpiration differ in plants growing in areas of abundant rain compared to plants in areas of scarce rain?

Quick Lab

Leaves

1. Collect a variety of leaves.
2. **Observe** Examine each leaf with a hand lens, and write down each structure that you can identify.
3. Place a thin piece of white paper over the leaf, and rub back and forth with a crayon, making a print or rubbing of the leaf.
4. **Classify** On the rubbing identify the leaf as simple or compound, and label each structure.
5. Using two colors of crayons, trace the flow of water and food through the veins.

How do plants reproduce?

All living things carry out **reproduction**, which is the production of more individuals of the same species. Reproduction occurs in several ways. *Sexual reproduction* (SEK•shew•uhl ree•pruh•DUK•shuhn) is the production of a new organism by the union of male and female sex cells. *Asexual* (ay•SEK•shew•uhl) *reproduction* is the production of a new organism using only one type of cell. Some organisms use both types of reproduction.

Plants With Seeds

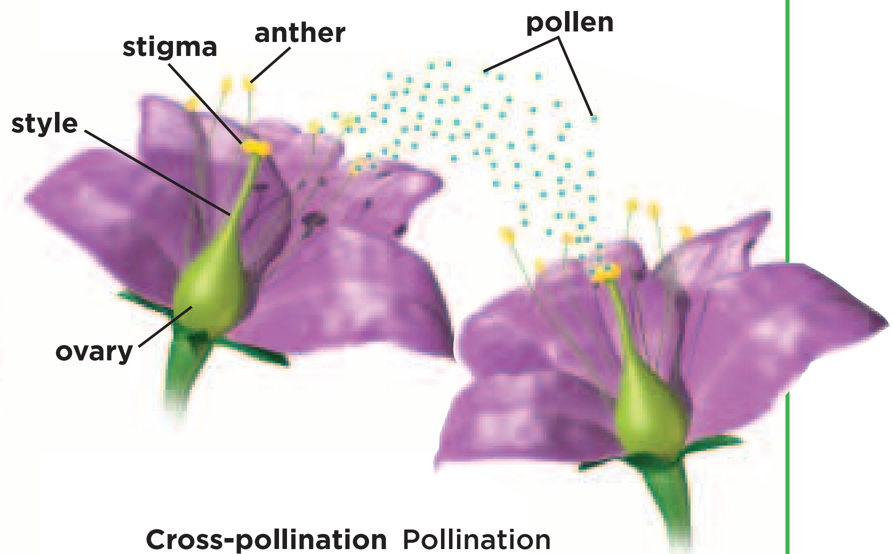
A **seed** is a structure that contains a young, developing plant and stored food. Under the right conditions, the seed will grow into a new plant. Where does a seed come from? Follow the diagrams on these pages to understand the entire process.

Seed plants reproduce by sexual reproduction. The male sex cell, the **sperm**, must unite with the female sex cell, the **egg**. Sperm cells are located within pollen grains. Pollen grains are produced in the anther of a flower. Eggs are located in the flower's ovary. The ovary is located at the bottom of the stigma. The transfer of pollen from an anther to a stigma is called **pollination**. The result of this transfer is the union of male sex cells and female sex cells.

Self-pollination occurs when pollen is transferred from an anther to a stigma on the same flower. Cross-pollination happens when pollen is transferred from the anther of one flower to the stigma of another flower. Organisms that transfer pollen from flower to flower—such as birds and insects—are called *pollinators*.

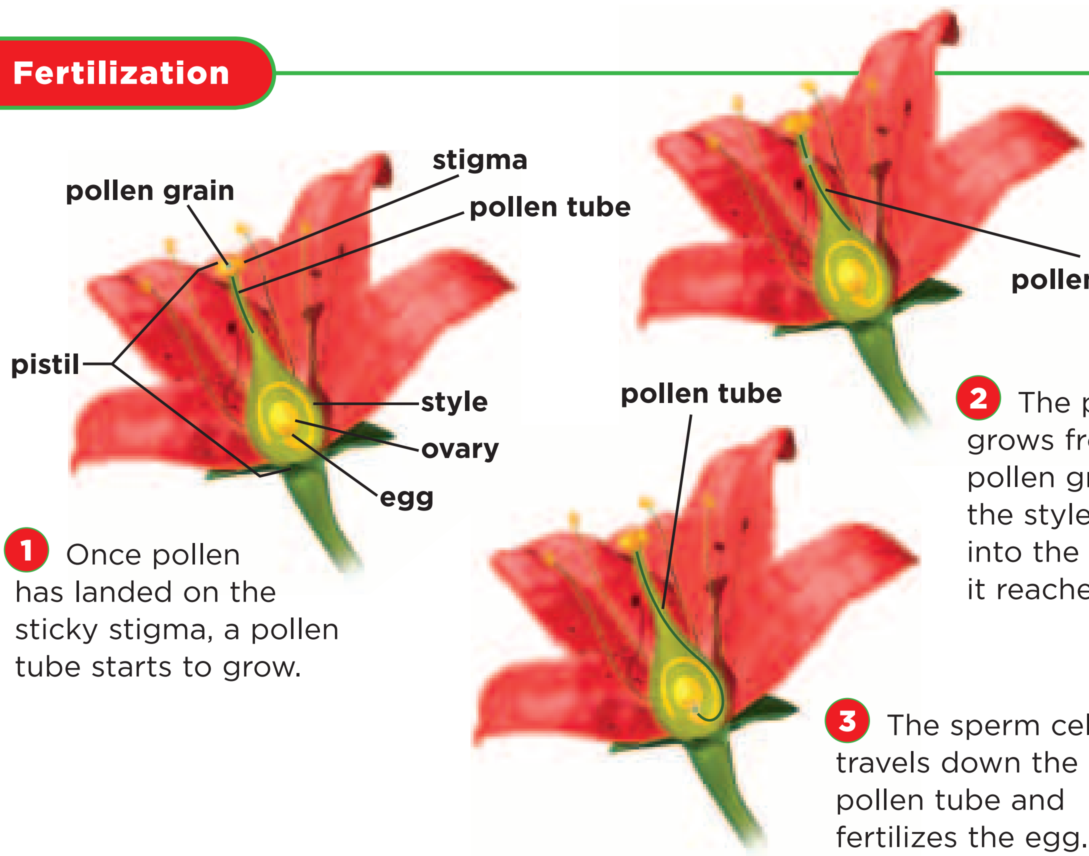
Pollination

Self-pollination Pollination occurs when pollen from an anther reaches the stigma. This flower is pollinating itself, because its pollen is reaching its own stigma.



Cross-pollination Pollination can occur between two or more flowers on separate plants. Here the pollen of one flower reaches the stigma of another.

Fertilization



Once pollen has landed on the stigma, a tube grows from it. The pollen then travels down the pollen tube into the flower's ovary, where the egg is located. At this point, the sperm cell joins with the egg. This joining is called *fertilization*. A seed develops from the fertilized egg.

If seeds always stayed near their parent plants, the competition for food, water, and sunlight would be great. Young plants have a greater chance for survival if they grow away from their parent plants. Seed dispersal is the spreading out of seeds away from their source. Seeds might blow away, or they might attach to animals' fur and then fall off in a distant location. An animal might eat seeds, pass them through its digestive system, and then deposit the seeds far from their parent plants.

Plants Without Seeds

Some plants are seedless. These plants grow from spores instead of seeds. *Spores* are cells that can develop into new organisms. Unlike seeds, spores do not contain food for the young, developing plants. These tiny structures are produced within spore capsules. Nonvascular plants, such as mosses and liverworts, reproduce from spores. Some vascular plants also use spores to reproduce.

Quick Check

Compare and Contrast How are asexual reproduction and sexual reproduction different in plants?

Critical Thinking What would happen to some flowering plants if there were suddenly no pollinators?

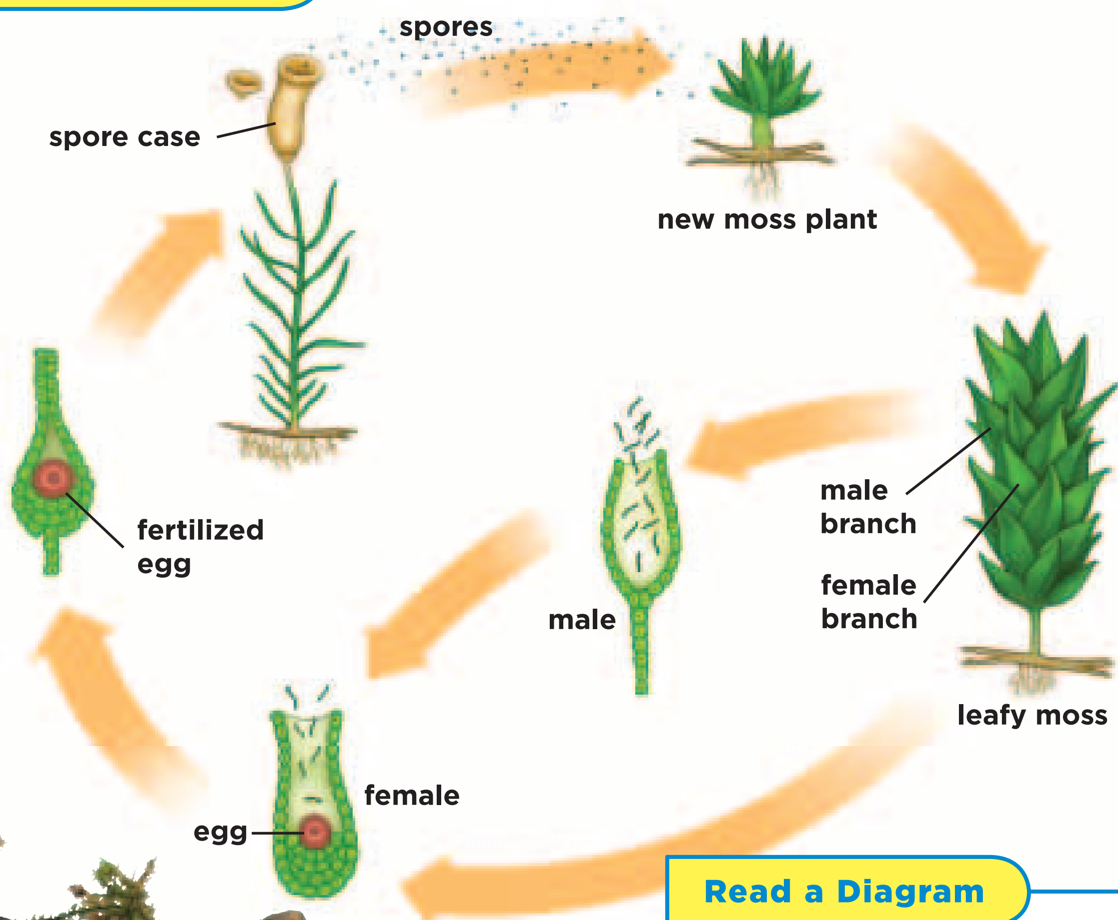
What are some plant life cycles?

Mosses and ferns are seedless plants. They use spores to reproduce. Mosses do not have true roots. However, they stay anchored in one place because they have hairlike fibers that play a role similar to that of roots. These fibers, called *rhizoids* (RIGH•zoydz), can also take in water from their surroundings. The water then travels from one cell in the plant to the next.

The life cycles of mosses and ferns have two separate stages. During one stage, asexual reproduction, the plant produces spores. The plant needs only one type of cell—the spore—to reproduce.

The other stage in the cycle is sexual reproduction. In this stage the plant needs both male sex cells and female sex cells in order to reproduce. The process of going from asexual reproduction to sexual reproduction is called *alternation of generations*.

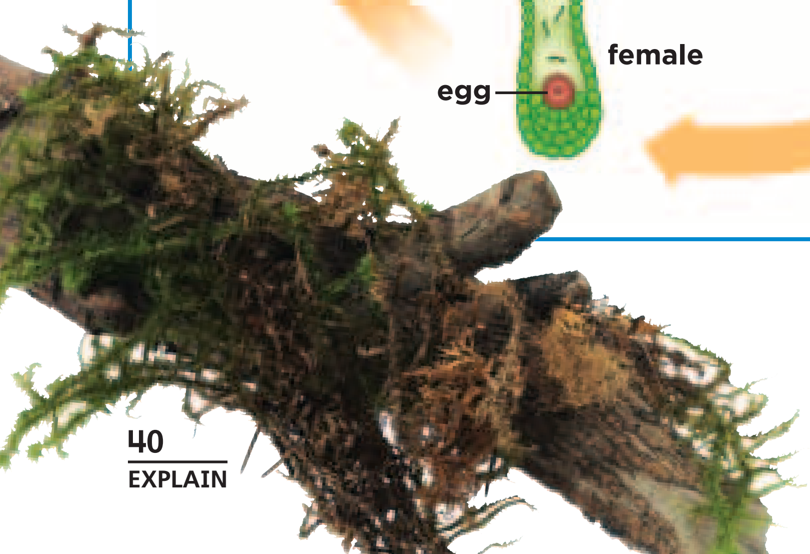
Life Cycle of a Moss



Read a Diagram

Where could you find spores on the plants on this mossy log?

Clue: Find the place from which spores are scattered.



▲ cones from a bristlecone pine

How Seed Plants Differ

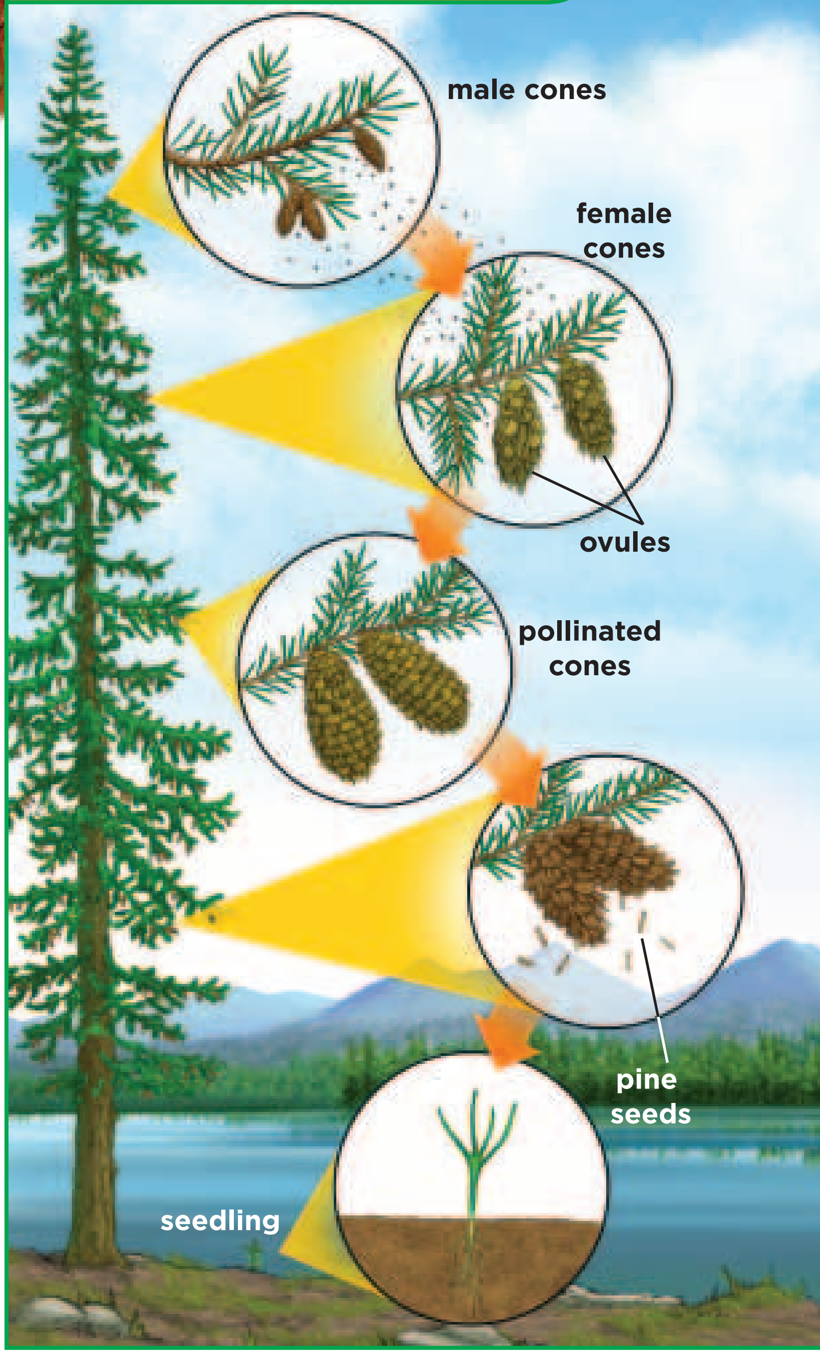
Angiosperms (AN•jee•uh•spurmz) and gymnosperms (JIM•nuh•spurmz) are two types of vascular seed plants. Angiosperms reproduce using flowers, but gymnosperms do not. Instead, the seeds of gymnosperms are produced in cones, such as those on pine trees.

Gymnosperms are the oldest seed plants. During the time when dinosaurs roamed Earth, gymnosperms were the dominant land plants. They first appeared on Earth about 250 million years ago. The first angiosperms did not appear until about 100 million years later.

Some gymnosperms are quite small, but others develop into large trees. In fact, gymnosperms make up most of the forests that are located at northern latitudes in Europe and North America.

The fruits, vegetables, grains, and most of the nuts that you eat are produced by angiosperms. However, one tasty nut—the pine nut, or pignoli—is a gymnosperm seed that is produced by certain pine trees.

Life Cycle of a Gymnosperm



Quick Check

Compare and Contrast How do the life cycles of mosses and gymnosperms differ?

Critical Thinking Why is the production of spores an example of asexual reproduction?

FACT Some bristlecone pines can live more than 5,000 years.

Produce markets sell many different types of fruits and vegetables.

How do plants store food?

The next time you shop for food, observe the produce section. All fruits and vegetables come from plants that capture energy from the Sun and store it as food.

Sweet potatoes, beets, parsnips, and carrots all come from plants that store food in their roots. Potatoes, sugar, and ginger all come from plants that store food in their stems. When people drink a cup of tea or eat vegetables such as spinach, cabbage, lettuce, and oregano, they are using plant leaves for food. Cauliflower and broccoli are flowers that are commonly eaten.

Seeds people eat include beans, corn, rice, peanuts, and even chocolate. Plant seeds are usually very nutritious, because they contain both the developing plant and its stored food.

▼ Both the seeds and the fruit of the pumpkin plant are nutritious.

Quick Check

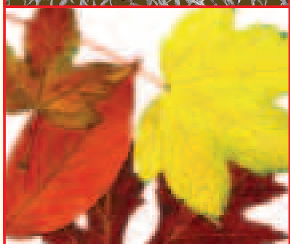
Compare and Contrast How do carrot plants and spinach plants store food differently?

Critical Thinking Why are plants important as a food source for so many organisms?

Lesson Review

Visual Summary

Roots anchor plants and absorb water and nutrients from the soil. **Stems** support plants and transport water and nutrients.



Leaves capture the energy of the Sun and produce food through **photosynthesis**.

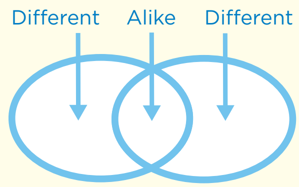
Plants carry out **reproduction** in several ways. Some plants produce seeds that each contain a developing plant.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the statements shown. Add details for each plant structure or process.

Think, Talk, and Write

1. **Main Idea** Plants carry out specific functions by means of various ________.
2. **Vocabulary** What structure holds a plant up and supports its leaves?
3. **Compare and Contrast** Compare the way that plants obtain food to the ways that animals obtain food.



4. **Critical Thinking** How does the life cycle of a flowering plant differ from the life cycle of a moss?
5. **Test Prep** **A bee's role in the reproduction of angiosperms is that of**
   - **A** honey maker.
   - **B** producer.
   - **C** seed disperser.
   - **D** pollinator.
6. **Test Prep** **Plant cells that can develop into new organisms are called**
   - **A** nonvascular plants.
   - **B** self-pollinators.
   - **C** angiosperms.
   - **D** spores.

Writing Link

Writing a Story
What if photosynthesis occurred in a factory instead of a leaf? Write a short story describing how your factory would work. How would food be packaged, stored, and shipped?

Art Link

Transportation Diagrams
Draw two diagrams to compare the transportation system in a vascular plant to the transportation system in your body. Compare how water, nutrients, and waste are transported.

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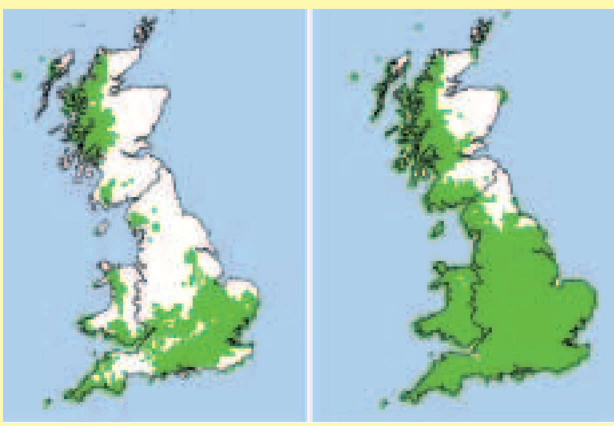
Meet Richard Pearson

What happens to plants when climates and environments change? Plants are well suited to the places in which they live. For example, in the hot, dry desert, cactuses store the scarce water in their stems. In the tropical rain forest, some leaves have special features called drip tips, which shed rainfall quickly and prevent fungi and bacteria from growing.

Climate changes can affect where plants grow. Richard Pearson is a scientist at the American Museum of Natural History. He studies how plants, over thousands of years, migrate or move to new places as rainfall and temperatures gradually change.

Richard Pearson is a biologist. (That's a scientist who studies living organisms.)

White Beaksedge Growth in Great Britain



The first map shows where *Rhynchospora alba* grows today. The second map estimates how it will spread in 50 years as a result of currently projected changes in climate.

Most plants are firmly rooted in the ground, so they can't pick up and move. To relocate, they send their seeds out by a process called seed dispersal. This is an important way in which plant species adapt to climate change. Seeds are dispersed in many ways.

Some plants, such as dandelions, rely on wind to disperse their seeds. Each white, fluffy dandelion thread has a small seed at the end. When the wind blows, it carries the threads like tiny parachutes to a new location—sometimes carrying them a great distance.

When coconuts fall from palm trees, they may roll down the beach to the water. Since coconuts float, ocean currents may then carry them thousands of kilometers away. ▶

Seeds that stick to an animal's fur, feathers, or claws may also travel long distances before dropping off and taking root. Birds eat fruit often, and they may fly far away before excreting the seeds.

In order to take root, seeds need to land in a place with the right soil and the right amounts of water and sunshine. As the climate warms, conditions may become less suitable, and new locations may become more favorable. For example, seeds that land higher up a mountain, where temperatures are cooler, may be more likely to survive.

What effect might people's land use have on seed dispersal? Richard develops computer models to make predictions about how plants might migrate. He looks at the way plants progress over flat, continuous landscapes such as prairies, and he compares it to the way they move across land broken up by highways, railroads, farms, or cities. Richard is looking at how these patterns of land use, coupled with rising global temperatures, might affect plant migration.

Write About It

Classify

1. What types of plants survive well in a desert environment?
2. What main categories of seed dispersal are addressed here?

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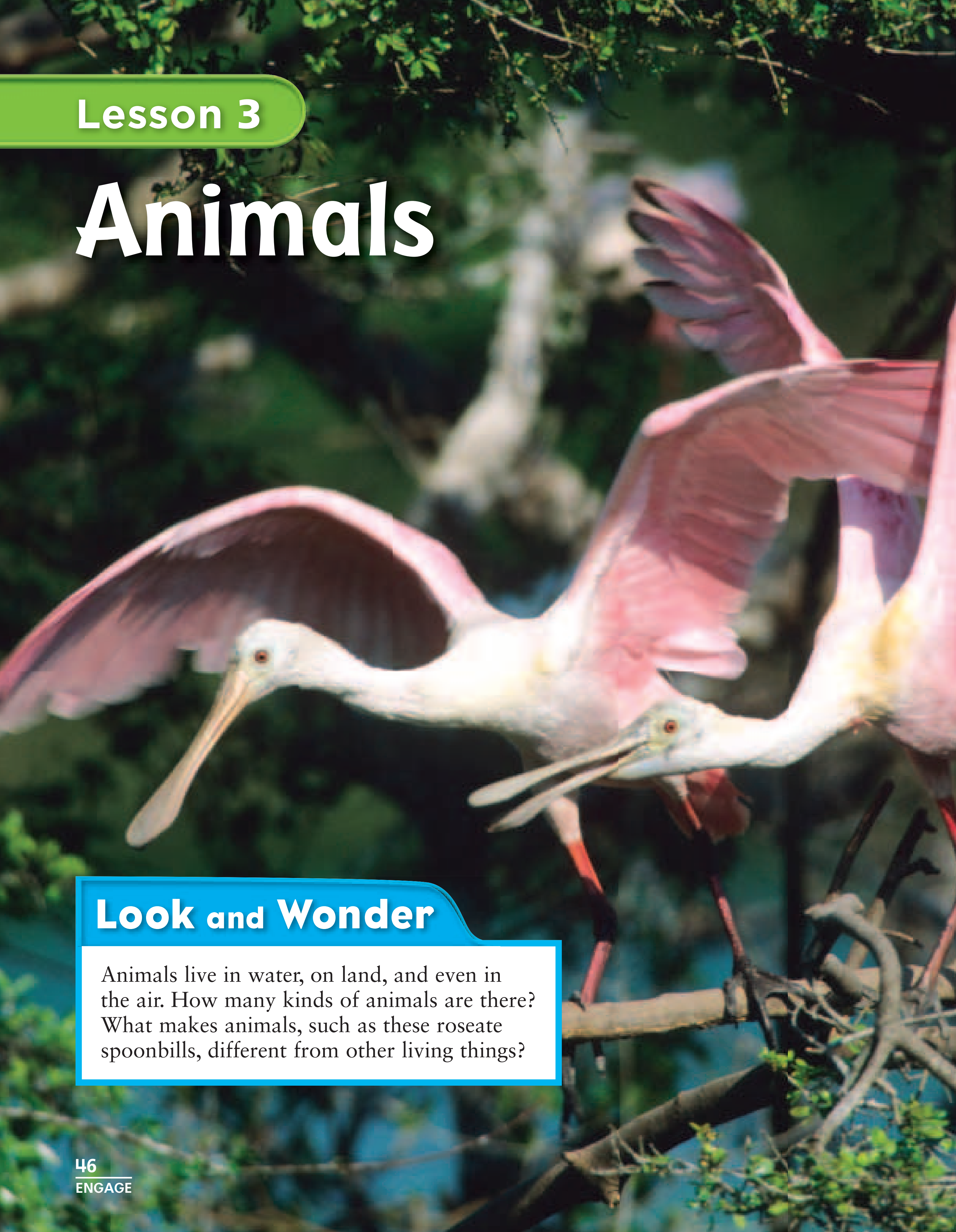
Classify

- ▶ Think about how items are grouped into categories.
- ▶ Consider which items belong together.

AMERICAN MUSEUM of NATURAL HISTORY



Lesson 3

Animals

Look and Wonder

Animals live in water, on land, and even in the air. How many kinds of animals are there? What makes animals, such as these roseate spoonbills, different from other living things?

Explore

Inquiry Activity

What are some characteristics of animals?

Purpose

What characteristics do you think animals have? Observe brine shrimp, and decide whether they have characteristics of animals.

Procedure

1. Pour water into your bowl. Add baking soda and salt according to package directions, and stir until dissolved. Then add the contents of the brine-shrimp package. Place the bowl in a warm area, in front of a sunny window. Allow it to sit for 12–24 hours. Then add a drop of baker's yeast, mixed with a small amount of water. What do you think the yeast is for?
2. **Observe** Using a hand lens, watch the brine shrimp carefully. Draw what you see, and write down any behaviors you notice. Do the brine shrimp have characteristics of animals?
3. **Measure** Look at the millimeter marks on your ruler, and then estimate the length of an average-sized brine shrimp.
4. **Communicate** Record your observations, and compare your results to those of your classmates. Make a poster that shows and explains your observations.

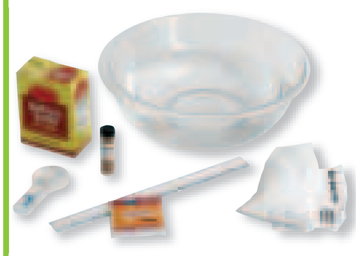
Draw Conclusions

5. **Interpret Data** What characteristics do animals display? Make changes to your original ideas based on your observations.

Explore More

Continue observations over the next few days. Have there been any changes? How should brine shrimp be classified? What kind of water environment do they require? Where do they fit in a food chain?

Materials



- water
- clear bowl
- baking soda
- sea salt
- package of brine shrimp
- baker's yeast
- hand lens
- metric ruler
- research books (optional)

Step 1

Step 2

Read and Learn

Main Idea

Animals are classified according to whether or not they have backbones.

Vocabulary

vertebrate, p. 48
chordate, p. 49
endoskeleton, p. 49
cartilage, p. 49
tetrapod, p. 49
invertebrate, p. 50
exoskeleton, p. 52

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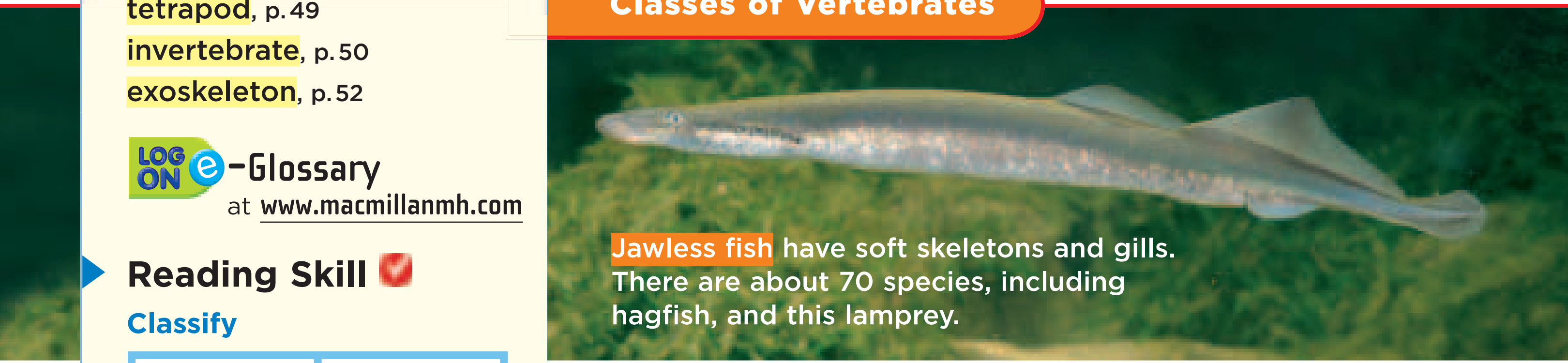
Reading Skill

Classify

What are vertebrates?

Think about visiting a zoo, an aquarium, or a nature museum. Which animal is your favorite? There is a good chance that you chose a vertebrate. A **vertebrate** (VUR•tuh•brayt) is an animal with a segmented backbone. Vertebrates are grouped into seven classes and include the largest animals on land and in the sea.

Classes of Vertebrates



Jawless fish have soft skeletons and gills. There are about 70 species, including hagfish, and this lamprey.

There are about 20,000 species of **bony fish**, including trout, salmon, tuna, goldfish, and this longnose hawkfish. They have hard, bony skeletons and breathe through gills.

Rays, skates, and this silky shark have skeletons made of **cartilage**. They breathe through gills. There are about 750 species of this type of fish.

Classification of Vertebrates

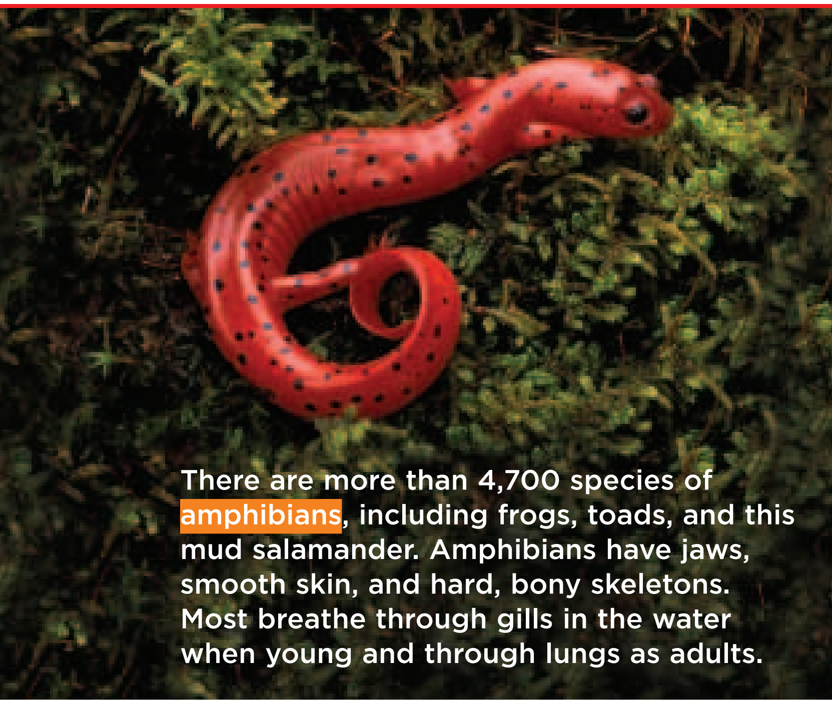
Vertebrates are animals with nerve cords running down their backs and are called **chordates** (KAWR•daytz). A backbone protects the nerve cord. Vertebrates also have **endoskeletons**, or inner skeletons, for protection and movement. An endoskeleton is made of bone and **cartilage** (KAHR•tuh•lij), soft, bonelike material that grows with the animal. Vertebrates include reptiles, amphibians, birds, and mammals.

Some mammals are **tetrapods**, animals with four feet, and others are *bipeds*, animals with two feet. Different types of fish complete the vertebrate classes.

Quick Check

Classify How are vertebrates classified?

Critical Thinking Why might there be many more species of bony fish than of fish with cartilage skeletons?



There are more than 4,700 species of **amphibians**, including frogs, toads, and this mud salamander. Amphibians have jaws, smooth skin, and hard, bony skeletons. Most breathe through gills in the water when young and through lungs as adults.

There are about 8,000 species of **reptiles**, including snakes, turtles, alligators, and this lizard. Some live in water, and some live on land. They have jaws, scales, and hard, bony skeletons. They breathe through lungs.

There are about 9,700 species of **birds**, including sparrows, pigeons, hawks, eagles, and this arctic tern. Birds have jaws, feathers, and hard, bony skeletons, and they breathe through lungs. Most birds can fly.

About 4,600 species of **mammals**, including humans, dogs, horses, and whales, exist on Earth. Mammals, such as these hippopotamuses, have jaws, hair or fur, and hard, bony skeletons. They breathe through lungs and feed their young on mother's milk. Most mammals live on land.

What are invertebrates?

Vertebrates may be the largest animals, but they are not the most common. More than 95 percent of all animals are **invertebrates**, or animals without backbones. Invertebrates live in a wide range of environments—in the desert, at the bottom of the ocean, and even inside other organisms.

Arthropods are the largest group of invertebrates, with more than 1 million species, including insects, spiders, crabs, shrimp, and lobsters.

Flatworms and roundworms live in water, in damp soil, or inside other animals. They have simple structures.

Segmented worms, unlike flatworms and roundworms, have bodies that are divided into compartments. Most segmented worms, including earthworms, live in damp soil. A few, such as leeches, can live in water.

Cnidarians (nigh•DAYR•ee•uhnz) include jellyfish and corals. They have stinging cells that they use to capture fish and other organisms. Hydras and sea anemones are also cnidarians.

Sponges belong to a phylum called Porifera. They come in many different colors. Sponges attach themselves to the ocean floor and filter small food particles from the water.

Marine Invertebrates

Echinoderms (i•KIGH•nuh•durmz) also live in the ocean. They have spiny skins and move very slowly. Sea stars and sea urchins are echinoderms.

Mollusks include clams, snails, oysters, squid, and scallops. Most mollusks live in water, but some, such as snails, live on land.

Quick Check

Classify How are invertebrates classified?

Critical Thinking Which types of invertebrates would most likely be seen in your community? Explain.

Quick Lab

Characteristics of Worms

Be Careful. Handle live animals gently and carefully.

1. Obtain an earthworm from your teacher.

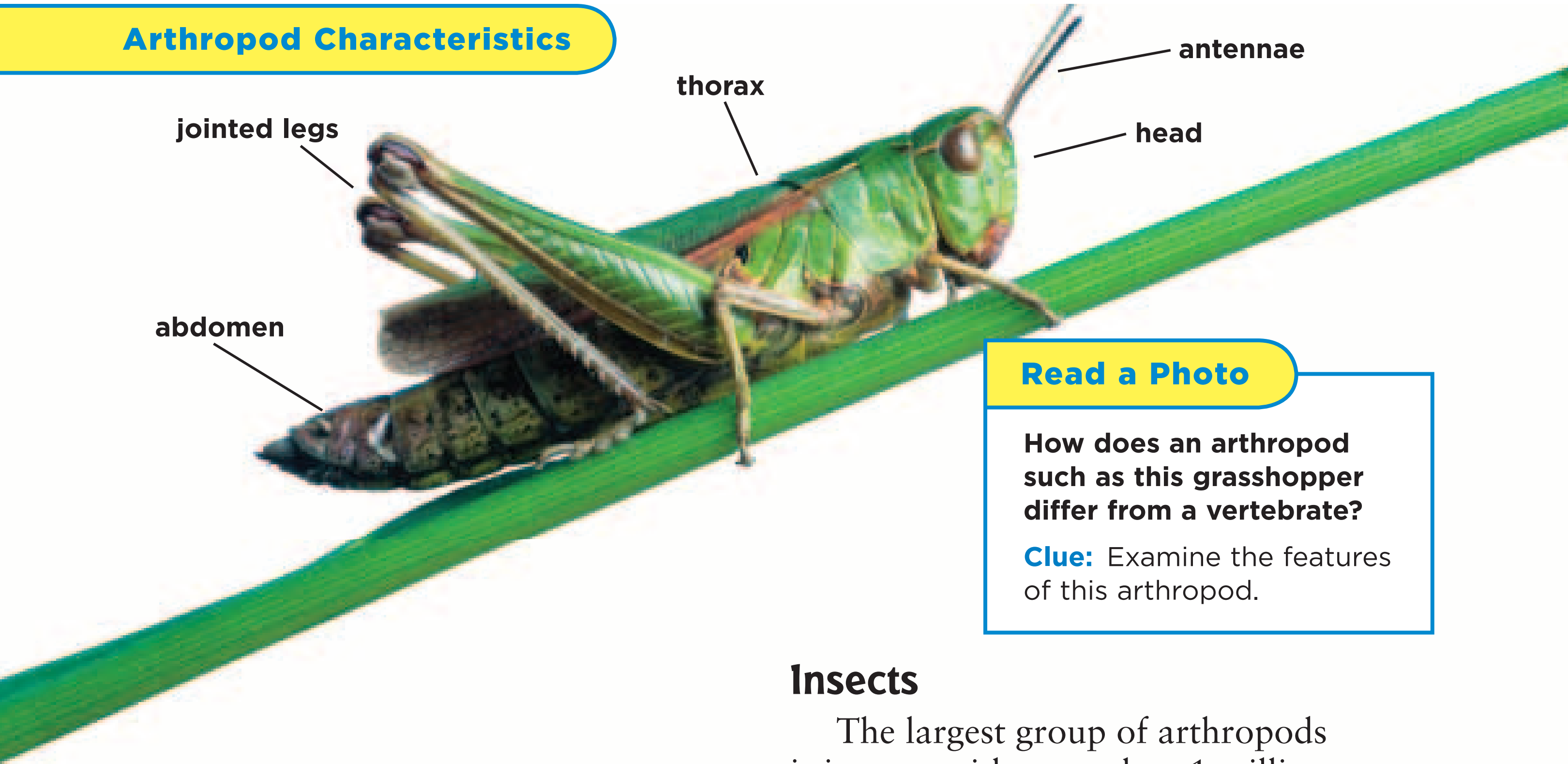
2. **Observe** Look at the earthworm, and record your observations. Use a hand lens for closer observation. Be sure to wash your hands after examining the earthworm.
3. **Record Data** Draw the earthworm, and label each part you recognize. Use a reference book to identify parts that are not familiar to you.
4. **Infer** How do earthworms move?

Read a Diagram

Which types of invertebrates do you see in this picture?

Clue: Invertebrates are animals without backbones.

Arthropod Characteristics



Read a Photo

How does an arthropod such as this grasshopper differ from a vertebrate?

Clue: Examine the features of this arthropod.

What are arthropods?

Arthropods are invertebrates with tough **exoskeletons**, or outer skeletons, that protect their internal organs. The exoskeleton does not grow with the animal; it must be shed as the animal grows. Arthropods also have jointed legs that help them move and segmented bodies with specialized sections. The three largest groups of arthropods are crustaceans (kru•STAY•shuhnz), insects, and arachnids (uh•RAK•nidz). Crustaceans live in either fresh water or salt water, or on land. Arachnids were probably the first animals to live on land.

Crustaceans

Crabs, shrimp, and lobsters are examples of crustaceans. There are more than 30,000 known species of crustaceans. They are the most abundant animals in the ocean.

Insects

The largest group of arthropods is insects, with more than 1 million species. The insect body consists of a head, a thorax, and an abdomen. Three pairs of legs are attached to the thorax. Antennae and eyes help the insect sense its environment.

Arachnids

Arachnids include spiders, ticks, scorpions, and mites. They have four pairs of appendages, one or two body sections, and no antennae. Spiders are predators that feed mainly on insects. All spiders produce a strong silk fiber. Some spiders weave this silk into webs that they use to capture prey.

Quick Check

Classify What characteristics identify an arthropod?

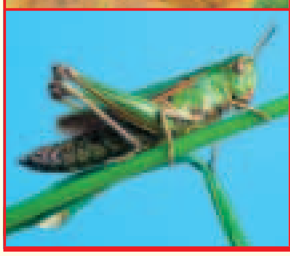
Critical Thinking "All spiders are arachnids, but not all arachnids are spiders." Explain this statement.

Lesson Review

Visual Summary

Vertebrates are animals with segmented backbones. They include the largest animals on Earth.

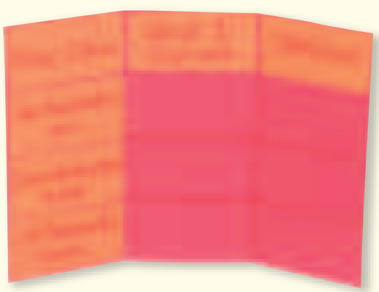
Invertebrates have no backbones and make up more than 95 percent of all animals.



Arthropods have jointed legs, segmented bodies and tough exoskeletons.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the statements, and include a sketch of a sample animal from each group.



Think, Talk, and Write

1. **Main Idea** Vertebrates include all animals with segmented ________.
2. **Vocabulary** An inner skeleton used for protection and movement is a(n) ________.
3. **Classify** What are the seven classes of vertebrates?

4. **Critical Thinking** Why must adult amphibians live near a body of water?
5. **Test Prep** **An organism with a hard exoskeleton, jointed legs, and a segmented body is classified as**
   A an arthropod.
   B a mammal.
   C an echinoderm.
   D a segmented worm.
6. **Test Prep** **All insects are**
   A eight legged.
   B spiders.
   C poisonous.
   D arthropods.

Math Link

Calculate Numbers of Insects

If you had 500 species of organisms in a museum display and 35 percent were insects, how many species of organisms other than insects would you have?

Social Studies Link

Defend a Position

Fish catches have decreased worldwide. Write a law that could help both the fish populations and the fishing industry. Find evidence to support your law. Then present your evidence to the class.

RAPTORS

Why Are They at the Top of Their Food Chain?

Have you ever seen an eagle, a hawk, or an owl swoop down and capture its food? These birds of prey, or raptors, are at the top of their food chain, because they have few predators. Their bodies are amazing flying machines that enable them to attack quickly and fly away with their prey.

Raptors have large wings and strong, sharp talons, or claws. Their wings help them soar and swoop down on their prey, which they capture in their talons. Raptors' wingspans (the distance from the tip of one extended wing to the tip of the other) are far longer than their bodies.

The table on the next page shows the lengths of some raptors' bodies and their corresponding wingspans. Look at the data, and complete the table by finding the ratio of body length to wingspan in decimal form. Then place these decimals on a number line to determine the order of the ratios of body length to wingspan in these raptors.

Find Ratios

To find the ratio of body length to wingspan,

- divide the body length by the wingspan

bald eagle:
80 cm ÷ 200 cm = 0.40 cm

expressed as a fraction:

$$\frac{40}{100} = \frac{4}{10} = \frac{2}{5}$$

expressed as a percent: 40%

Bird	Body Length (in centimeters)	Wingspan (in centimeters)	Ratio of Body to Wingspan
Bald Eagle	80	200	0.40
White-Tailed Hawk	50	120	0.42
Gray Hawk	38	89	
Swainson's Hawk	46	124	
Sharp-Shinned Hawk	27	54	0.50
Long-Eared Owl	33	99	
Golden Eagle	81	198	
Cooper's Hawk	39	71	0.55

Number Line

Solve It

1. Which bird's body length is one half, or 0.5, of its wingspan?
2. If a raptor's wingspan were 112 cm, how long would its body have to be for it to have a body-to-wingspan ratio of 0.45?
3. Picture yourself as a bird. Use a tape measure to determine the ratio of your arm span to your body length. Is it possible for more than one person to have the same ratio of arm span to body length? Explain your answer.

Lesson 4

Animal Systems

Look and Wonder

Computers, cars, and appliances all require energy to work. How are animals similar to these machines? How does an animal such as this panda obtain and process the water and energy it needs to live?

Explore

Inquiry Activity

How does the large intestine help with digestion?

Make a Prediction

If you use paper to model the way the large intestine absorbs water, which paper will absorb the most water? Write your answer in the form "If the paper that absorbs the most water is most like the large intestine, then the large intestine will be best modeled by . . ."

Test Your Prediction

1. Cut each type of paper into strips of equal size. Fold the papers to fit into the graduated cylinder.
2. Fill the graduated cylinder about half full with water. Record the water level on your chart.
3. Dip one paper into the graduated cylinder until half of the paper is covered by water. Keep it in the water for 1 minute.

Paper Type	Initial Water Level	Final Water Level	Amount of Water Absorbed

4. After 1 minute, remove the paper from the water. Record the water level in your chart. Calculate the amount of water the paper absorbed. Starting from step 2, repeat this process for each type of paper.

Draw Conclusions

5. **Infer** Which paper absorbed the most water? Why do you think this happened? What characteristics could it share with the large intestine?

Explore More

What other aspect of digestion could you test? Design and perform an experiment. Then share your results.

Materials

- scissors
  Be Careful.
- textured paper towels
- plain paper towels
- construction paper
- computer paper
- graduated cylinder
- water
- stopwatch

Step 2

Step 3

Read and Learn

Main Idea
All animals have organs and organ systems that have specific functions.

Vocabulary
digestion, p. 58

excretion, p. 58

respiration, p. 60

diffusion, p. 60

circulation, p. 62

cold-blooded, p. 62

warm-blooded, p. 62

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Reading Skill
Problem and Solution

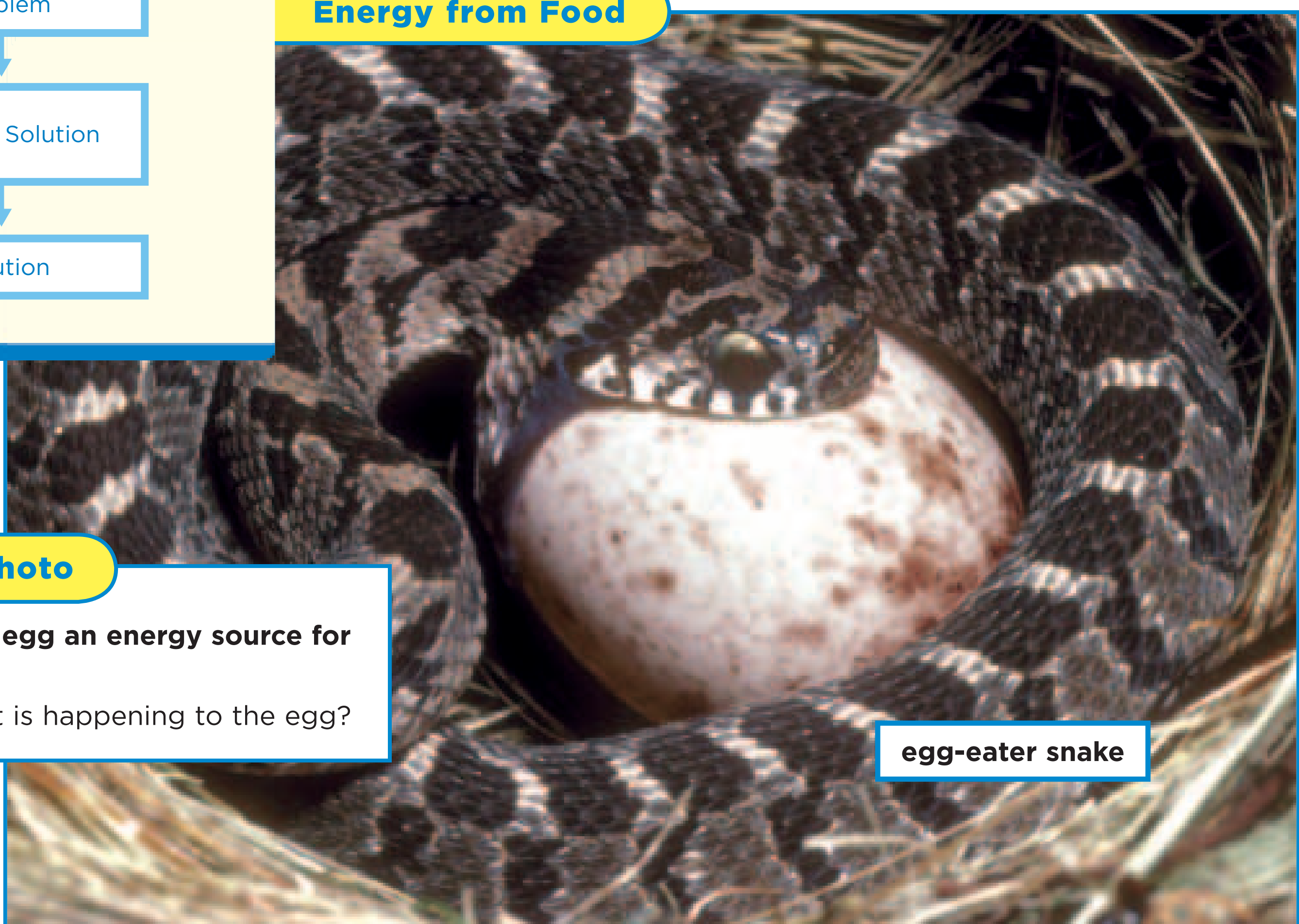
Problem → Steps to Solution → Solution

What are digestion and excretion?

One characteristic of living things is that they use energy from food. Photosynthetic organisms can make their own food. Most other organisms must obtain, or ingest, food from their environments. Each animal has a way of ingesting food, breaking the food down, and eliminating wastes. You may obtain food and energy by eating a sandwich. A cow gets its food and energy by eating grass. Some marine animals simply absorb their food to obtain energy.

For organisms that ingest their food, digestion is the first step toward releasing the food's stored energy. **Digestion** is the process in which ingested food is broken down into molecules that are usable by cells. Once food is broken down into simpler substances, it can be carried to cells throughout the body. **Excretion** is the removal of wastes from the body. These waste materials have no value and may be poisonous to cells and tissues.

Energy from Food



egg-eater snake

Read a Photo
How is the egg an energy source for the snake?

Clue: What is happening to the egg?

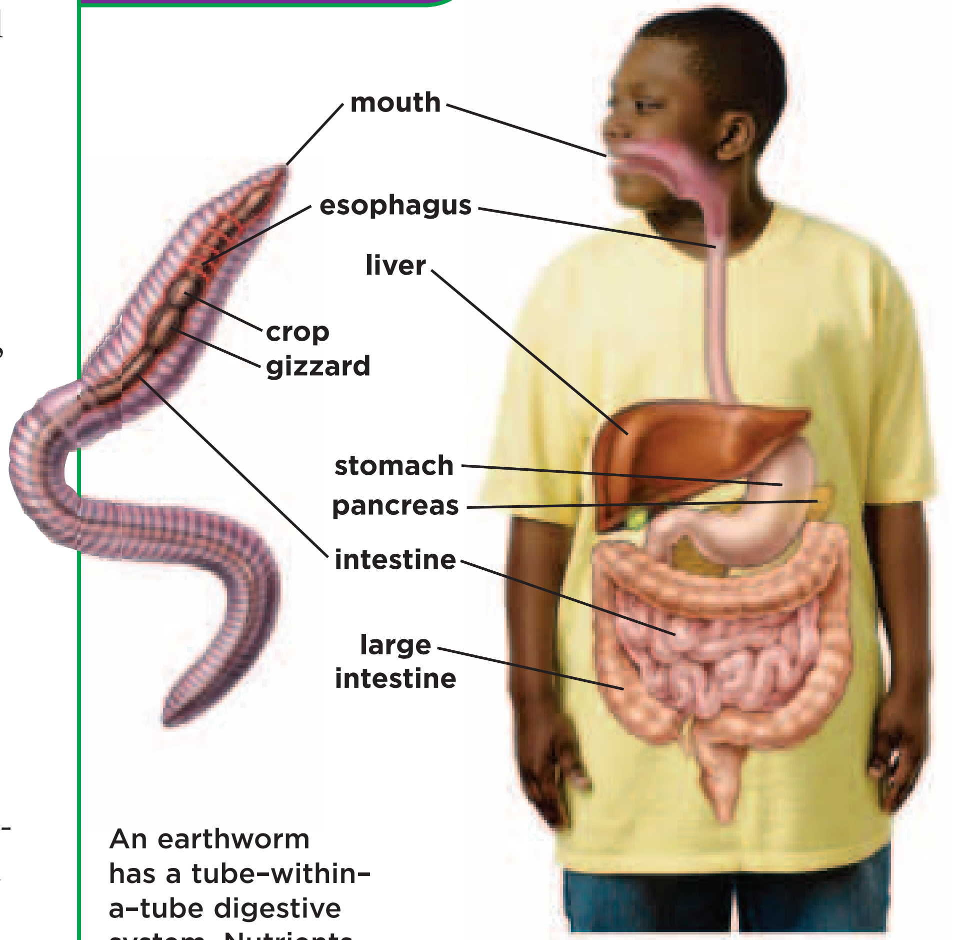
Invertebrates

Invertebrates have several ways to digest food and excrete wastes. Sponges are filter feeders. The pores of a sponge strain food particles from the water.

In other organisms, such as cnidarians and flatworms, food enters and leaves from the same opening. For example, special cells in the digestive cavity of a flatworm digest the food and absorb nutrients. The nutrients move to other cells in the body, and unused materials are then released.

More advanced digestive systems use a "tube-within-a-tube" system. An earthworm has this type of digestive system. There are separate openings for ingested food and for excreted wastes.

Digestive System



An earthworm has a tube-within-a-tube digestive system. Nutrients pass through and are then absorbed by the blood.

Acid and an enzyme in the stomach break food into small particles. Bile made in the liver breaks up fat. Chemicals from the pancreas break down proteins, starches, and fats.

Vertebrates

Animals that are more complex have more complex digestive systems as well. Vertebrates have many differences in their digestive structures in order to handle their varied diets. For example, rabbits, cows, and elephants eat plants. Their teeth grind plant material thoroughly. Their digestive systems also contain bacteria that help digest plant tissues.

Human digestion occurs in the mouth, stomach, and small intestine. Nutrients are absorbed inside the small intestine and then move into the blood. Solid wastes are processed and are then eliminated from the body. The kidneys, lungs, liver, and skin help eliminate wastes from the body as well.

Quick Check

Problem and Solution How have animal digestive systems solved the problem of digesting food?

Critical Thinking Why is excretion important?

Respiration unlocks energy in food for these racers.

What is respiration?

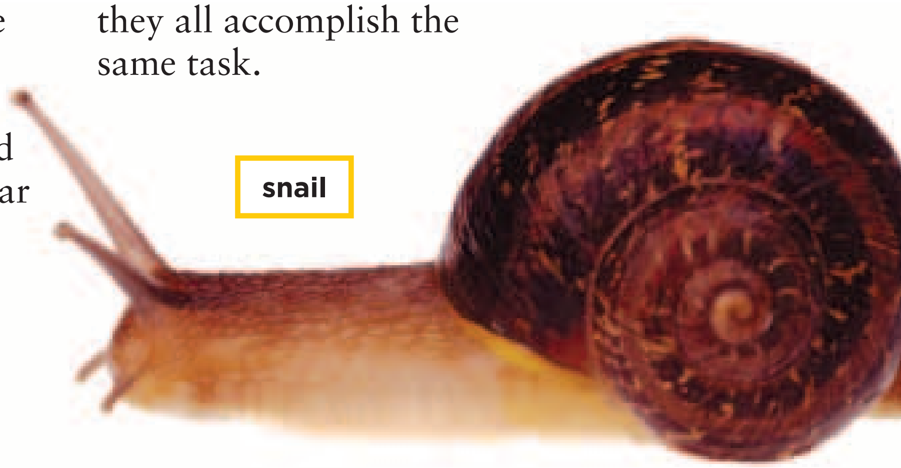
Once an organism digests food, it must "unlock" the energy in the food molecules. In animals, as in most other organisms, a food molecule that results from digestion is *glucose* (GLEW•kohs), a simple sugar. **Respiration** is the process of releasing energy from food molecules such as glucose. This occurs within the cells, in the presence of oxygen. All organisms, including plants, undergo respiration to obtain energy from food.

The term *respiration* is also used to refer to breathing. However, the purpose of breathing is to provide the oxygen needed to unlock the energy in food. Exhaling rids the body of wastes such as the carbon dioxide and water that are produced during cellular respiration. The lungs are organs of the respiratory system because they provide oxygen that goes to the cells.

Invertebrates

For some soft-bodied invertebrates, such as flatworms, respiration is a simple exchange of gases by diffusion (di•FYEW•zhuhn). **Diffusion** is the movement of molecules from areas of higher concentration to areas of lower concentration. For diffusion of oxygen across living tissue, surfaces must be moist. This is why worms, snails, and slugs tend to stay in moist locations.

Larger organisms need special organs for respiration. These organs range from simple to complex, depending on the animal. However, they all accomplish the same task.



snail

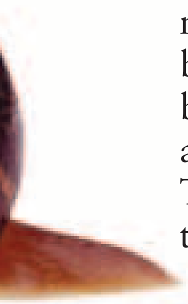
Invertebrates such as mollusks, crustaceans, and some worms also have gills, feathery structures that have a rich supply of blood vessels near the surface. Gas exchange occurs in these blood vessels. Similar to gills are book lungs, which are found in most spiders and their relatives. Book lungs are thin, platelike structures that are stacked on top of one another, like pages in a book. Insects, and most spiders, have branching tubes called trachea. They form a network that connects all of an insect's cells to oxygen-rich air.

Vertebrates

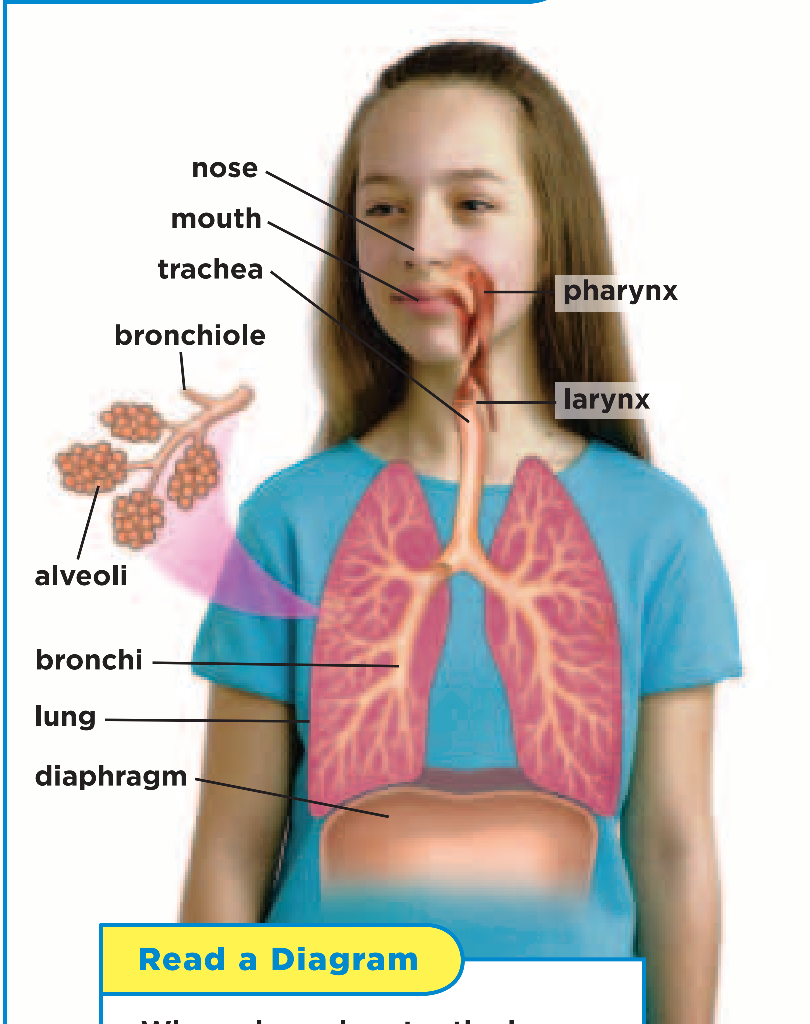
The word *amphibian* comes from the Greek roots *amphi*, meaning "both," and *bio*, meaning "life." Amphibians are animals that live in water when young and on land as adults. Young amphibians exchange gases through their skin and gills. Most adult amphibians use lungs but continue to exchange gases through their skin.

There are three vertebrate classes that use lungs exclusively for respiration. The first of these is the reptile class. Gases and water do not pass through reptiles' scaly skin—reptiles use lungs to breathe. The bird and mammal classes also use lungs to breathe.

In humans, air enters through the nose and mouth. Air then passes into the pharynx and then into the larynx. After entering the trachea, the air moves into branched bronchi. Many bronchioles branch out from the bronchi. Gas exchange occurs in tiny air sacs called alveoli (al•VEE•uh•ligh). The diaphragm contracts and expands the lungs to control breathing.



Human Respiratory System



Read a Diagram

Where does air enter the human body?

Clue: Follow the path from the outside to the inside. What parts take in air?

Quick Check

Problem and Solution Why do cells need oxygen?

Critical Thinking Find and explain an example of diffusion in the kitchen.

What is circulation?

Digestion and respiration work together to maintain life. Digestion provides glucose for cells, and respiration provides the oxygen that helps break glucose down into usable energy. Both systems are necessary for cells.

Multicellular animals must transport oxygen and glucose to each cell and must also remove waste materials. **Circulation** is the movement of important materials such as oxygen, glucose, and wastes throughout the body.

Those invertebrates that thave a circulatory system have either an open or a closed system. In an open circulatory system, the blood is not entirely enclosed within blood vessels. Instead of moving into smaller vessels, the blood is released by the heart directly into tissues in the body. A closed circulatory system contains the blood within blood vessels. Materials diffuse in and out of the blood through the thin walls of the blood vessels.

Body Temperature

Many activities of the body require a certain temperature. The body temperature of some animals changes with the temperature of the surrounding air or water. For example, snakes bask in sunlight for warmth or burrow under rocks to cool down. Amphibians, reptiles, and most fish are **cold-blooded** animals.

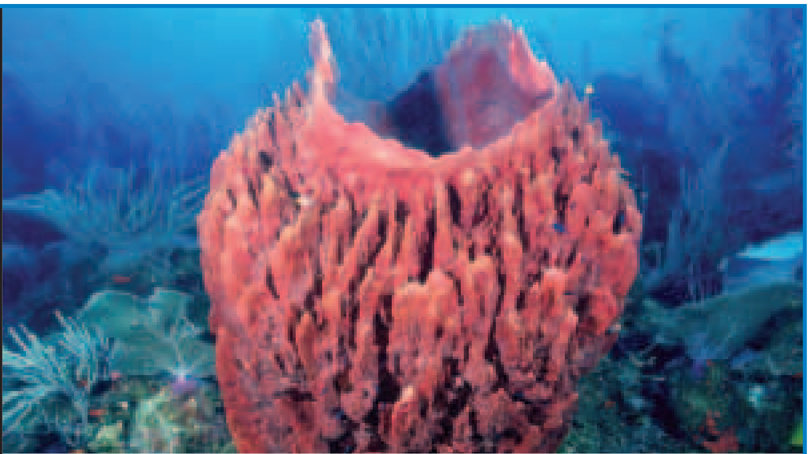
Mammals and birds are **warm-blooded**. Their body temperature stays the same, even when the temperature of the air changes. Various body mechanisms control their body temperature. If these animals become too hot, they give off the excess heat, often by perspiring. Some animals have insulation to keep too much heat from leaving their bodies. For example, many whales have thick layers of blubber to keep heat from escaping into the cold waters in which they swim.

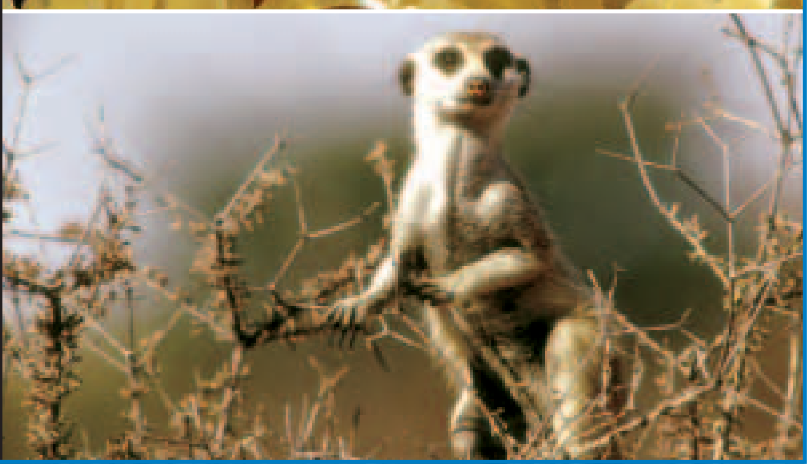
At the most basic level, circulation occurs by diffusion. Water, flowing through soft-bodied organisms such as this sponge, moves glucose, oxygen, and wastes. The tubes that make up this system work like blood vessels.

This praying mantis has an open circulatory system. Blood moves from its heart directly into tissues in its body. The blood collects in openings called sinuses, and from there it is returned to the heart.

Animals such as this clown fish that use gills have a single-loop circulatory system. The blood makes a simple circuit from the heart to the gills to the body cells and back to the heart.

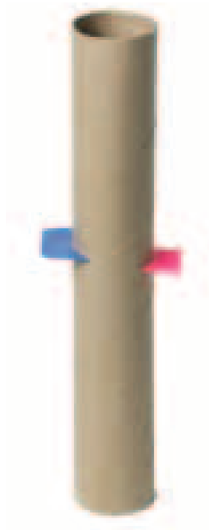
Animals such as this meerkat use lungs for respiration and have a double-loop circulatory system. The first loop carries blood between the heart and lungs. The second loop carries blood between the heart and the rest of the body.





Quick Lab

Vein-Valve Model

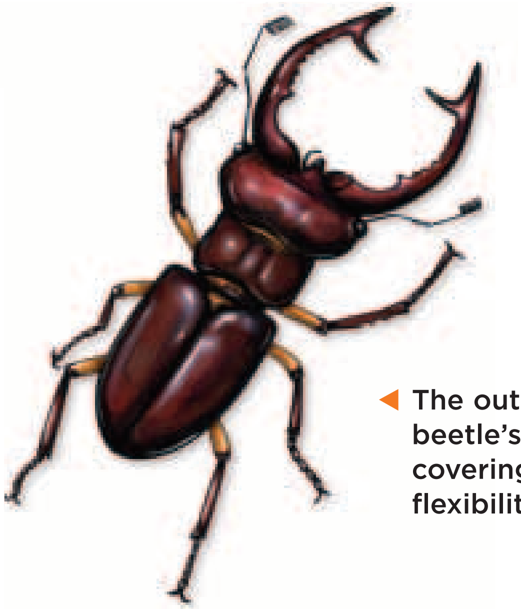


1. Cut a thin, horizontal slit halfway across the center of the tube.
2. Opposite the first slit, but 0.6 cm below it, cut a slit 1.5 cm wide.
3. Cut paper inserts for each slit as shown. Trim the insert for the top slit so it blocks the tube but can swing a little. Cut the insert for the bottom slit wide enough that it can only be inserted partway. Tape the tails of the inserts to the tube's side.
4. **Observe** Pour beans down the tube. Try both ends. Explain the results.
5. **Infer** How are your body's veins like the tube with the paper flaps?

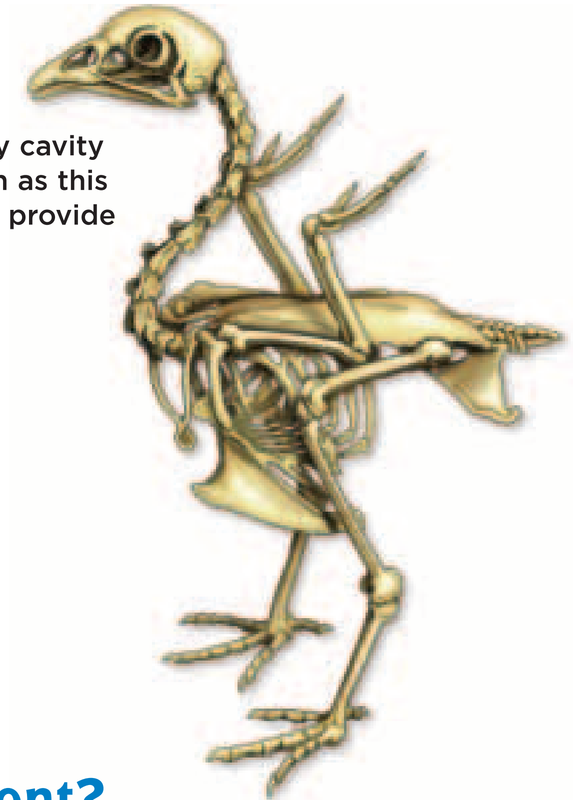
Quick Check

Problem and Solution Why would the circulation of a cold-blooded animal slow down at night?

Critical Thinking Why is it important to stop the loss of blood after a severe injury?



◀ The outside of this stag beetle's body has a tough covering. Joints allow for flexibility and movement.



Inside the body cavity of animals such as this chicken, bones provide support. ▶

What are support and movement?

Animals must move in order to obtain food and escape enemies. Three basic designs in the animal kingdom enable animals to move.

Cnidarians, some flatworms, roundworms, and some mollusks have hydrostatic skeletons. The prefix *hydro-* means "water." Think of a water balloon with rubber bands around it. By contracting and expanding the rubber bands, you can change the shape of the balloon. A hydrostatic skeleton has no bones. It is a fluid-filled cavity surrounded by muscle fibers. When these muscles contract, the cavity wall pushes against the fluid and produces motion.

The prefix *exo-* means "outside." An exoskeleton is a hard coating on the outside of the body. Arthropods have exoskeletons. Muscles attached to the inside of the exoskeleton help arthropods move their joints. The shells of many mollusk species are considered to be exoskeletons as well.

The prefix *endo-* means "inside." Sponges, some echinoderms, and vertebrates have *endoskeletons*, which are made of hard structures within the body. Except for sponges, which have no muscles, animals with endoskeletons have muscles that are attached to individual bones.

Skeletons also provide protection. The hard outer coverings of arthropods protect their internal organs. Internal ribs protect vital organs such as lungs and the heart. A vertebrate's backbone protects the nerves of its spinal cord.

Quick Check

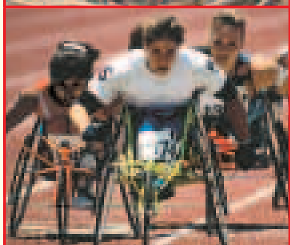
Problem and Solution How do muscles help an organism move?

Critical Thinking What happens to an animal's exoskeleton as the animal grows?

Lesson Review

Visual Summary

Digestion breaks food down into usable nutrients. **Excretion** removes wastes from the body.

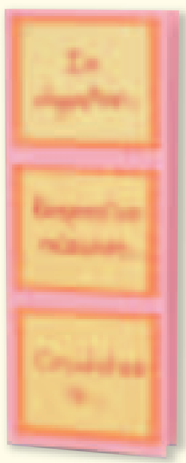


Respiration releases energy from food molecules in the presence of oxygen.

Circulation is the movement of important materials throughout the body.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide supporting details.



Think, Talk, and Write

1. **Main Idea** The process by which organisms break down ingested food into a usable form is called ________.

2. **Vocabulary** The movement of materials throughout the body is called ________.

3. **Problem and Solution** How do vertebrates obtain and distribute oxygen?

   Problem
   ↓
   Steps to Solution
   ↓
   Solution

4. **Critical Thinking** What is the advantage of being warm-blooded?

5. **Test Prep** Insects have
   A exoskeletons,
   B endoskeletons,
   C hydrostatic skeletons,
   D vertebrate skeletons,

6. **Test Prep** **A circulatory system that releases blood directly into an animal's tissues is**
   A a single-loop system,
   B a diffusion system,
   C a closed circulatory system,
   D an open circulatory system,

Math Link

Pumping Machine
If the heart pumps 7,500 L of blood through the human circulatory system per day, how many liters of blood are circulated per hour?

Art Link

Organ-Systems Book
Make a class book of invertebrate and vertebrate organs or organ systems. Sketch each organ or organ system, and label its name, various organisms that have it, and the task it accomplishes.

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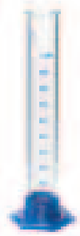
Be a Scientist

Materials

plastic tubing

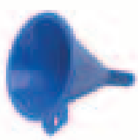
ruler



graduated cylinder

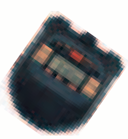
dropper

food coloring



small funnel

cup



stopwatch

Structured Inquiry

How do different-sized blood vessels compare?

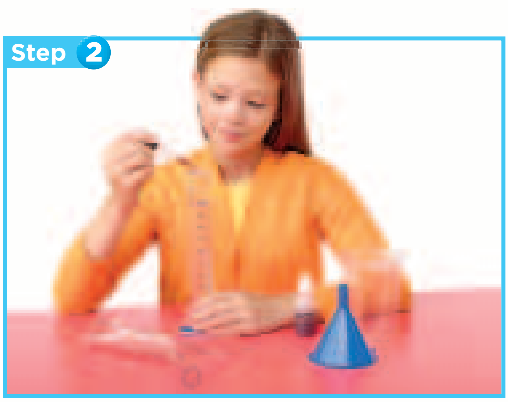
Form a Hypothesis

There are many types of tubes to carry blood from the heart to the body and lungs and back again. The blood vessels that carry blood away from the heart are called arteries. They carry very large quantities of blood. Arterioles are smaller than arteries, but they can still carry large quantities of blood. The blood flows from arterioles into capillaries, which are very small. This is where oxygen and carbon dioxide are exchanged. How does the size of each blood vessel affect the flow of blood? Write your answer in the form of a hypothesis: "If the diameter of a blood vessel is made smaller, then the flow of blood will . . ."

Test Your Hypothesis

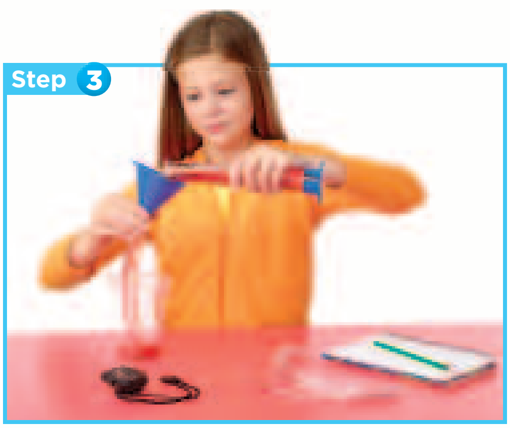
1. **Use Numbers** The plastic tubing represents different blood vessels. Measure and record the diameter of each piece of tubing.

2. Fill a graduated cylinder with 100 mL of water. Add 3 drops of food coloring to represent blood.



3. **Experiment** Put the funnel into the opening of the widest tubing. Put the other end of the tubing in a cup. Pour the water into the funnel. Use the stopwatch to record how long it takes for all the water to pass through the tube. Return the water to the graduated cylinder. Repeat this twice, and record the time for each trial.

4. **Use Variables** Repeat step 3 with the medium-diameter tubing. Then repeat step 3 with the narrowest tubing.



5. Connect the tubing so that the widest piece is at the top and the narrowest is at the bottom. Repeat step 3.

Draw Conclusions

6 **Compare** What differences did you observe between the widest tubing and the narrowest? Which required the longest time for the water to pass through the tubing?

7 **Interpret Data** What happened when you connected all three pieces of tubing in step 5?

8 **Infer** What did step 5 demonstrate about the circulatory system in the human body?

Guided Inquiry

How does the respiratory system work?

Form a Hypothesis

The lungs in vertebrates take in oxygen and expel carbon dioxide. The heart pumps blood, carrying those same gases, around the body. How do the lungs work in the human body? Write your answer in the form of a hypothesis: "If humans have lungs, then the human body must also have the following parts for the lungs to work: . . ."

Test Your Hypothesis

Design an experiment that uses classroom materials to model the human lungs. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

Did your results support your hypothesis? What parts did you find to be necessary for the lungs to work in the human body?

Open Inquiry

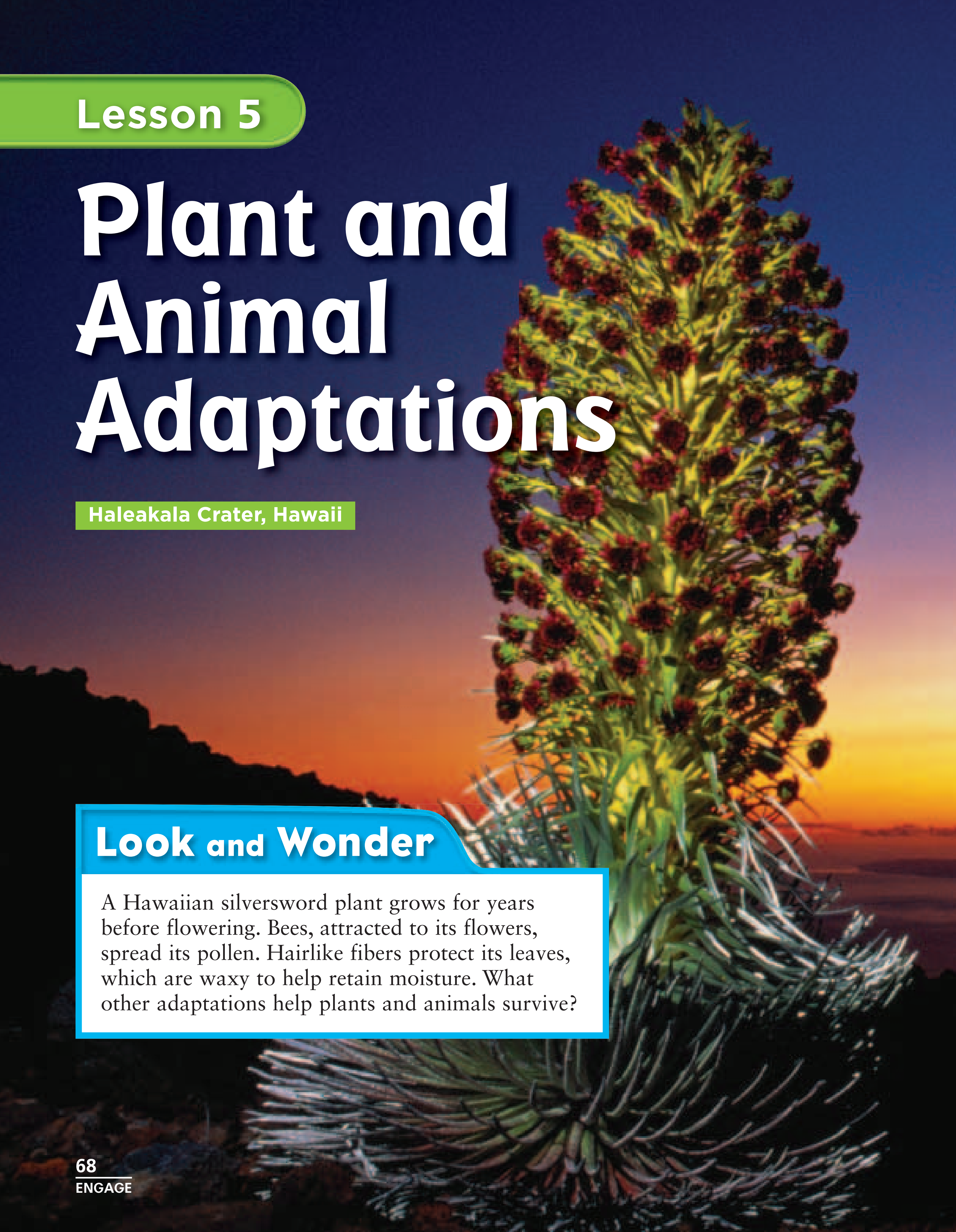
What else can you learn about the circulatory systems of organisms? For example, what are the differences between a bird heart and a human heart? Design an experiment to answer your question. Organize your experiment to test only one variable. Write your experiment so that another group could repeat your experiment by following your instructions.

Remember to follow the steps of the scientific process.

Ask a Question → Form a Hypothesis → Test Your Hypothesis → Draw Conclusions

Lesson 5

Plant and Animal Adaptations



Haleakala Crater, Hawaii

Look and Wonder

A Hawaiian silversword plant grows for years before flowering. Bees, attracted to its flowers, spread its pollen. Hairlike fibers protect its leaves, which are waxy to help retain moisture. What other adaptations help plants and animals survive?

Does a waxy coating help a plant retain moisture?

Form a Hypothesis

Some plants grow where there is very little water. How do these plants survive? Does a waxy coating make a difference? Write your answer in the form of a hypothesis: "If a plant is covered by a waxy coating, then the plant will . . ."

Test Your Hypothesis

1. **Make a Model** Dampen three identical paper towels so that they are evenly moist but not dripping wet. Measure the water in a graduated cylinder, and use the same amount of water to dampen each paper towel.
2. **Use Variables** Lay one paper towel in between two identical pieces of waxed paper. Fasten the edges together with tape or paper clips.
3. Roll up a second paper towel, and cover it with waxed paper. Fasten the edges together. Leave the third paper towel flat and uncovered.
4. **Observe** Place all three paper towels on a tray in a sunny location. Observe the paper towels after 30 minutes. Which paper towel retained the most moisture? Which retained the least?

Draw Conclusions

5. **Interpret Data** Was your hypothesis correct?
6. **Infer** How can you explain your observations?

Explore More

Would a different type of coating or covering help reduce moisture loss? Design an experiment to test your hypothesis, try it, and then share your results.

Materials

- 3 paper towels
- water
- graduated cylinder
- waxed paper
- tape or paper clips
- tray

Read and Learn

Main Idea

Adaptations are changes that help plants and animals survive in their environments.

Vocabulary

adaptation, p. 70
tropism, p. 70
camouflage, p. 72
mimicry, p. 72
insulation, p. 73
instinct, p. 74
migrate, p. 76

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Reading Skill

Draw Conclusions

Text Clues	Conclusions

Technology

SCIENCE QUEST

Explore ecosystems with a park ranger.

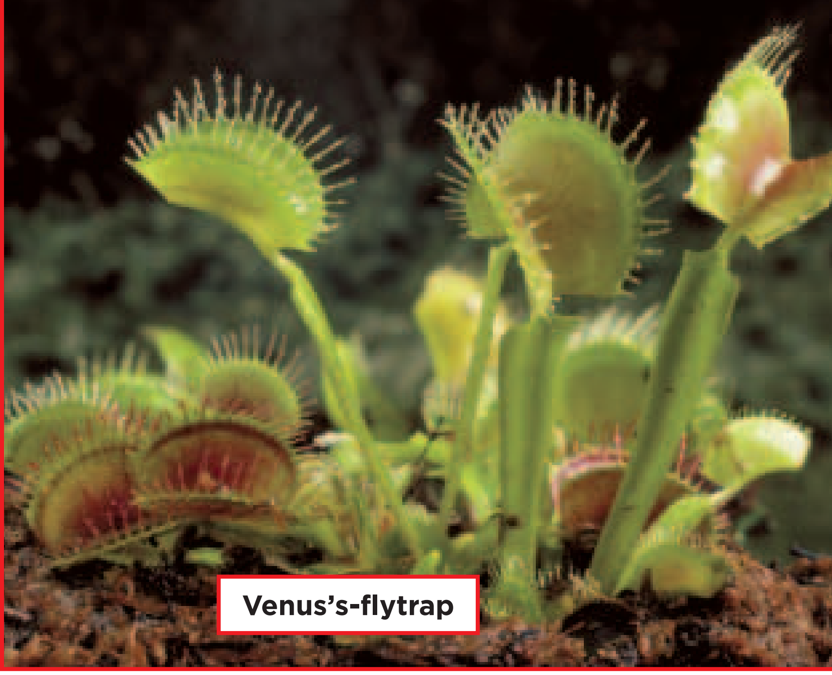
What are adaptations?

Organisms often react to changes in their environments by altering their behaviors. They might practice a new method of obtaining food or a new way to avoid capture. They might move to a different area. Environmental changes may even result in the deaths of different organisms. For example, a dramatic climate change might mean that a particular species will not survive.

An **adaptation** enables an organism to survive and reproduce. If you compare individual organisms of a single species, you might note differences. One plant may be taller than another. One animal may be faster than others of its species. Often the differences are not visible. The individuals that survive pass on their characteristics to their young.

Organisms respond to their environments. Something that causes a response is called a *stimulus*. The response of an organism toward or away from a stimulus is called a **tropism** (TROH•piz•uhm). The growth of a plant toward a stimulus is a positive tropism. The movement of a plant away from a stimulus is a negative tropism. Tropisms help organisms survive and reproduce.

This flowering shamrock plant grows toward the light. This is an example of phototropism.



Venus's-flytrap

tropical pitcher plant

Types of Plant Adaptations

There are several kinds of tropisms, each named after the stimulus that causes it. The term *tropism* comes from a word meaning "to turn." The prefix *photo-* means "light." A positive phototropism occurs when a plant turns, or bends, toward the light. The prefix *hydro-* means "water." When a plant's roots grow toward water, they are demonstrating a positive hydrotropism. Gravitropism is a plant's response to gravity. The roots of a plant show positive gravitropism, and its stems show negative gravitropism.

Tropisms are caused by chemicals called auxins (AWK•suhnz). Auxins can stimulate parts of a plant to grow quickly or slowly. For example, if there is light on one side of a plant, the auxins move away from that side. This causes an increase in auxins on the shaded side, where more growth will now occur. The side in the light will not grow as much. The unequal growth causes the stem to bend toward the light.

Many plants have adaptations that allow them to grow in harsh conditions. Desert plants are masters of survival. The stem of a cactus can store enough water from one rainfall to survive years of drought.

Carnivorous plants are meat-eating plants. Plants such as the Venus's-flytrap or the pitcher plant grow in nitrogen-poor soil. To make up for the lack of nitrogen, they have adaptive structures to capture and digest insects.

Plants have other adaptations as well. For example, it is a bad idea to grab a poison-ivy plant if you want to pull it out of the ground. The plant produces oils that may cause a severe rash. Thorns are another adaptation that some plants have for protection.

Quick Check

Draw Conclusions How do thorns help plants survive?

Critical Thinking How have desert plants adapted to their environment?

▲ Chameleons change color to blend in with their environment.

▲ Would a bird searching for a meal have difficulty spotting this stick bug?

▲ Do you see a caterpillar or a snake? A bird looking to eat it cannot tell the difference, either. This moth caterpillar is likely to be left alone!

How are animals adapted to their surroundings?

A common characteristic of animals is that they usually can move from place to place. Often an animal moves in search of food. This search can put the animal in danger of being eaten by another animal. Animals have several adaptations that allow them to eat without being eaten.

Camouflage (CAM•uh•flahzh) is a disguise used to make something look like its surroundings. It offers some protection from predators, or animals that hunt and eat other animals. There are two ways an animal can blend in with its environment: shape and color.

A chameleon (kuh•MEEL•yuhn) can change its color in as little as 20 seconds based on the temperature and light, or to blend in with its environment. Chameleons also move slowly in order to avoid detection. Some animals, such as the stick bug, hide from predators by looking like something other than a meal. Stick bugs avoid predators by looking just like bark, leaves, or twigs.

Another way animals stay safe from predators is by imitating other animals. **Mimicry** (MIM•i•kree) is an adaptation in which an animal is protected against predators by its resemblance to a different animal. For example, different kinds of hoverflies resemble bees or wasps, and this helps protect the hoverflies from predators.

FACT Camouflage helps some animals hide and helps others hunt.

Adaptation

Read a Photo

What makes the feathers of this snowy owl an adaptation?

Clue: How do you think the owl's feathers help the bird survive?

Adapting to Climate

Besides protection from predators, organisms often need protection from the elements of nature. Living things thrive in all areas of the world, including deserts and the frozen areas near Earth's poles.

In very hot climates, animals must be able to get rid of excess heat. Desert animals have adapted in different ways. The fennec, a kind of fox, has huge ears that provide a large surface area from which heat can escape into the environment. The humps of camels are made of fat. Camels can live off this stored fat when food is scarce.

In colder climates, animals must reduce heat loss. In some cases, they have insulation. **Insulation** is a material that does not conduct heat well. Animals that live in cold climates are often insulated by having adaptations such as a thick layer of body fat, called blubber, or a heavy coat of fur. The fur closest to an animal's skin is very soft and traps air, which is a good insulator. In birds, this air-trapping layer is often made of soft, thick down feathers.

Quick Check

Draw Conclusions What might happen if an animal with camouflage in its own environment moved into a different area?

Critical Thinking What are some examples of animals that have adapted to extreme temperatures?

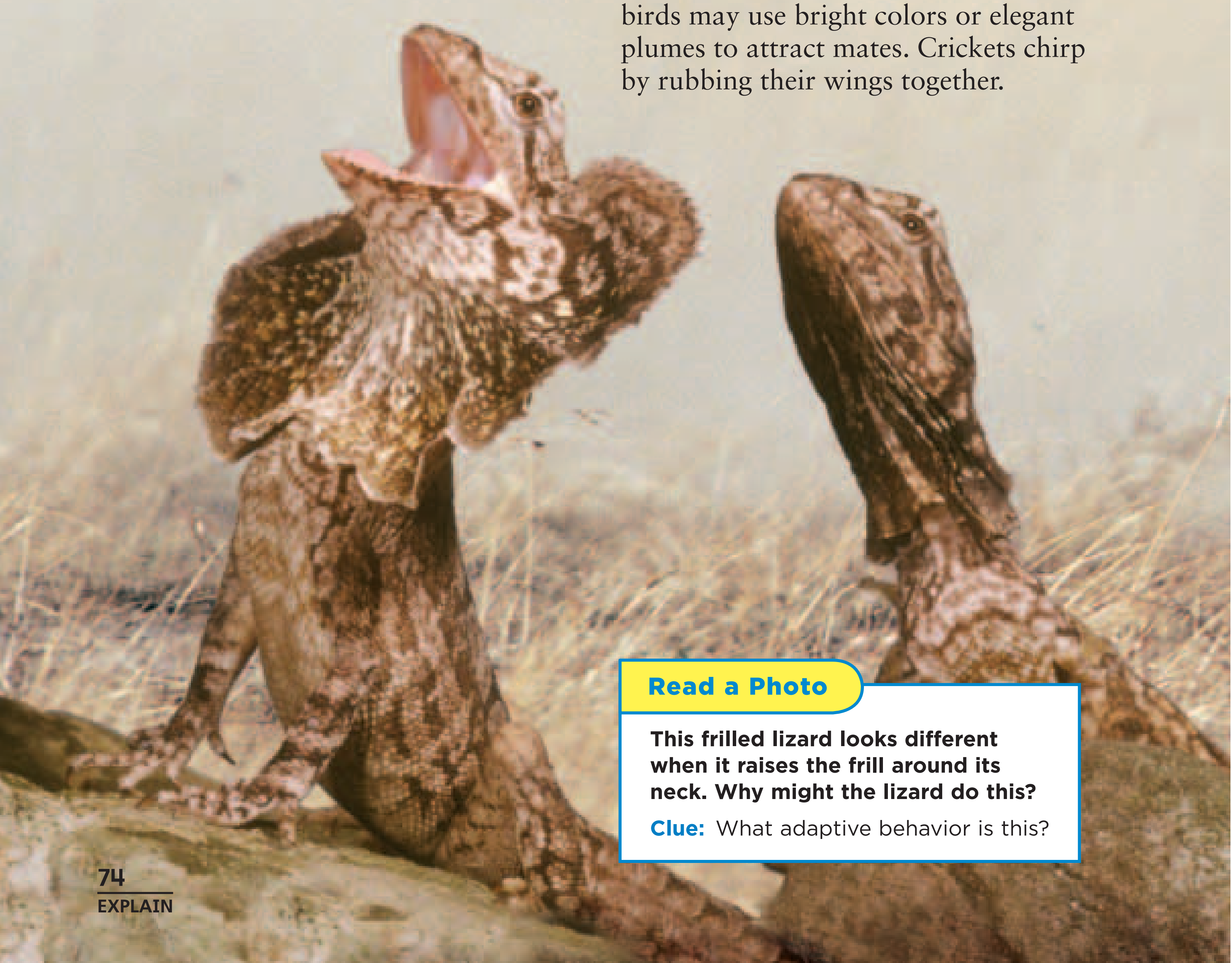
What are some adaptive behaviors of animals?

In addition to physical adaptations, animals have behavioral adaptations that can also help them survive. Some of these behaviors help animals find food, and others help animals defend themselves. Behavioral adaptations can help an animal build a nest or find a home. Because reproduction is necessary for a species to survive, some adaptive behaviors can help animals attract mates. Some adaptive behaviors can also help organisms take care of their young.

Many of these behaviors come naturally. An **instinct** is an inherited behavior, one that is not learned but is instead done automatically. A newborn puppy with its eyes still unopened can find its way to its mother's milk. A spider can weave webs within hours of hatching. Birds know how to build safe, strong nests. These animals are not taught how to do these things. The skill or knowledge is an instinct.

Animals display various behaviors as they attempt to attract mates. Some birds may use bright colors or elegant plumes to attract mates. Crickets chirp by rubbing their wings together.

Adaptive Behavior



Read a Photo

This frilled lizard looks different when it raises the frill around its neck. Why might the lizard do this?

Clue: What adaptive behavior is this?

▲ Male peacocks display tall feathers to attract mates.

Some adaptations help animals defend themselves. If you pick up a pill bug and watch it curl into a tight ball, you observe a defense mechanism. Turtles tuck their bodies into their protective shells, and skunks spray attackers with a nasty-smelling liquid.

Seasonal Adaptations

Seasonal changes can sometimes make adaptations necessary. Have you ever noticed increased activity among animals in autumn? Some of these animals are collecting and storing food for winter.

When temperatures drop and days are shorter, some animals will hibernate. Instead of struggling to keep warm or to find food and water, they sleep during the winter. Some animals dig into the ground below the frost line, the depth to which the soil freezes, to hibernate. Other animals, such as some frogs, hibernate underwater. During hibernation, all body activities slow down. The animal lives on its own previously stored energy.

Quick Lab

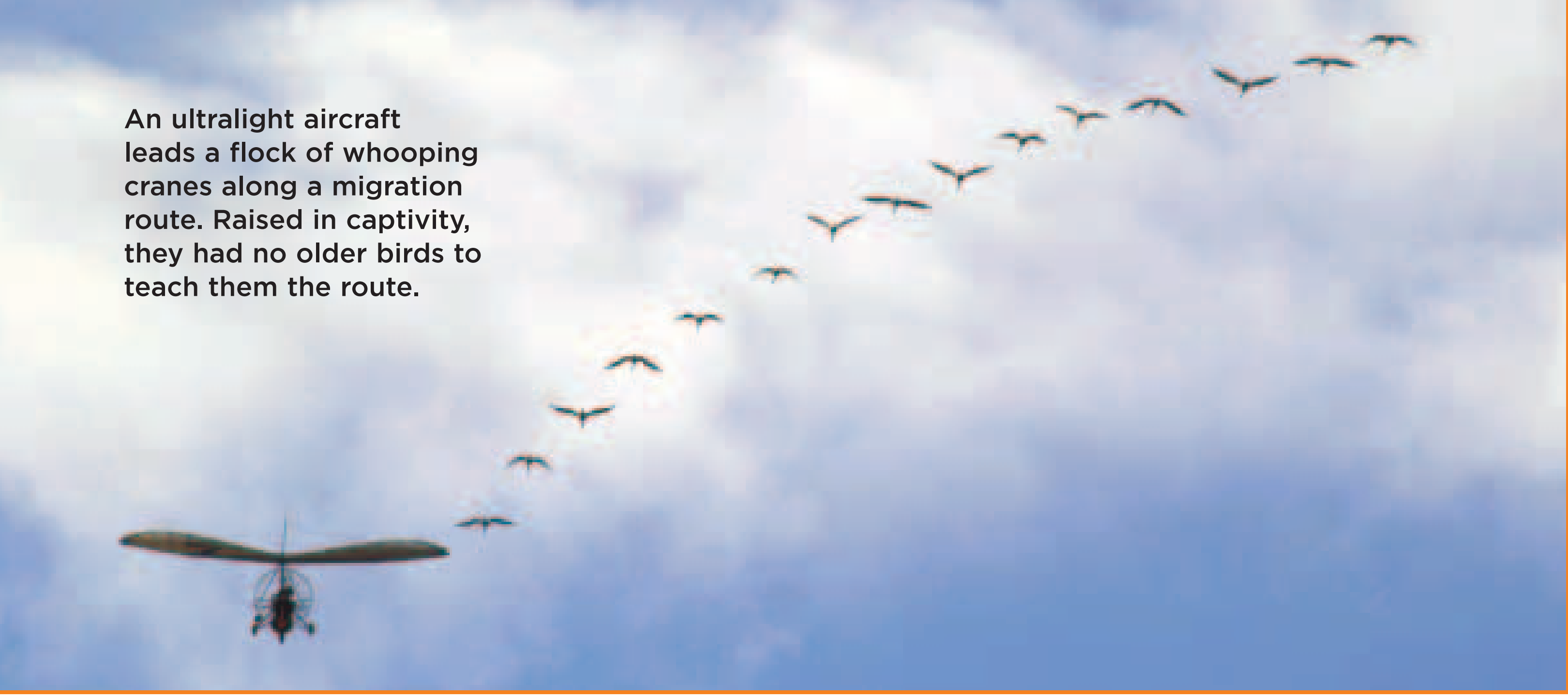
Modeling an Adaptation

1. **Make a Model** Lay out 64 dried beans on a sheet of graph paper so they form a square shape.
2. Use chopsticks to pick up as many beans as possible. Place the beans in a cup. Give yourself exactly 1 minute, and then stop. Record the number of beans in the cup.
3. Repeat steps 1 and 2, using forceps instead of chopsticks.
4. **Interpret Data** Suppose that the beans represent a food source. If the chopsticks and forceps represent animals, which is better adapted to feed on the beans?
5. **Predict** Which "animal" will survive longer? Which will produce more young? Explain your predictions.

Quick Check

Draw Conclusions How do animals adapt to changes in the seasons?

Critical Thinking How do nesting instincts help an animal survive?

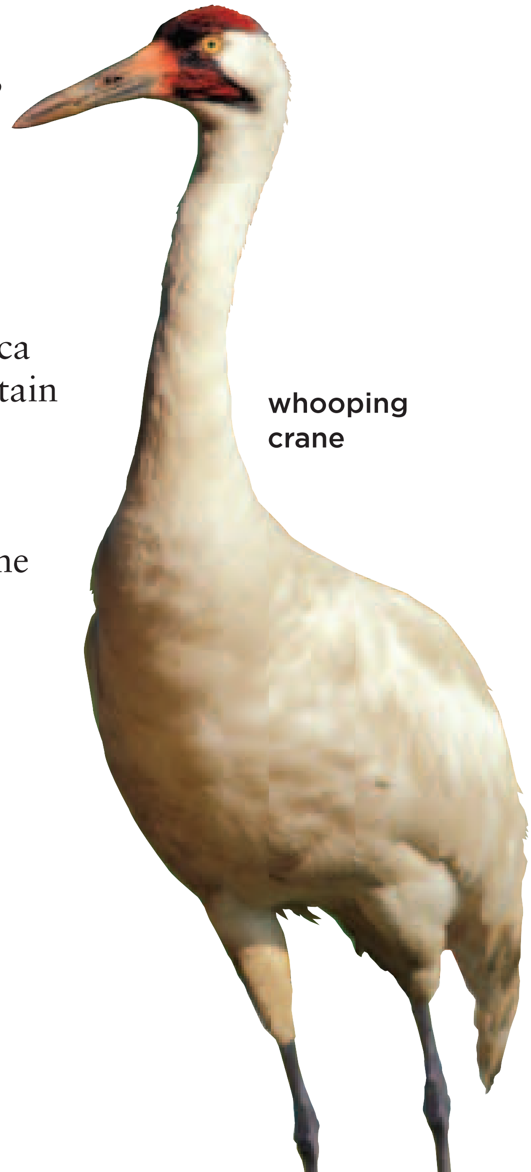


An ultralight aircraft leads a flock of whooping cranes along a migration route. Raised in captivity, they had no older birds to teach them the route.

Why do animals migrate?

To **migrate** is to move from one place to another. Some animals migrate seasonally or periodically in response to their environments. A change in climate, availability of food, or habitat might cause them to migrate. Sometimes, migration is a one-way trip. Arctic lemmings make a mass migration every three to four years. Many of them do not survive the journey, leaving only a select number to reproduce and start again in a new area.

For many other organisms, migrations are round-trip journeys. Many birds migrate seasonally. In North America there are several important flyways, or paths, used by certain types of birds. These routes mainly follow a north-south path. The method by which birds navigate, or find their way, has several sources. Wind direction and the position of the Sun and stars are factors. Parts of the brains of some migratory birds act much like compasses, responding to Earth's magnetic field.



whooping crane

Quick Check

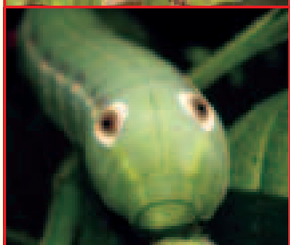
Draw Conclusions Why do some animals migrate to warmer locations during winter?

Critical Thinking About 520 of the 650 bird species that nest in the United States migrate south in winter. What percent do not migrate?

Lesson Review

Visual Summary

Adaptations can increase an organism's ability to survive in its environment.

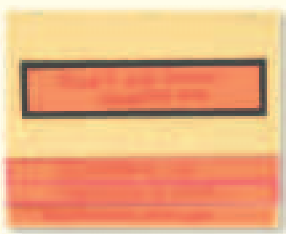


Plants and animals benefit from adaptations such as **camouflage** and **mimicry**.

Instincts and adaptive behaviors help animals survive.

Make a FOLDABLES™ Study Guide

Make a Layered-Look Book. Use the titles shown. On the inside of each fold, complete the statement, and explain what conclusions you could draw about adaptations.



Think, Talk, and Write

1. **Main Idea** How do adaptations help desert plants live in dry conditions?

2. **Vocabulary** The response of an organism toward or away from a stimulus is a(n) ________.

3. **Draw Conclusions** What are some conclusions you could draw about a plant that has a thick stem?

Text Clues	Conclusions

4. **Critical Thinking** Bees use a special dance to tell other bees about food sources. How is this an adaptation that helps the bees' chances of survival?

5. **Test Prep** **An insect that looks like a leaf is an example of**
   - **A** mimicry.
   - **B** camouflage.
   - **C** an instinct.
   - **D** a tropism.

6. **Test Prep** **An adaptation in response to seasonal changes is**
   - **A** a hydrotropism.
   - **B** a defense mechanism.
   - **C** mimicry.
   - **D** hibernation.

Writing Link

Personal Narrative

Write a first-person narrative from the point of view of a chameleon. Tell about the chameleon's life, and describe how it hides from predators. Include a beginning, middle, and end to the story.

Math Link

Calculate Migration Rate

A migrating bird flies 50 km each day and rests 1 day after each day of flight. How many days will it take for the bird to complete its 2,000 km trip?

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Life in the DEEP

Expository Writing

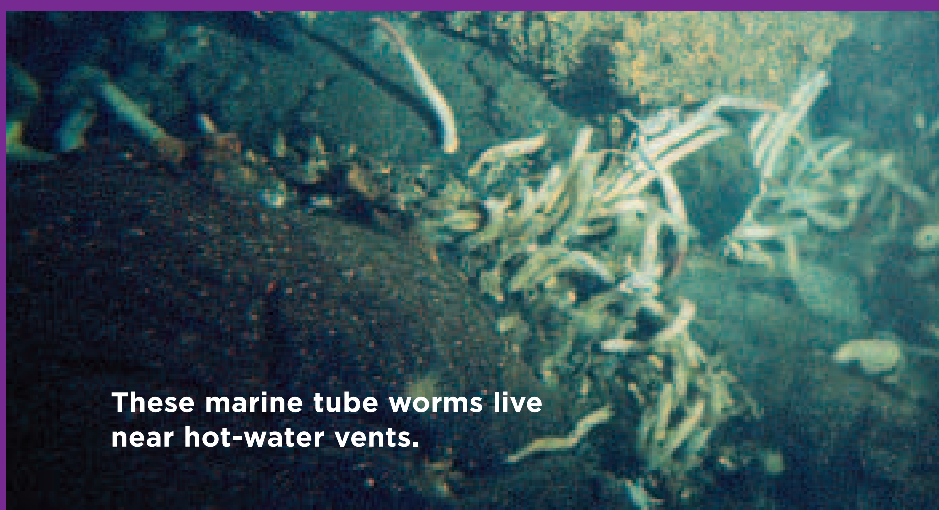
Good expository writing

- introduces the main idea and develops it with facts and supporting details
- gives important information about a topic
- summarizes information from a variety of sources
- uses transition words, such as *therefore* and *then*, to connect ideas
- draws a conclusion based on the facts and information presented

For hundreds of years, scientists thought that all life on Earth depended on sunlight. However, in the 1970s, the scientists made a startling discovery. They found organisms on the ocean floor that did not need sunlight to live. Once these organisms were discovered, scientists then questioned how these living things could possibly survive on the cold, dark ocean floor.

Earth's mantle contains hot, melted rock called magma. When breaks in Earth's crust occur on the ocean floor, magma wells up, fills in the spaces, and then gushes forth as a hot liquid called lava. Lava contains large amounts of sulfur-rich chemicals that certain types of bacteria depend upon to make food.


galatheid crab


These marine tube worms live near hot-water vents.

These breaks in Earth's crust are usually found in areas that are volcanically active. The spots that release heat and chemicals on the ocean floor are called hydrothermal vents.

Once these vents were discovered, scientists then used advanced equipment to explore these areas. They found over 300 new species of worms, clams, crabs, mussels, and fish living near hydrothermal vents. The various organisms survive in this environment because their ecosystem is based on bacteria that use chemicals, not sunlight, to make food.

Most life on Earth depends on the Sun and on photosynthesis—but not all life does! Nature is certainly full of surprises.

Write About It

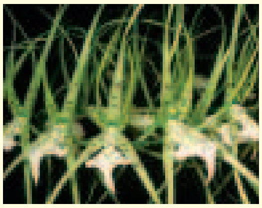
Expository Writing Write a report telling how sunlight helps support your life. Engage your reader right away, and clearly state your purpose for writing. Introduce the main idea, and develop it with facts. Use supporting details and precise verbs, nouns, and adjectives to describe and explain your subject. Do research using books and online sources. Summarize your findings at the end of the report.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

CHAPTER 1 Review

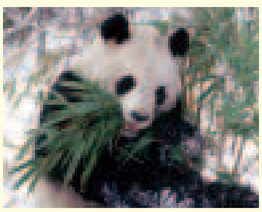
Visual Summary

Lesson 1 All living things are classified based on various characteristics.

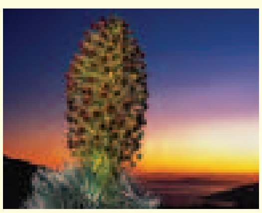


Lesson 2 Plants have structures that carry out specific functions. They use sunlight to make their own food.

Lesson 3 Animals are classified according to whether or not they have backbones.



Lesson 4 All animals have organs and organ systems that have specific functions.



Lesson 5 Adaptations are changes that help plants and animals survive in their environments.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.

Vocabulary

Fill each blank with the best term from the list.

diffusion, p. 60	**migrate**, p. 76
excretion, p. 58	**pollination**, p. 38
instinct, p. 74	**seed**, p. 38
kingdom, p. 24	**tetrapod**, p. 49

1. A young, developing plant is contained in the ________ of a plant.

2. An animal with four feet is called a(n) ________.

3. An inherited behavior that is done automatically is a(n) ________.

4. Molecules move from areas of higher concentration to areas of lower concentration in ________.

5. The largest and most general grouping of organisms is the ________.

6. Some animals ________ from one place to another.

7. The kidney is one of the organs of ________, or the removal of wastes from the body.

8. The transfer of a plant's sperm cells from an anther to a stigma is called ________.

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Skills and Concepts

Answer each of the following in complete sentences.

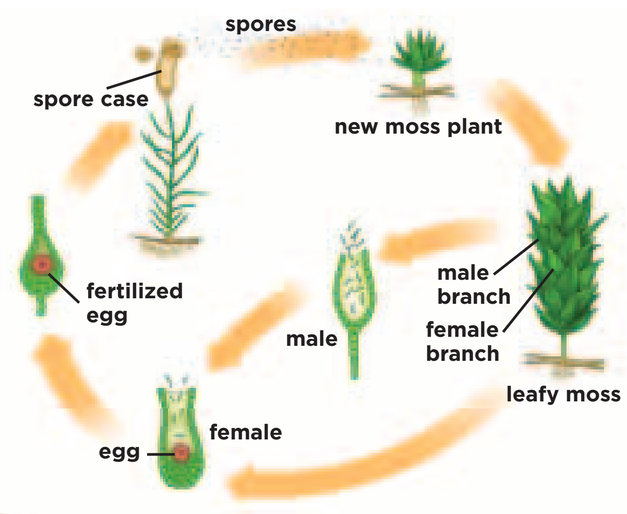
9. **Problem and Solution** How do cold-blooded animals control their body temperatures?

10. **Expository Writing** Explain how a virus reproduces.

11. **Classify** To which group of animals do sponges, worms, and arthropods belong?

12. **Critical Thinking** Some plants have very large leaves. For what kind of environment are these plants most likely adapted? Explain.

13. **Sequence** What must happen to the egg before spores are produced?



Big Idea

14. How do scientists classify Earth's living things?

Performance Assessment

Scientific-Name Game

Your goal is to research an organism such as an animal or a plant and find its scientific name, family, order, class, and phylum or division.

What to Do

1. Choose an organism that is common in your area.
2. Describe your organism's characteristics. What does it look like? How does it function?

Analyze Your Results

- What characteristics does your organism share with other members of its genus, family, order, class, phylum or division, and kingdom?
- Make a poster describing your organism. Include pictures and information from your research.

Test Prep

1. The photo below shows a bird in flight.

Which list BEST describes the adaptations that allow birds to fly?

A feathers, two wings, and a tail

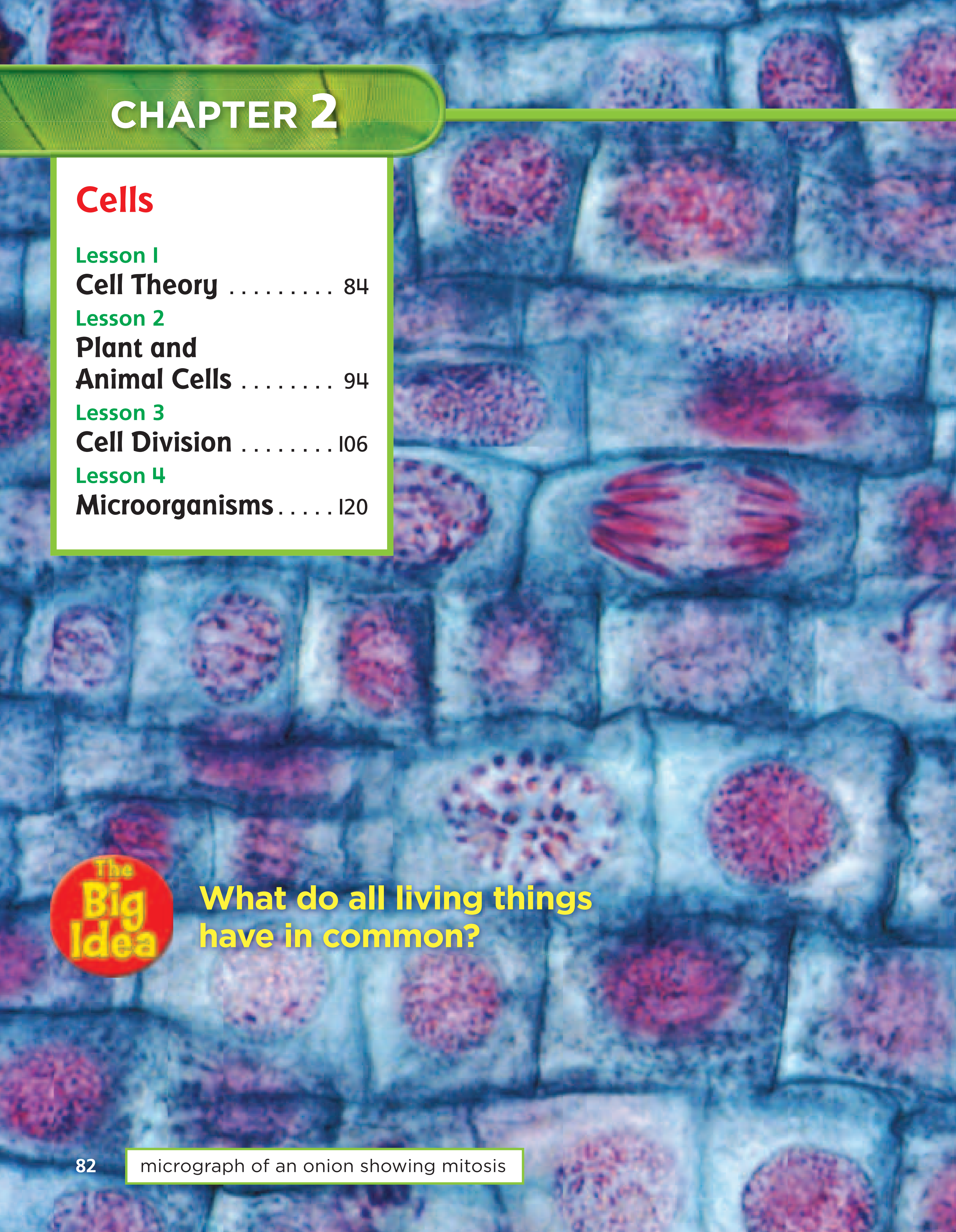
B eyes, feet with toes, and two legs

C different colors, a head, and a tail

D a beak, claws, and short legs

CHAPTER 2

Cells

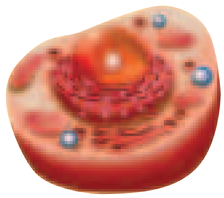


The Big Idea

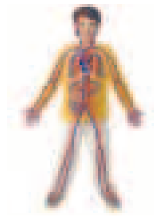
What do all living things have in common?

micrograph of an onion showing mitosis

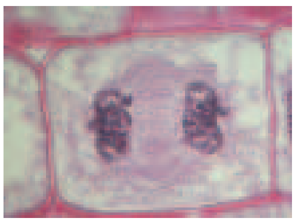
Key Vocabulary



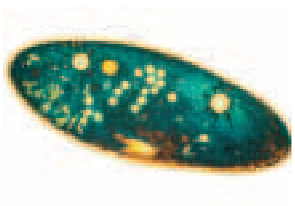
cell
The basic unit of life and the smallest part of a living thing that is capable of life. (p. 86)



organ system
A group of organs that work together to do a certain job. (p. 89)

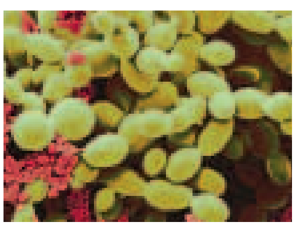


mitosis
The division of the nucleus while a cell is dividing into two identical cells. (p. 110)



unicellular
A single-celled organism. (p. 122)

binary fission
A type of asexual reproduction in which an organism divides in two. (p. 124)



budding
A form of asexual reproduction used by some fungi, such as yeasts. (p. 125)

More Vocabulary

tissue, p. 88

organ, p. 88

element, p. 90

compound, p. 90

passive transport, p. 98

osmosis, p. 98

cellular respiration, p. 101

active transport, p. 102

cell cycle, p. 108

zygote, p. 112

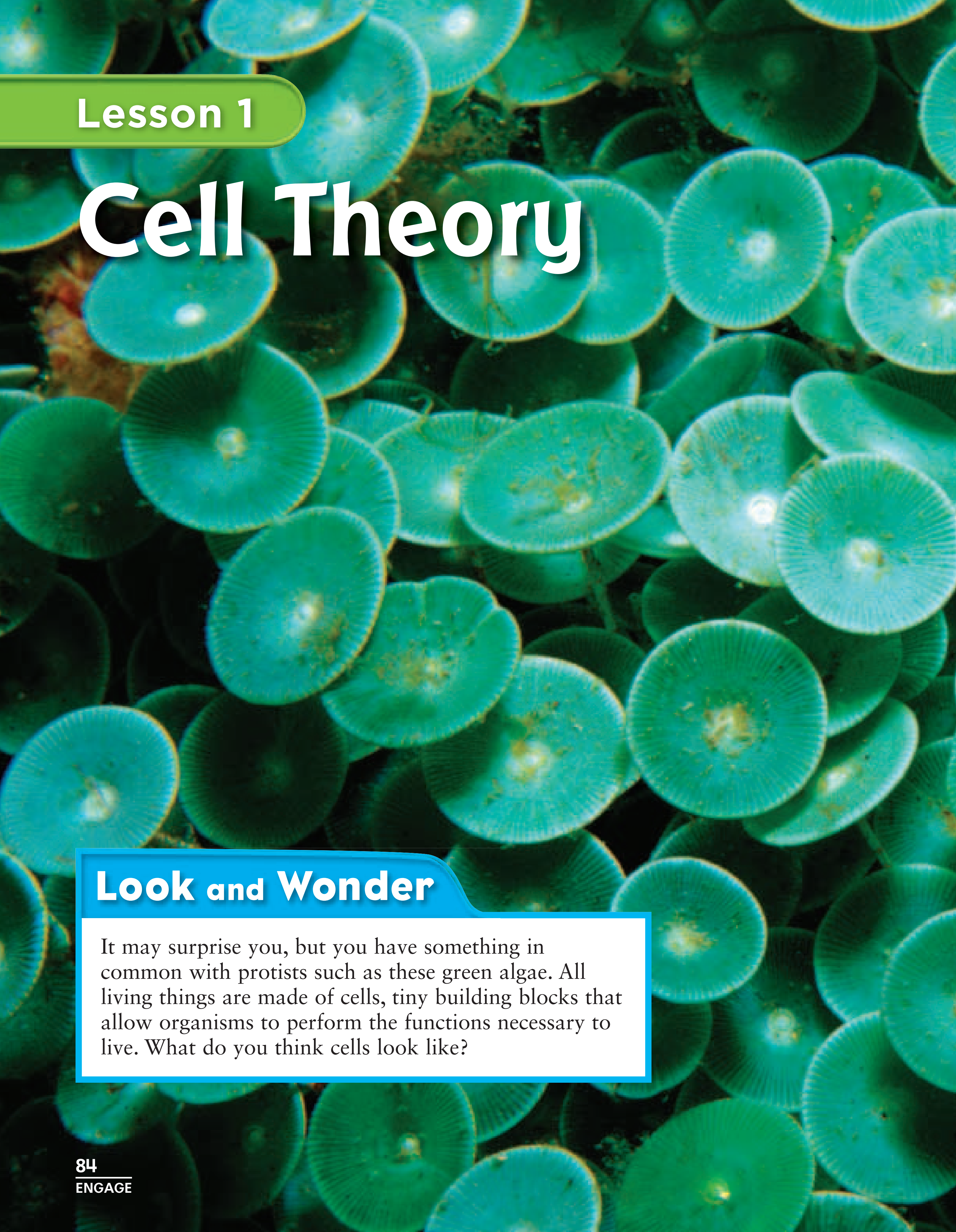
meiosis, p. 112

fertilization, p. 115

microorganism, p. 122

microbe, p. 122

conjugation, p. 124



Lesson 1

Cell Theory

Look and Wonder

It may surprise you, but you have something in common with protists such as these green algae. All living things are made of cells, tiny building blocks that allow organisms to perform the functions necessary to live. What do you think cells look like?

Explore

Inquiry Activity

What do cells look like?

Purpose

Many cells are specialized so that organisms can function and stay alive. How small are these cells that are the building blocks of all living things? Is it possible to see them? Examine pieces of cork, and record your observations. Make a chart like this one:

Tool	Description of What You See	Drawing of What You See
your eyes		
hand lens		
two hand lenses		
microscope under low power		
microscope under high power		

Procedure

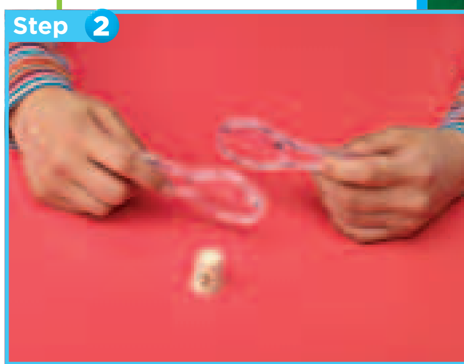
1. **Observe** Examine a piece of cork. Describe and draw what you see, noting details such as shape, pattern, texture, and color. Does cork seem more likely to come from an animal or from a plant?
2. **Observe** What details of the cork can you see with a hand lens? Using a second hand lens, try to magnify the image even more by using both lenses at once. What difficulties did you have?
3. **Compare** Examine the prepared slide of cork with your hand lens. Compare it to the cork in your hand. What are the differences between the two?
4. **Observe** View the slide through the microscope under low power. Describe and draw what you see. Repeat this process using high power.

Draw Conclusions

5. **Interpret Data** As your sample was magnified more and more, what information did you sacrifice in order to view greater detail?

Materials

- piece of cork
- 2 hand lenses
- prepared slide of cork
- microscope



Step 2

Explore More

Could you use a microscope to recognize cells in other samples? Repeat the investigation, using different samples and slides. Compare your observations. Then share your results with the rest of the class.

Read and Learn

Main Idea

All living things are made up of one or more cells.

Vocabulary

cell, p. 86
tissue, p. 88
organ, p. 88
organ system, p. 89
element, p. 90
compound, p. 90

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Reading Skill

Sequence

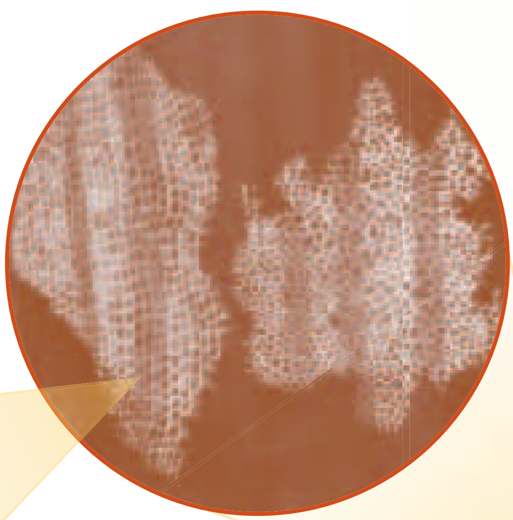
First → Next → Last

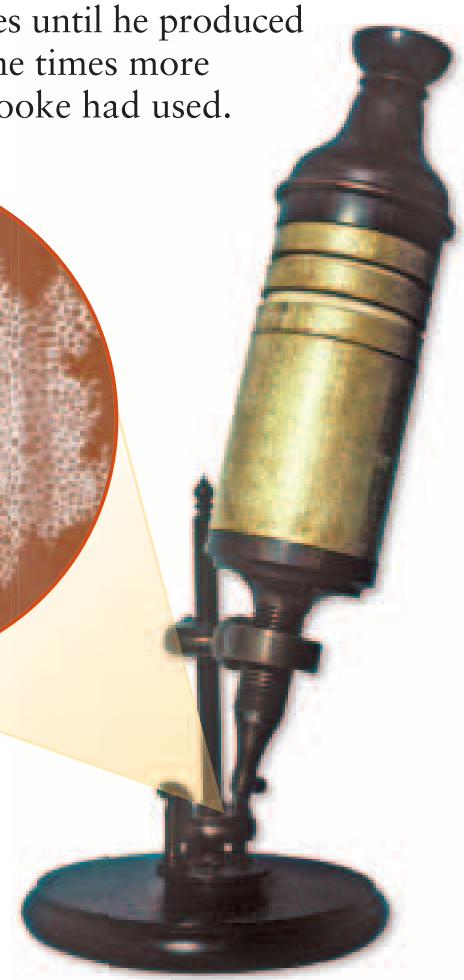
How were cells discovered?

All living things are made up of one or more cells. A **cell** is the basic unit of life and the smallest part of a living thing that is capable of life. Most cells are so small that we are not able to observe them without using a microscope. Until the development of the microscope, scientists were not even aware of the existence of cells.

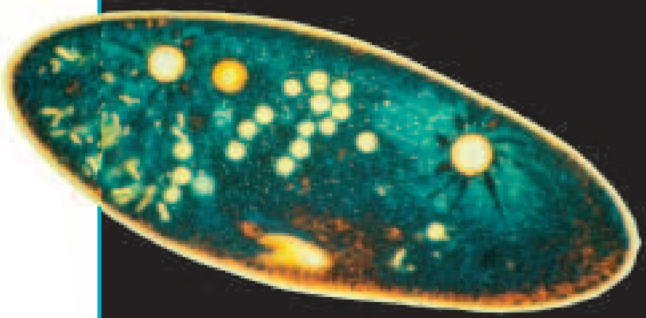
English scientist Robert Hooke was the first person to observe a cell. He was also the first to use the term *cell* to describe what he saw. In 1665, Hooke made a microscope and used it to examine very thin slices of cork. Using magnification Hooke was able to see the walls of the cork tissue, which he described as "many little boxes" or "cells."

Soon afterward, a Dutch merchant named Anton van Leeuwenhoek (LAY•vuhn•hook) was the first person to observe unicellular organisms. He ground and polished lenses until he produced a microscope that was nine times more powerful than the one Hooke had used.

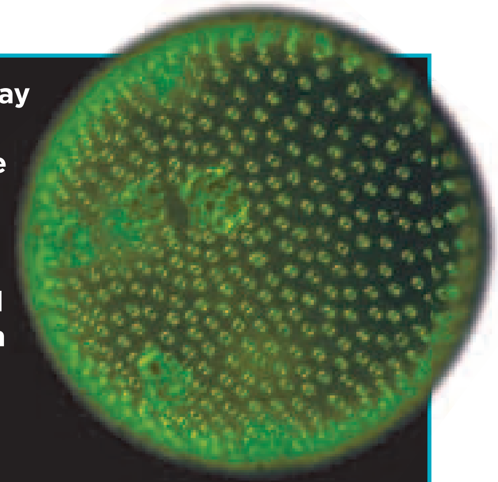




Hooke viewed cork cells through a microscope like the one at right. At left is a view of cork cells through a scanning electron microscope.



▲ A paramecium is a unicellular organism that lives in water.



A volvox colony may consist of more than 500 cells. The cells each have a whiplike tail, which they move in unison to propel the colony through the water. ▶

Developing Cell Theory

Leeuwenhoek observed many tiny living things with his microscope, making drawings of each new discovery. As detailed as his drawings of bacteria, yeast, and blood cells were, our understanding of cell structure increased over the years as improved microscopes were developed.

In 1831, Scottish scientist Robert Brown discovered the nucleus of a plant cell. German scientist Matthias Schleiden used a microscope to observe plants. In 1838, Schleiden concluded that all plants were made up of cells. A year later, Theodor Schwann, another German scientist, discovered that animals were also made up of cells. Together, Schleiden and Schwann built on the work of Hooke, Leeuwenhoek, and Brown to develop the cell theory.

Cells and Organisms

All organisms are made of one or more cells. Some organisms are unicellular, or made up of only one cell. Bacteria, paramecia, and euglenas are all unicellular organisms. Multicellular organisms are made of more than one cell. Multicellular organisms may have trillions of cells in their bodies, performing a variety of specialized functions. Your body has different types of cells that make up your skin, nerves, blood, and muscles.

Cell Theory

The *cell theory* contains three main ideas:

- **all living things are made of one or more cells;**
- **cells are the basic units of structure and function in living things;**
- **all cells come from existing cells.**

Quick Check

Sequence Make a time line that shows the development of the cell theory.

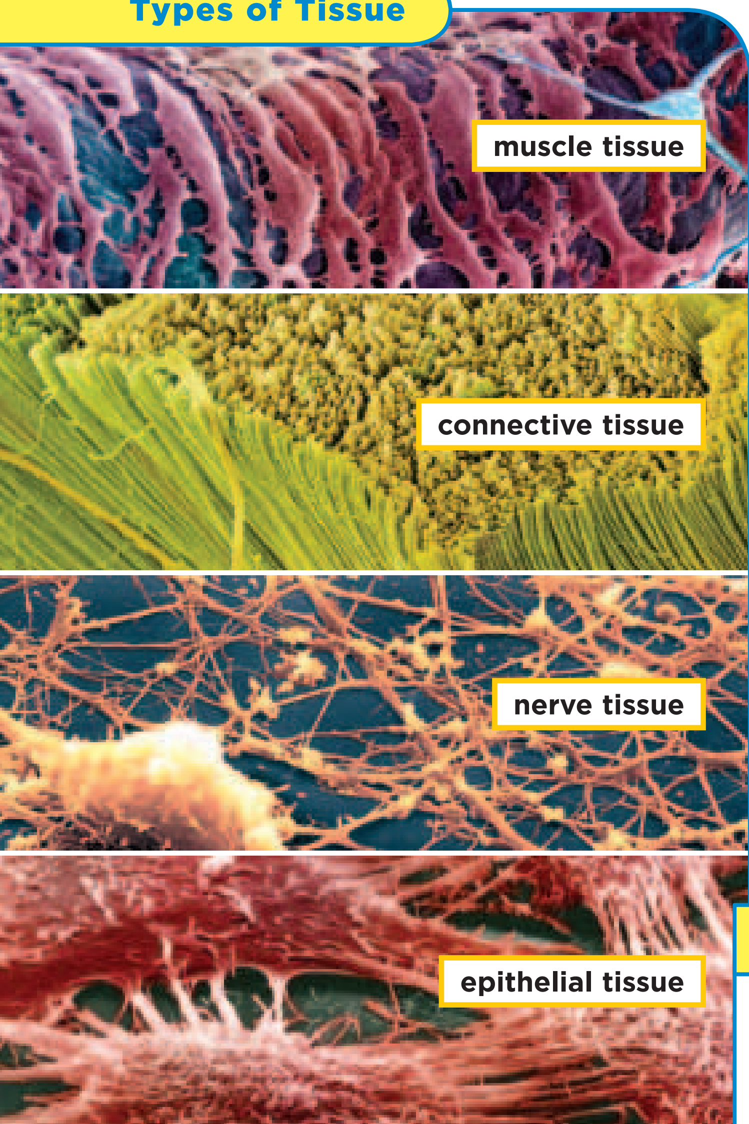
Critical Thinking What is significant about the development of more-powerful microscopes?

How are cells organized?

In some ways, cells are similar to building blocks. Together, groups of cells allow an organism to perform all of its life functions.

The single cell of a unicellular organism carries out all of the activities necessary to stay alive and reproduce. However, in many multicellular organisms, each cell performs a special function. A group of similar cells that work together to perform the same function makes up a type of **tissue**. Animals are mostly composed of four types of tissue. *Muscle tissue* is made up of cells and fibers that move bones, pump blood, and push substances through the digestive system. Bone, cartilage, tendons, fat, and blood are *connective tissue*. *Nerve tissue* carries messages throughout your body. Examples of *epithelial* (ep•uh•THEE•lee•uhl) *tissue* include the outer layer of skin cells and the cells lining your cheeks and digestive system.

Types of Tissue



Organs and Organ Systems

An **organ** is a group of two or more types of tissue that work together to carry out one specific function. Your skin is your body's largest organ, with several different layers that cover the inside of your body. The heart, also an organ, relies on nerve tissue and connective tissue to help its muscle tissue carry out its duties. The brain, lungs, and eyes are examples of other organs found in animals.

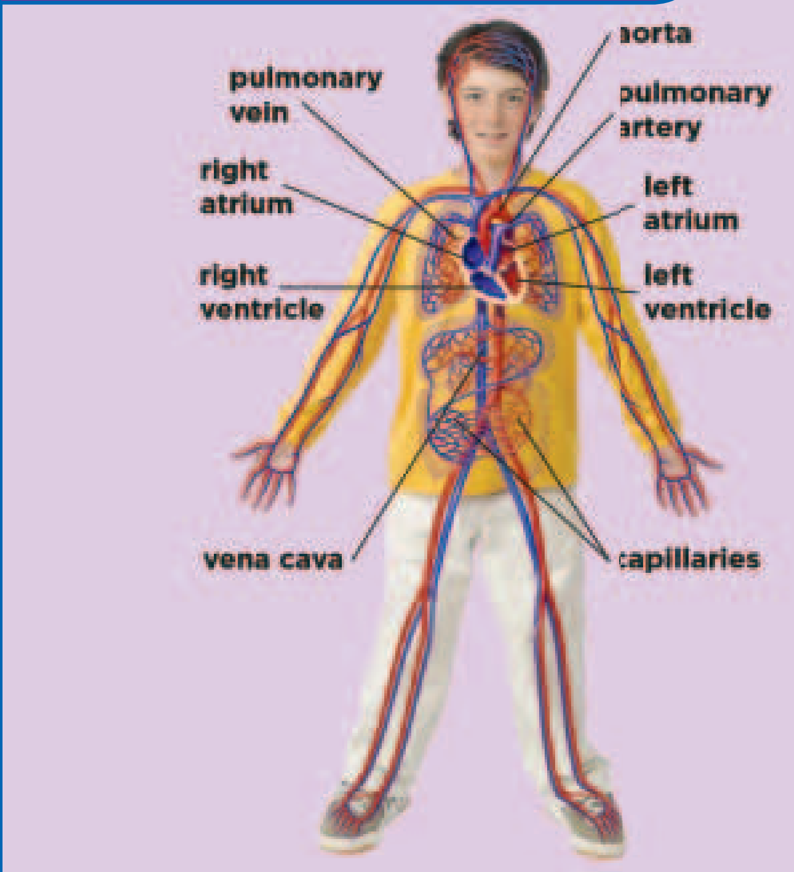
Plants also have organs. The shoots include the stem, leaves, and flowers. Shoots are responsible for a variety of a plant's life functions, including support, photosynthesis, and reproduction. The roots absorb water and nutrients from the ground and then supply these substances to all the other parts of the plant.

Read a Photo

Why does each type of tissue have a different appearance?

Clue: What function does each type of tissue perform?

Human Circulatory System



A group of organs working together is called an **organ system**. Multicellular organisms are often made up of groups of organ systems that perform various life functions. The circulatory system in humans combines blood vessels, blood, and the heart to deliver oxygen and nutrients to the cells and remove wastes. The human body relies on the lungs and the respiratory system to replenish its required supply of oxygen.

Quick Check

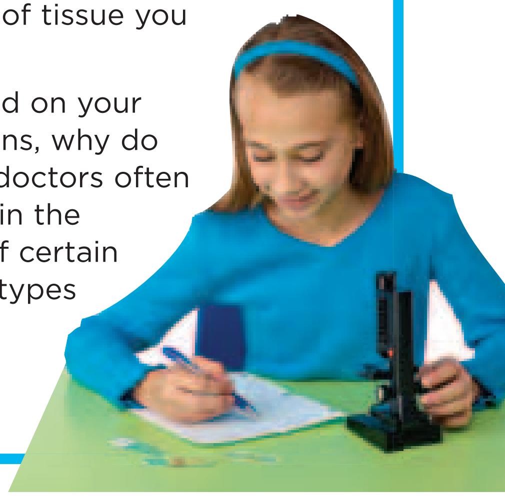
Sequence What are the levels of organization found in most multicellular organisms?

Critical Thinking What would happen if one of the organ systems in an organism did not exist?

Quick Lab

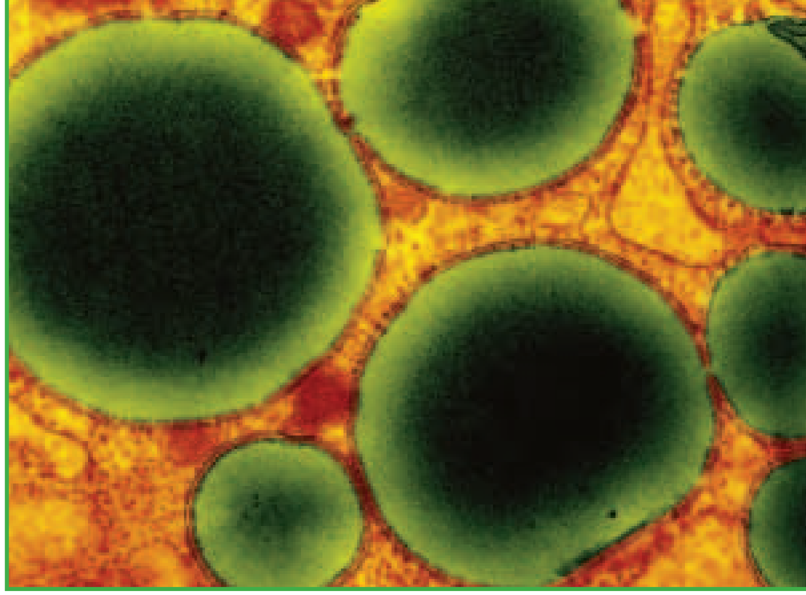
Comparing Cells in Animal Tissue

1. In multicellular organisms, cells that make up different types of tissue perform specific functions. Obtain slides of epithelial, nerve, connective, and muscle tissue from your teacher. Fold a piece of $8\frac{1}{2}$ by 11 in. paper in half lengthwise and then widthwise, making four boxes. Use this paper to record your observations.
2. **Observe** Pick up a slide, and write the name of the tissue in the first box on your paper. Use the microscope to examine the slide. On your paper draw what you see, and note anything interesting about the cells. Repeat this process for the other three slides, using one box of your paper for each type of cell.
3. **Compare** Review all four of your drawings. What are some of the characteristics of each type of cell? Can you identify any cell structures? Make additional notes on your diagrams. Label any parts you can identify.
4. **Classify** Use your textbook to label each type of tissue you examined.
5. **Infer** Based on your observations, why do you think doctors often specialize in the diseases of certain organs or types of tissue?



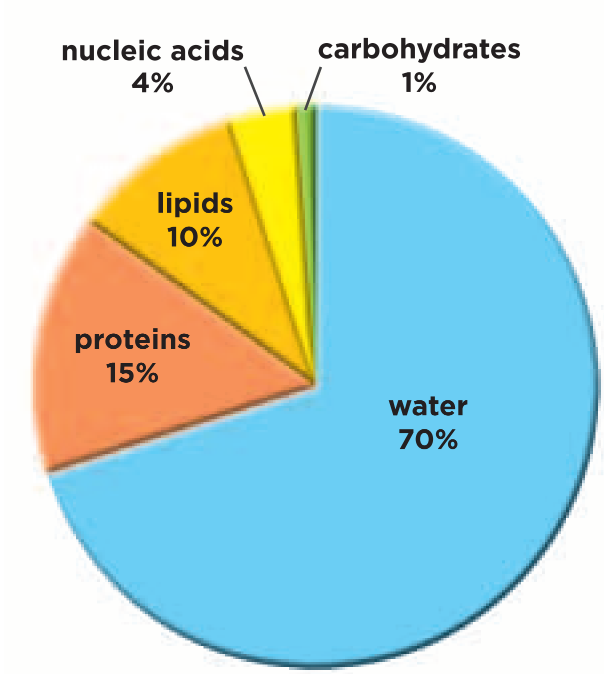
What substances are found in all organisms?

Everything in the world is made up of tiny particles called atoms. There are more than 100 different kinds of atoms, and each kind has its own properties. Atoms of a given element have the same structure. An **element** is a pure substance that cannot be broken down into a simpler substance and is made of only one type of atom. Elements can combine to form compounds. A **compound** is a new substance formed by the chemical combination of two or more elements.



▲ microscopic view of lipids within a human fat cell

Contents of Human Cells



Read a Graph

Which two substances make up one quarter of the contents of human cells?

Clue: Try adding some of the percents together.

Elements and Compounds Found in Cells

There are many compounds that are found in all cells. *Carbohydrates* are compounds made of carbon, hydrogen, and oxygen. Carbohydrates provide energy to cells. *Lipids*, which include fats, are made of carbon, hydrogen, and oxygen. Lipids store and release more energy than carbohydrates because of the way they are structured. *Proteins* are made of carbon, hydrogen, oxygen, and nitrogen. Proteins are needed for cell growth and repair. *Nucleic acids* are made of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Nucleic acids enable cells to build their own proteins. Together, these different compounds are used by cells to perform all the organism's life functions.

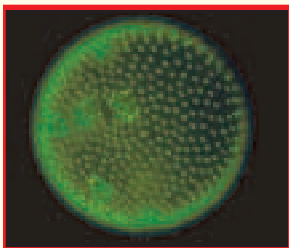
Quick Check

Sequence What are the building blocks of all compounds?

Critical Thinking How is a compound similar to a tissue?

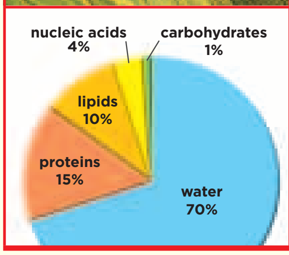
Lesson Review

Visual Summary



The **cell theory** states that living things are made of cells and that cells are the basic units of living things.

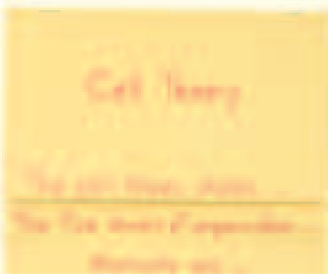
The five **levels of organization** found in living things are cells, tissues, organs, organ systems, and organisms.



Compounds, such as those found in cells, are substances made of two or more atoms of different elements.

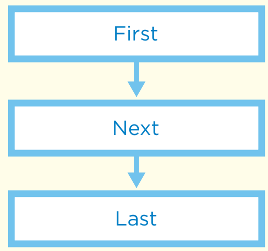
Make a FOLDABLES™ Study Guide

Make a Layered-Look Book. Use the titles shown. On the inside of each fold, explain what you learned about that topic.



Think, Talk, and Write

1. **Main Idea** What is the cell theory?
2. **Vocabulary** A group of similar cells that work together to perform the same function makes up ________.
3. **Sequence** Make a flowchart that shows the order of the levels of organization found in living things.



4. **Critical Thinking** In what ways can advances in technology lead to advances in biology?
5. **Test Prep** **Water is made up of hydrogen and oxygen. How would you classify water?**
   A a compound
   B an atom
   C an element
   D a cell
6. **Test Prep** **What are the kidneys?**
   A tissues
   B organ systems
   C organs
   D organisms

Writing Link

Explanatory Writing

Explain why the human body needs to take in compounds such as proteins, nucleic acids, lipids, and carbohydrates.

Health Link

Organ Systems

Use library resources to learn about the functions of one of the organ systems in your body. What happens if this organ system does not work properly?

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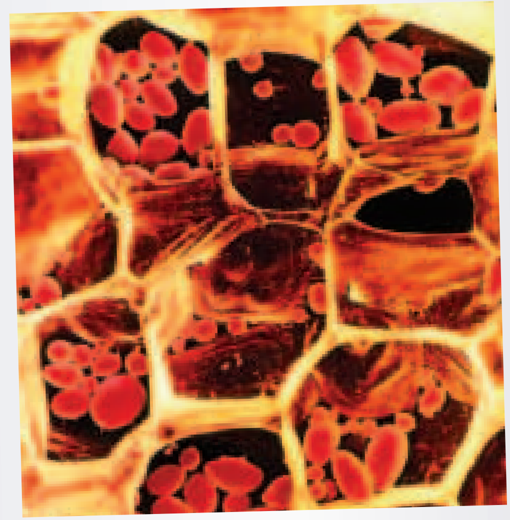
Focus on Skills

Inquiry Skill: Observe

Every cell is enclosed in a membrane, or thin covering, that allows nutrients to enter the cell and wastes to exit. Scientists know a lot about how cells work, but they always want to learn more. One way to learn is to **observe** cells during osmosis. What happens to cells when water moves from an area of low salt concentration to an area of high salt concentration?



microscopic view of potato cells

▶ Learn It

When you **observe**, you use one or more of your senses to identify or learn about something. It is important to record your observations and any measurements you take. It is also a good idea to organize this data on a chart or graph. That way, you can see your information at a glance.

▶ Try It

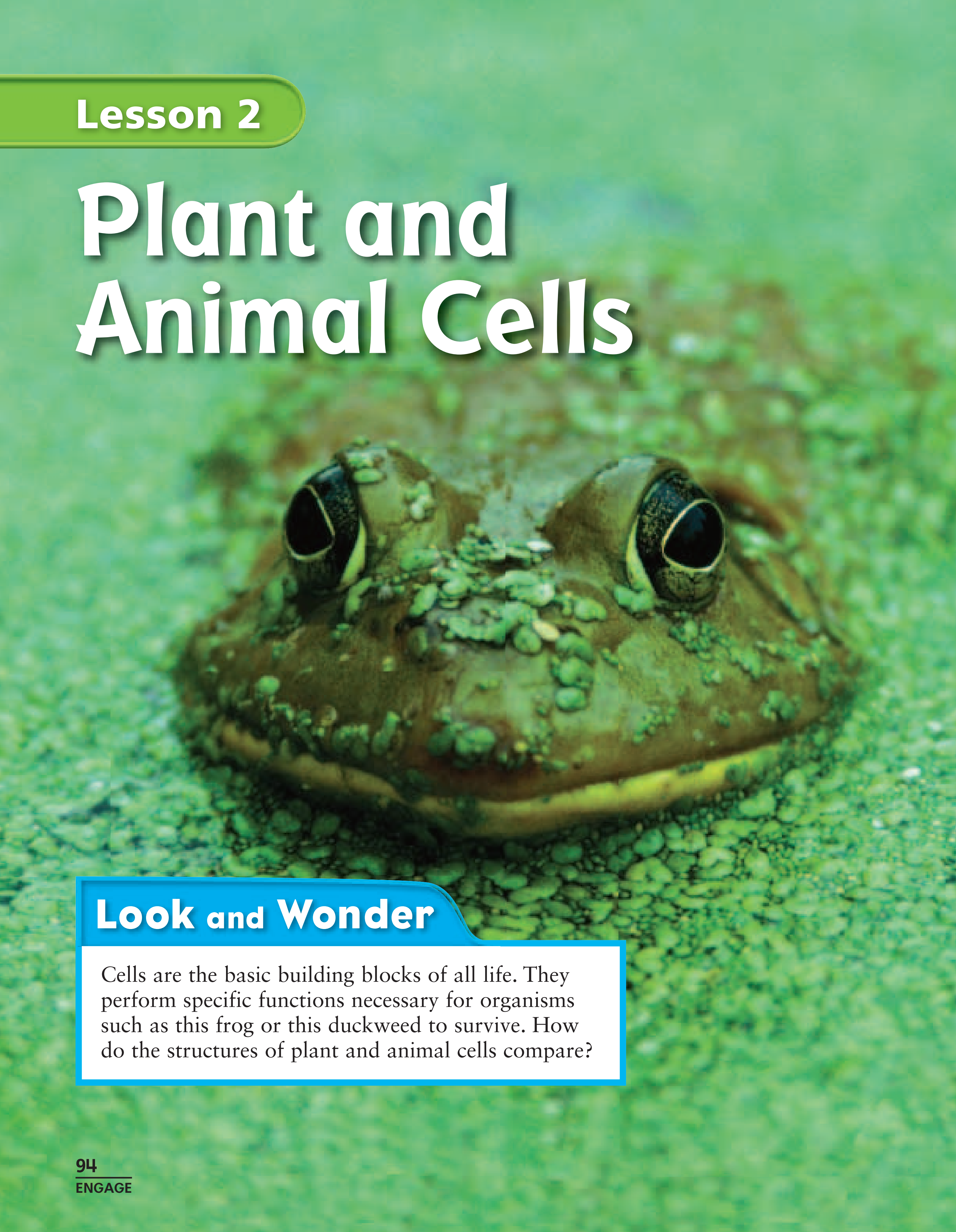
Materials **2 beakers or plastic cups, 2 paper towels, 2 potato slices, metric ruler, water, tablespoon, salt, 2 index cards, timer or clock**

1. Label one cup *Fresh Water*, and label the other cup *Salt Water*.
2. Place each cup on a paper towel.
3. Place a potato slice on each towel, and trace it.
4. Find the diameter of each slice to the nearest millimeter, and record it on a chart as shown.
5. Pour fresh water into each cup. Add 3 tablespoons of salt to the *Salt Water* cup.
6. Put a potato slice in the bottom of each cup. Place an index card over each cup as a lid, and leave the cups undisturbed for 20 minutes.
7. Remove the potato slice from each cup, and place it over its original tracing. Measure the diameter of each potato slice. What do you **observe**?
8. On your chart, record your observations about the *Fresh Water* and *Salt Water* slices.

Apply It

1. What did you observe about the *Fresh Water* potato slice?
2. What did you observe about the *Salt Water* potato slice?
3. Now put each potato slice back into its cup. Cover the cups again with the index cards, and leave them untouched for 24 hours. Then take the slices out, measure them again, and add that data to your chart.
4. Compare these results to your original findings. What can you conclude from your observations?
5. What do you think your results might be if you put one potato slice in a cup of salt water and the other in a cup of sugar water? Perform this experiment, and **observe** what happens. What new information have you learned from your observations?

Contents of Cup	Potato Measurements	My Observations
fresh water	beginning	
	after 20 minutes	
	after 24 hours	
salt water	beginning	
	after 20 minutes	
	after 24 hours	



Lesson 2

Plant and Animal Cells

Look and Wonder

Cells are the basic building blocks of all life. They perform specific functions necessary for organisms such as this frog or this duckweed to survive. How do the structures of plant and animal cells compare?

Explore

Inquiry Activity

How do plant and animal cells differ?

Purpose

Cells are the basic units of all living organisms. Plant cells and animal cells share many of the same structures. How do plant and animal cells compare? Look at epithelial cells of both plants and animals. Determine the similarities and differences.

Procedure

1. Make a wet-mount slide of a leaf from near the tip of an elodea plant. Place a small drop of water on the slide with a dropper. Use the forceps to pick up a leaf and place it in the drop of water on the slide. Lower the coverslip onto the leaf.
2. **Observe** Examine the elodea leaf under low power, focusing on the top layer of cells. Focus on one cell, and record your observations. Look at the center of the cell under high power, and draw what you see. Return the microscope to low power. Remove the slide, and follow your teacher's instructions for what to do with it.
3. **Observe** Repeat step 2, using a prepared slide of human cheek cells instead of the elodea leaf.

Draw Conclusions

4. **Compare** Describe the similarities and differences in your observations of the elodea cells and the human cheek cells.
5. **Interpret Data** What accounts for some of the similarities and differences in these cells?

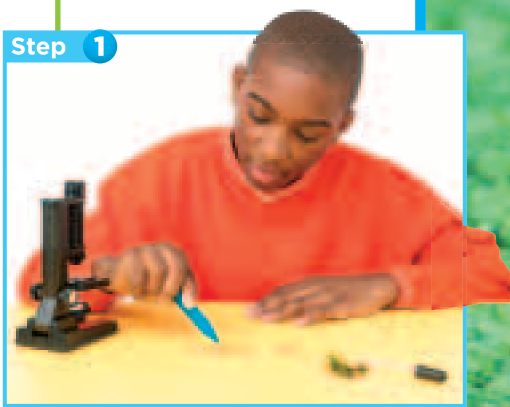
Explore More

Look at prepared slides of other cell samples. Do they look more like elodea cells or human cheek cells? Why?

Materials

- water
- microscope slide
- dropper
- forceps
- elodea leaf
- coverslip
- microscope
- prepared slide of human cheek cells

Step 1



Step 2

Read and Learn

Main Idea

Cells are made up of different structures that work together to conduct life processes. Each structure has a particular function.

Vocabulary

passive transport, p. 98
osmosis, p. 98
cellular respiration, p. 101
active transport, p. 102

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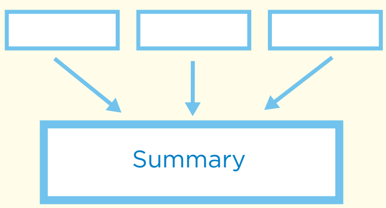
Reading Skill

Summarize



Technology SCIENCE QUEST

Explore energy for life with a farmer.

How do animal and plant cells compare?

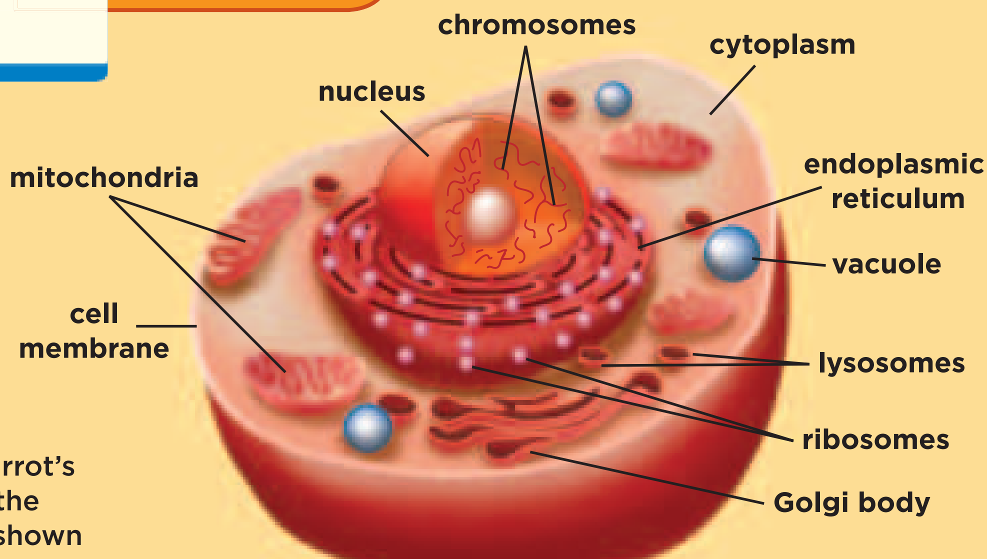
Each cell is a tiny system with parts that work together. Although plant and animal cells share many of the same parts, there are some differences. First, consider what these cells have in common.

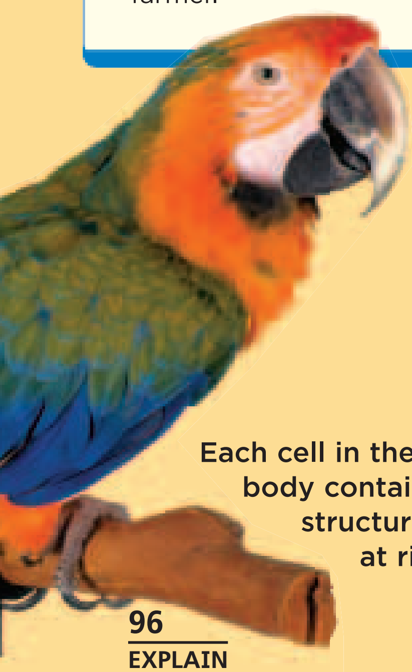
Every cell has a *cell membrane* around it that gives the cell shape. Like a protective fence around a factory, the cell membrane controls what goes into and out of the cell.

Most cells have a nucleus. The nucleus acts as the control center of the cell. It controls chemical reactions within the cell and stores important information needed for cell division. Because it is a large, dark structure, the nucleus is usually easy to see. The nucleus has its own membrane.

The nucleus also contains most of the cell's genetic information, which tells the cell how to make copies of itself. Within the nucleus, long strands of nucleic acids called *chromosomes* store directions for all cellular activities. The chromosomes save this information so that it can be transmitted to the next generation of cells and the offspring of the organism.

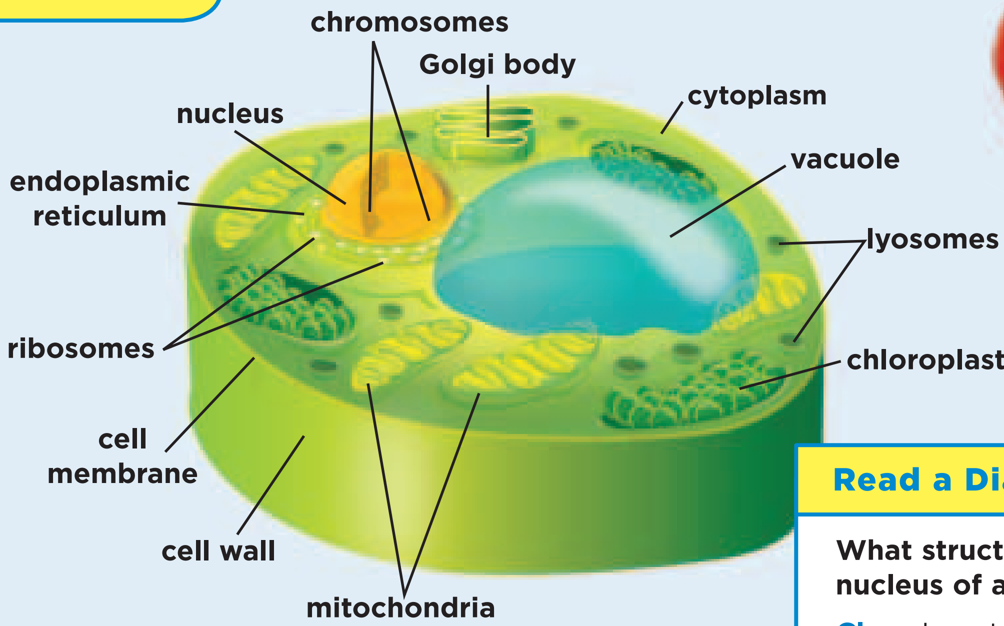
Animal Cell





Each cell in the parrot's body contains the structures shown at right.

Plant Cell



Cells in a rose plant contain the structures shown at left.

Read a Diagram

What structures surround the nucleus of a plant cell?

Clue: Locate the nucleus, and look at the surrounding structures.

The gel-like substance between the nucleus and the cell membrane is *cytoplasm*. Cytoplasm contains a large amount of water. Cell structures and chemicals that have specific functions in the cell are located in the cytoplasm. The cell's transport system moves essential materials such as proteins through the cell. This system extends throughout the cytoplasm.

Mitochondria (migh•tuh•KON•dree•uh) are the powerhouses of the cell. These rod-shaped structures perform *aerobic respiration*, in which chemicals in food are changed into energy that the cell can then use. Cells that need constant energy, such as heart-muscle cells, contain thousands of mitochondria.

Vacuoles (VAK•yew•ohlz) are saclike structures that store water and food. They also store waste materials before these substances are passed out of the cell. The vacuoles in plant cells are much larger than those in animal cells.

Cell Structures of Plants

Plant cells have some structures and chemicals that animal cells do not, including cell walls, chloroplasts (KLAWR•uh•plasts), and chlorophyll (KLAWR•uh•fil).

The *cell wall* is the stiff layer that surrounds the cell membrane. It supports the plant cell, maintains its shape, and protects it from the environment. *Chloroplasts* are structures found in many plant leaves and stems that trap the energy of light and make food. *Chlorophyll* is the green pigment inside chloroplasts. It absorbs light and gives many plants their green color.

Quick Check

Summarize What do vacuoles do?

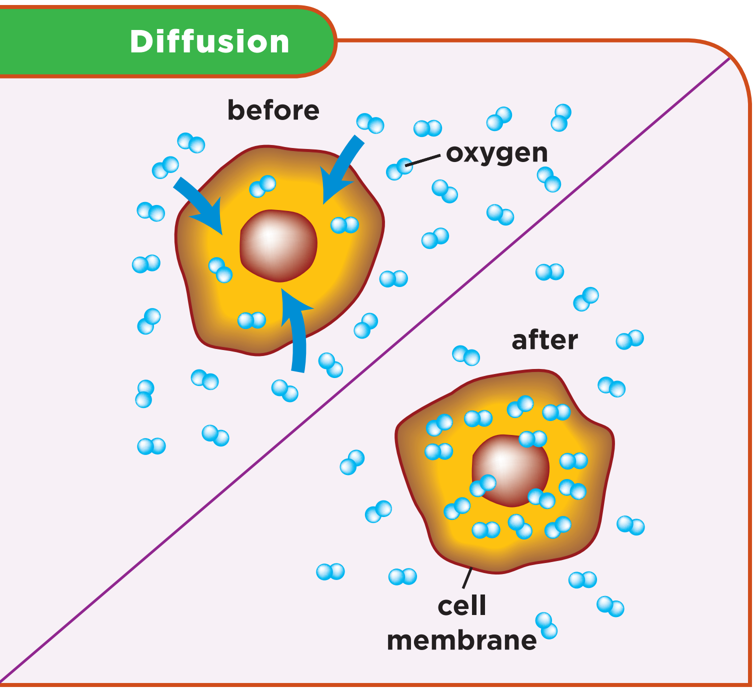
Critical Thinking Compare the functions of the cell membrane and the cell wall in a plant cell.

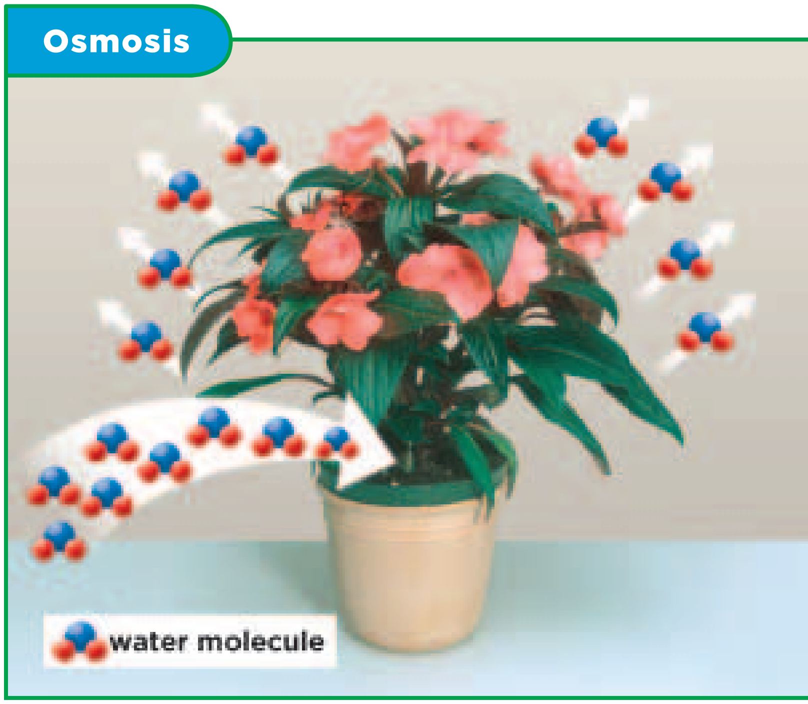
What is passive transport?

A bakery constantly receives deliveries of supplies. These supplies are used to mix, bake, and package baked goods. Trash is also taken out each day.

Your cells operate in a similar way. The blood delivers constant supplies of food, oxygen, and other substances that the cells need in order to carry out their activities. At the same time, the blood carries away waste products such as carbon dioxide. However, blood does not actually enter the cells. How do the substances your cells need and the wastes they produce move into and out of the cells?

Passive transport is the movement of substances through membranes without the use of the cell's energy. The two forms of passive transport are diffusion and osmosis (oz•MOH•sis). Both of these forms of transport are essential to living cells.





▲ In a healthy plant, the exchange of water molecules is balanced. The plant wilts when more water molecules have left the plant than are coming in.

The liquid surrounding living cells promotes passive transport. Substances such as sugar, oxygen, and carbon dioxide pass through cell membranes by the process of diffusion. Diffusion is the movement of substances from an area of higher concentration to an area of lower concentration.

The particles that make up all substances are in constant motion, colliding and spreading out. Just as adding soap to water eventually results in evenly soapy water, particles move from more-crowded to less-crowded areas without needing energy to do so.

All cells need water to live. **Osmosis** is the movement of water particles through a membrane. Water, like substances in diffusion, tends to move from areas of higher concentration to areas of lower concentration.

Suppose water and hydrogen peroxide were separated only by a thin membrane. The water particles would move by osmosis into the hydrogen peroxide—moving from the higher concentration of water to the lower concentration of water. This process would not require the use of energy.

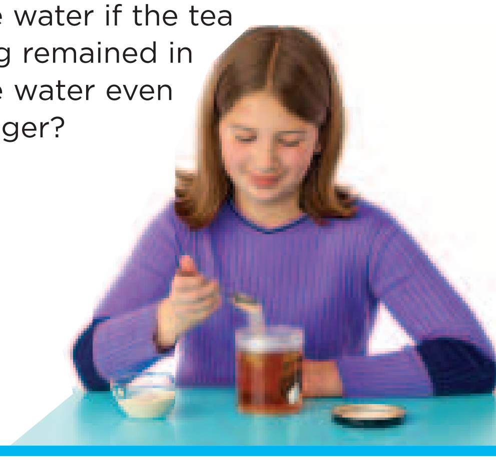
Diffusion and osmosis continue until there is an equal concentration of substances on both sides of a membrane. When the concentrations are equal, diffusion and osmosis stop. At this point, a state of *equilibrium*, or balance, has been reached.

A plant is healthiest in a state of equilibrium, when water exits and enters its cells in equal amounts. When more water exits the cells of a plant than enters them, the plant cells shrink. The cell membranes shrink with the cells, pulling away from the rigid cell walls. As a result, the plant wilts.

Quick Lab

Diffusion and Osmosis in Action

1. **Experiment** Fill a jar with very warm water. Place a tea bag in the water, and add 1 tsp of sand.
2. **Observe** Shake the jar, and then leave it undisturbed for 15 minutes. What color is the water? Is the water's color evenly distributed?
3. **Record Data** Remove the tea bag from the jar, and place it on a paper towel. Look closely at the water in the jar. Are there any tea leaves floating in the water? Cut the tea bag open with scissors. Is there any sand in the tea bag?
4. **Interpret Data** What moved into and out of the tea bag? How do you know that this happened?
5. **Infer** What do you think determines which particles move into or out of a tea bag? What would happen to the water if the tea bag remained in the water even longer?

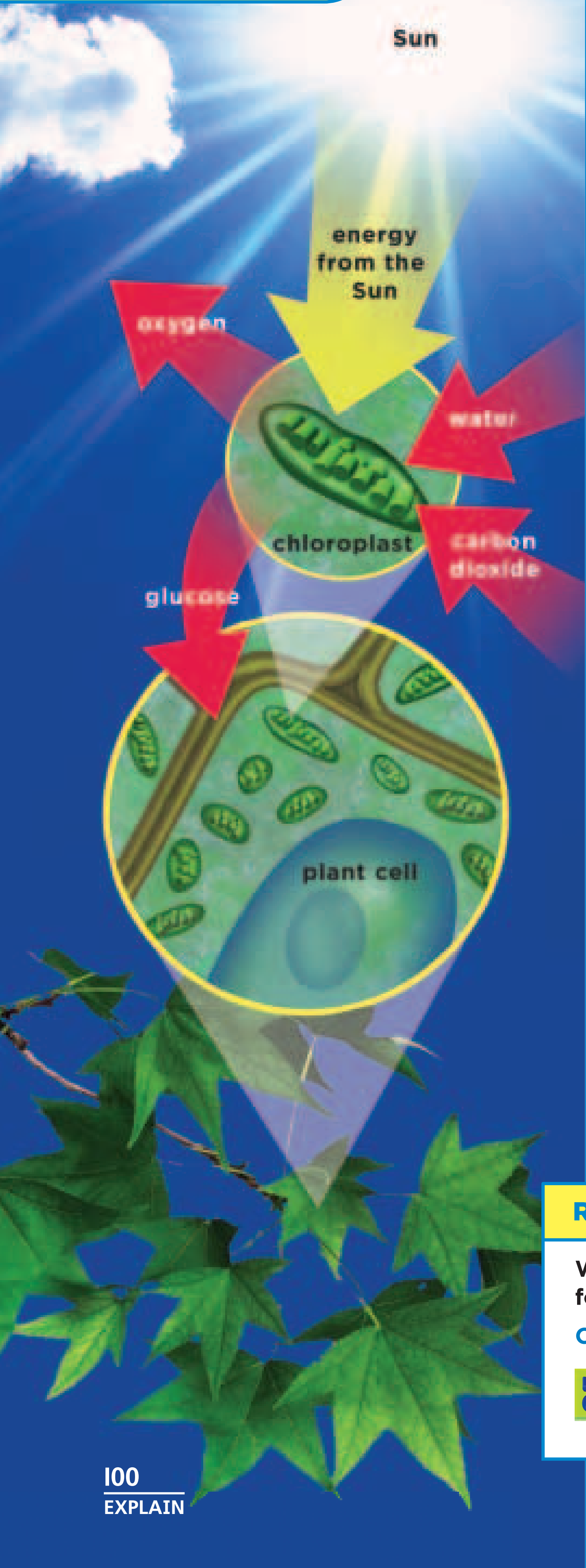


Quick Check

Summarize What takes place during osmosis?

Critical Thinking How do grapes and raisins illustrate equilibrium?

Photosynthesis



What are photosynthesis and respiration?

When you bake a cake, you mix together ingredients such as flour, baking powder, sugar, and eggs. The addition of heat produces a reaction that turns these ingredients into a cake. In some ways, the process of photosynthesis resembles baking a cake.

Photosynthesis is the process in which plants and some other organisms use energy from the Sun to produce food in the form of glucose, a type of sugar. The main reactants, or ingredients, of photosynthesis are carbon dioxide and water. The products of photosynthesis are glucose and oxygen. Energy from the Sun sets the whole process in motion. Represented as a word equation, the process of photosynthesis looks like this:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

Photosynthesis takes place inside chloroplasts. These special structures in plant cells contain the green pigment called chlorophyll. Chlorophyll captures energy from the Sun. This energy powers photosynthesis. The glucose produced in the process is stored within the organism. Oxygen, a waste product of photosynthesis, is released into the atmosphere.

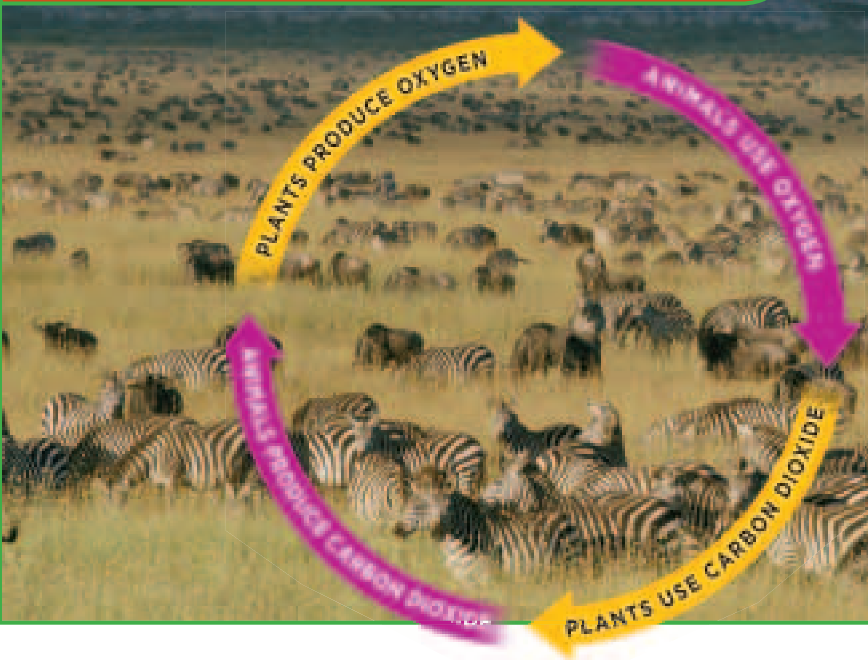
Read a Diagram

What raw materials does a plant need for photosynthesis?

Clue: Sunlight is not a raw material.

LOG ON *Science in Motion* Watch photosynthesis at www.macmillanmh.com

Photosynthesis and Respiration



Photosynthesis
carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen
happens only in cells with chloroplasts
needs light
stores energy
turns energy into a sugar
produces oxygen
uses water to make food
uses carbon dioxide

Respiration
glucose + oxygen ⟶ carbon dioxide + water + energy
happens in most cells
happens in light or darkness
releases energy
releases energy from a sugar
uses oxygen
produces water
produces carbon dioxide

Respiration and Fermentation

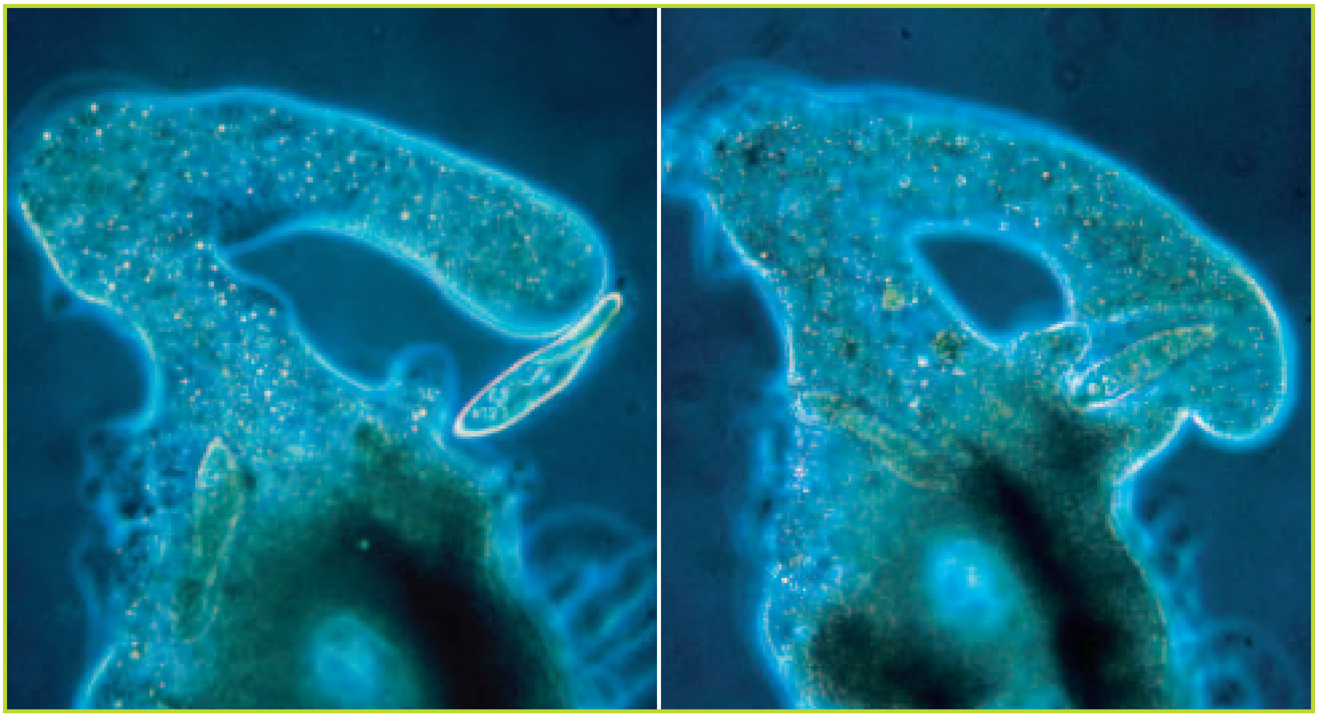
Plants and animals use the energy from glucose through a process called **cellular respiration**. During cellular respiration, cells break down glucose to release energy. Think of cellular respiration as the burning of fuel. In this case, the "fuel" is glucose instead of gas or wood. Cellular respiration takes place in the mitochondria of cells. In plants and animals, cellular respiration is usually *aerobic*, meaning "requiring oxygen." Cells use oxygen to break down glucose, releasing usable energy. This process produces water and carbon dioxide as waste products. Plants then use these waste products during photosynthesis.

Cellular respiration that does not use oxygen is *anaerobic*, meaning "without oxygen." The most common anaerobic process is called *fermentation*. It is usually associated with ways to produce or preserve foods, such as yogurt. However, anaerobic respiration occurs in all cells when aerobic respiration cannot take place. This sometimes occurs during strenuous exercise. Although a person may breathe hard when exercising, oxygen still may not be able to reach all the cells. If cells do not get enough oxygen, fermentation releases the energy needed to power the muscles. Anaerobic respiration also releases a waste product called lactic acid, which causes a burning or aching sensation in the muscles.

Quick Check

Summarize Describe the process of photosynthesis.

Critical Thinking What is the effect of strenuous exercise on the body?



▲ An amoeba ingests food by enclosing it within a pocket of the cell membrane. This amoeba has engulfed a smaller paramecium. The pocket and the paramecium are soon located inside the cell.

What is active transport?

Both diffusion and osmosis involve the passive transport of substances from areas of high concentration to areas of low concentration. Passive transport does not require that cells use energy. However, materials sometimes must move from low- to high-concentration areas, and this does require energy. When energy is required to move materials through a cell membrane, **active transport** takes place. For example, energy is required to remove the wastes produced by living cells. Structures in the cytoplasm called *lysosomes* contain chemicals that digest cellular wastes and worn-out cell parts. Lysosomes remove these wastes from the cell through active transport.

Substances can also move into a cell by active transport. However, some necessary particles are too large to pass through a cell's membrane by either active or passive transport. Substances such as large proteins and ingested bacteria enter a cell by being enclosed in a pocket of the cell membrane. This is how amoebas and many other unicellular organisms take in food.

Quick Check

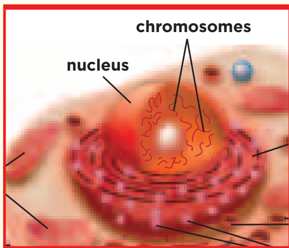
Summarize How does a cell get rid of waste materials?

Critical Thinking Why might active transport be important to a cell?

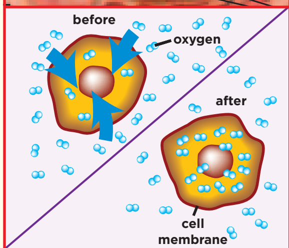
FACT Active transport can only take place across intact, closed membranes.

Lesson Review

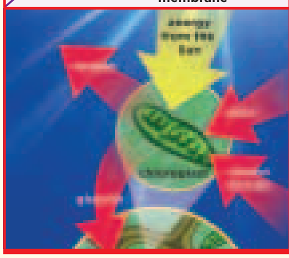
Visual Summary



Cells are made up of many parts, each with a function and a role in the activities that maintain life.



Substances move into and out of cells by **diffusion**. Water molecules pass through cell membranes by **osmosis**.



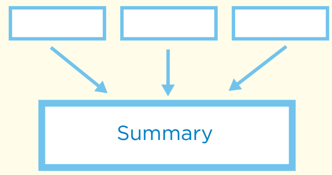
Photosynthesis is the process in which plants make food, and **cellular respiration** is the process in which cells use energy.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Use the phrases shown. On the inside of each tab, complete the phrase and provide supporting details.

Think, Talk, and Write

1. **Main Idea** What functions are performed by plant cells but not by animal cells?
2. **Vocabulary** When substances move from an area of low concentration to an area of high concentration, and energy is required, this is called ________.
3. **Summarize** Describe how plant cells make food.



4. **Critical Thinking** Why might someone experience leg pain after running for a long time?
5. **Test Prep** **A substance that exists in equal concentrations on both sides of a cell membrane is in**
   A fermentation.
   B osmosis.
   C diffusion.
   D equilibrium.
6. **Test Prep** **Which of the following are known as the powerhouses of cells?**
   A mitochondria
   B transport systems
   C cell walls
   D vacuoles

Writing Link

Fictional Narrative

What if you operated a plant or animal cell as if it were a business? How would you control the deliveries to your cell and the garbage removal? Write a short story describing your day as "cell boss."

Art Link

Cell Diagram

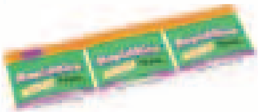
Draw a three-dimensional image of a cell, showing the structures that you have learned about. Label each structure, and write a short description of its role in the cell.

LOG ON e-Review Summaries and quizzes online at www.macmillanmh.com

Be a Scientist

Materials

2 pipettes


yeast

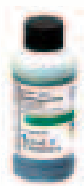

water


sugar


2 insulated wires (10 cm long)

2 test tubes


dropper


bromothymol blue


scissors


stopwatch

Structured Inquiry

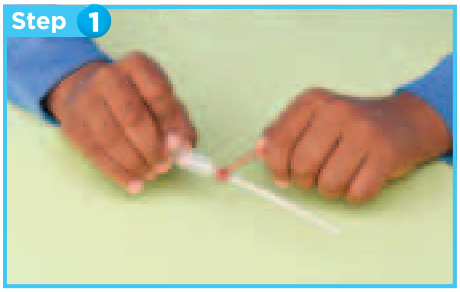
What is cellular respiration?

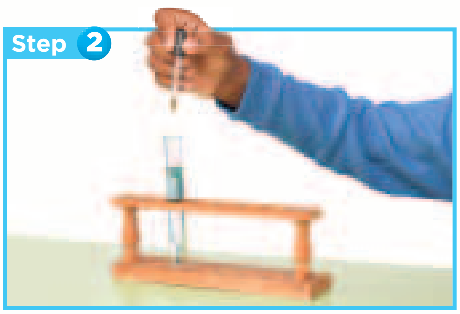
Form a Hypothesis

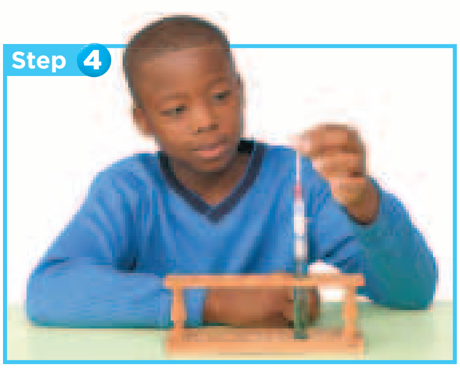
Cellular respiration is the process cells use to break food molecules into energy and carbon dioxide. Cells use this energy to maintain their functions. Unicellular organisms, such as bacteria, use this energy to regulate the flow of materials into and out of the cell, to move from one place to another, and to perform many other functions. Some organisms go through cellular respiration without oxygen. How can you measure the rate of cellular respiration in yeast? Write your answer in the form of a hypothesis: "If yeast cells are breaking down sugar molecules, then the rate of bubble production will . . ."

Test Your Hypothesis

1. Fill the bulb of a pipette with a solution of yeast, water, and sugar. Wrap a 10 cm piece of wire around the pipette; this will act as a weight to keep the pipette submerged.
2. Fill a test tube half full with water. Add 5 drops of bromothymol blue.
3. Use scissors to cut off 2.5 cm of the pipette tip. ⚠ **Be Careful.** This will allow the water to cover the pipette.
4. Hold the pipette with the tip pointed up, and submerge the pipette in the test tube. Add water to the test tube until it covers the pipette tip.
5. **Communicate** Record how many bubbles form in 10 minutes. In addition, record any changes of color in the test tube.
6. Repeat steps 1 through 5 for a second trial. Record your results.







Draw Conclusions

7 **Infer** Why was it useful to repeat steps 1 through 5?

8 **Infer** The yeast solution contained yeast, water, and sugar. What were the yeast cells doing that produced bubbles?

9 **Infer** If cells break down sugar to produce energy and carbon dioxide, what were the bubbles that formed during the experiment?

Guided Inquiry

What affects the rate of cellular respiration?

Form a Hypothesis

Many things can affect the rate of cellular respiration. If you go for a run or ride your bike, you will start to take deeper breaths. How can you increase the rate of cellular respiration in yeast? Write your answer in the form of a hypothesis: "If the yeast's environment is changed by _________, then the rate of cellular respiration will increase."

Test Your Hypothesis

Design an experiment to increase yeast's rate of cellular respiration. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

Did your results support your hypothesis? Why or why not? What affected yeast's rate of cellular respiration?

Open Inquiry

What else can you learn about cellular respiration? For example, what are some differences between aerobic respiration, which involves oxygen, and anaerobic respiration, which occurs without oxygen? Design an experiment to answer your question. Organize your experiment to test only one variable, or one item being changed. Write your experiment so that another group could complete the experiment by following your instructions.

Remember to follow the steps of the scientific process.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions

Lesson 3

Cell Division

Look and Wonder

Like all animals, a frog begins life as a single cell. Cells can grow, but there is a limit to how large one individual cell can become. How does a single cell develop into a fully grown frog?

Explore

Inquiry Activity

How does one cell become many?

Purpose

How does a single cell develop into a fully grown organism? To find out more about this, look at slides of cells that are in various stages of cell division—the process of making more cells.

Procedure

1. **Observe** Examine the first slide under low power. Use the large focus knob to get the image nearly focused. Use the smaller knob to make the image clear and crisp. Can you see any details inside the individual cells? If not, repeat this process using high power. What details do you notice inside the different cells? Look at other cells by moving the slide slightly. Draw several examples of what you observe. Repeat this process for each slide.
2. **Communicate** Compare each of your drawings to the others that you made. Which cells seem to be in similar stages of cell division? Which seem to be in different stages? Discuss this with a partner.
3. **Classify** Cut out your diagrams, and group the diagrams of cells that seemed the same. Compare your diagrams to those of your classmates. Your class will decide together how many groups to use.

Draw Conclusions

4. Tape a diagram on the unlined side of an index card to represent one of the groups of cells. Do this for each group. Save your index cards to use as a reference throughout this lesson.

Explore More

Can these same processes be observed in both plant and animal cells? Where in a plant do you think these processes are most likely to occur? Design an investigation to test your prediction. Try it, and share your results with your class.

Materials

- prepared slides of cell division
- microscope
- large piece of paper
- scissors
  Be Careful.
- tape
- index cards

Step 1

Step 3

Read and Learn

Main Idea

Cells reproduce by cell division.

Vocabulary

cell cycle, p.108
mitosis, p.110
zygote, p.112
meiosis, p.112
fertilization, p.115

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Reading Skill

Sequence

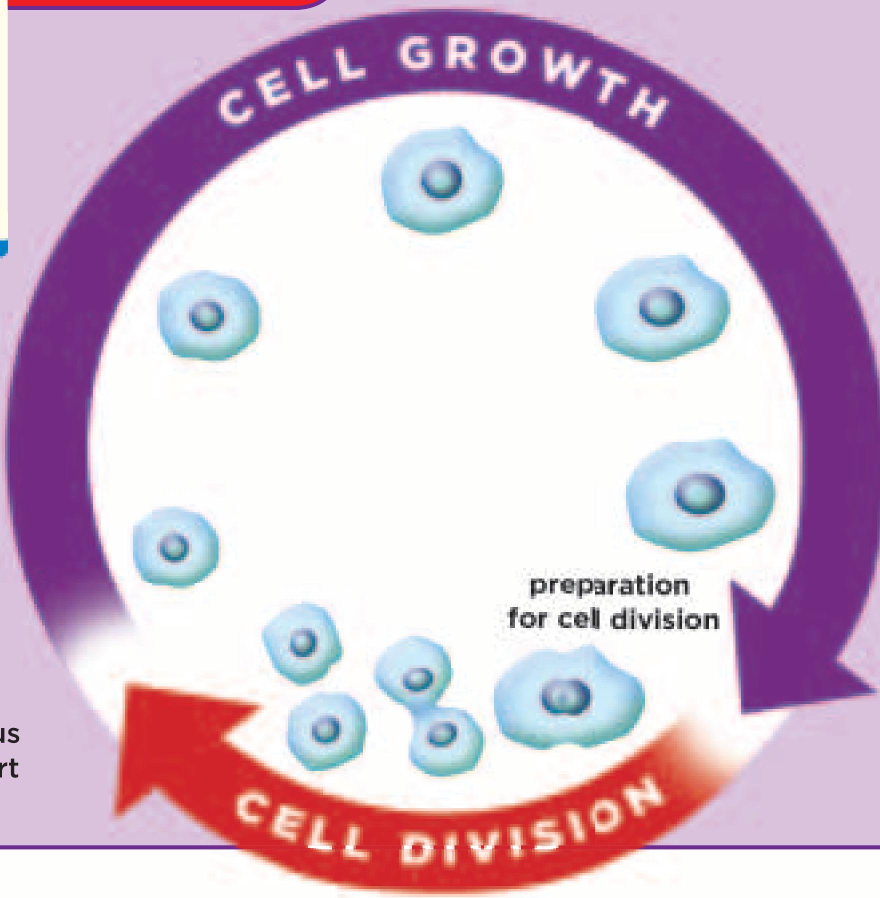
First → Next → Last

What is the cell cycle?

All living organisms are made of one or more cells. Cells grow for a certain length of time and then stop growing. After growth, some cells die. Others divide and produce new cells, replacing dead cells. This ongoing process of growth, division, and replacement is called the **cell cycle**.

The cell cycle can be fast or slow, depending on the type of organism and the type of tissue in which cells are located. For example, a bacterial cell can divide to produce two new cells in about 20 minutes. The two new cells divide to produce four, and those four divide to produce eight. In a matter of hours, a single bacterial cell can produce millions and millions of cells.

The Cell Cycle



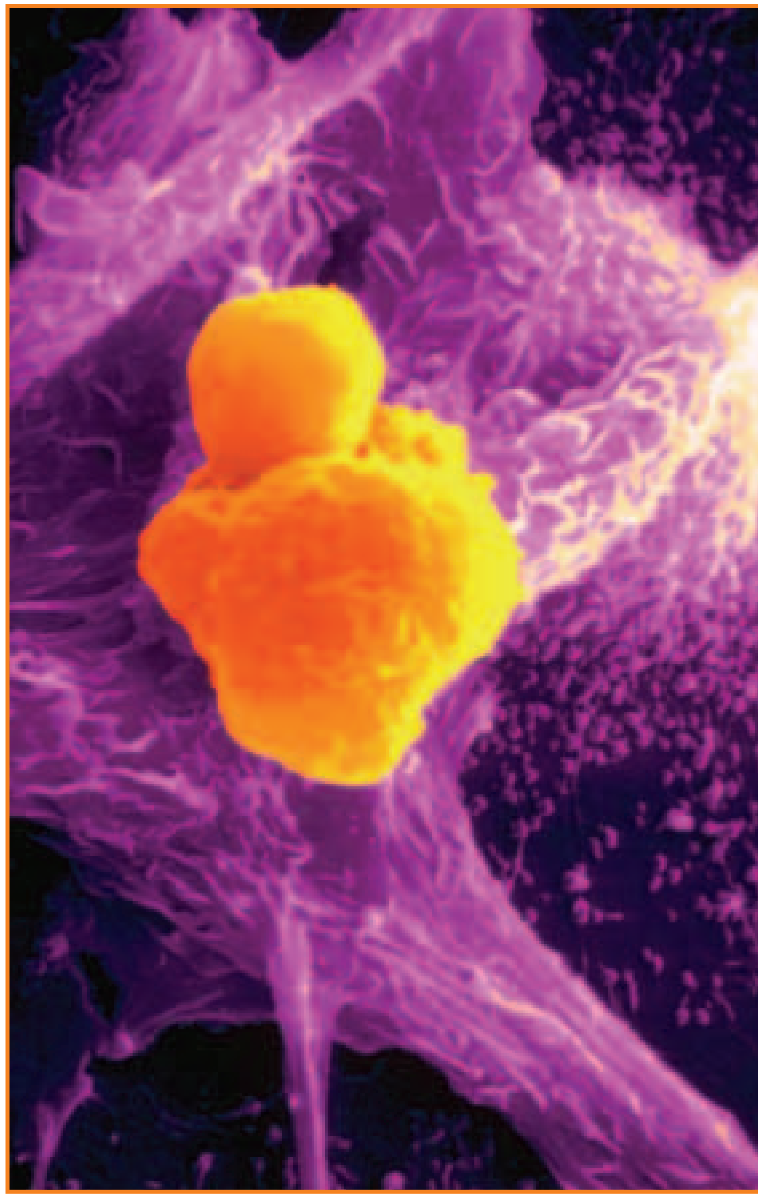
Cell growth and cell division are continuous processes that are part of the cell cycle.

FACT The human body replaces all of its red blood cells about every 120 days.

Limits on Cell Size

Cells grow to different sizes, but most cells are so small that we can see them only with a microscope. Several factors limit cell size. Each cell requires oxygen, sugars, and other nutrients. The cell must also get rid of wastes. These materials pass into and out of the cell through the cell membrane.

As a cell grows, its *volume*, the space inside, increases. To fill this growing volume, the cell needs to obtain more nutrients. The cell also needs to remove more wastes. As the cell becomes larger, the cell membrane also grows so that it is large enough to carry out these functions. The amount of space on the outside of the cell is the *surface area*. However, the cell's surface area does not grow at the same rate as its volume. This difference in growth rate is the main reason that cells remain small. Cells that grew too large would not have enough surface area to be able to obtain needed nutrients or to rid themselves of the higher amount of waste products that such a large cell would produce.



▲ In this electron micrograph, a purple macrophage (Greek for "big eater") attacks a yellow cancer cell. Macrophages are large white blood cells.

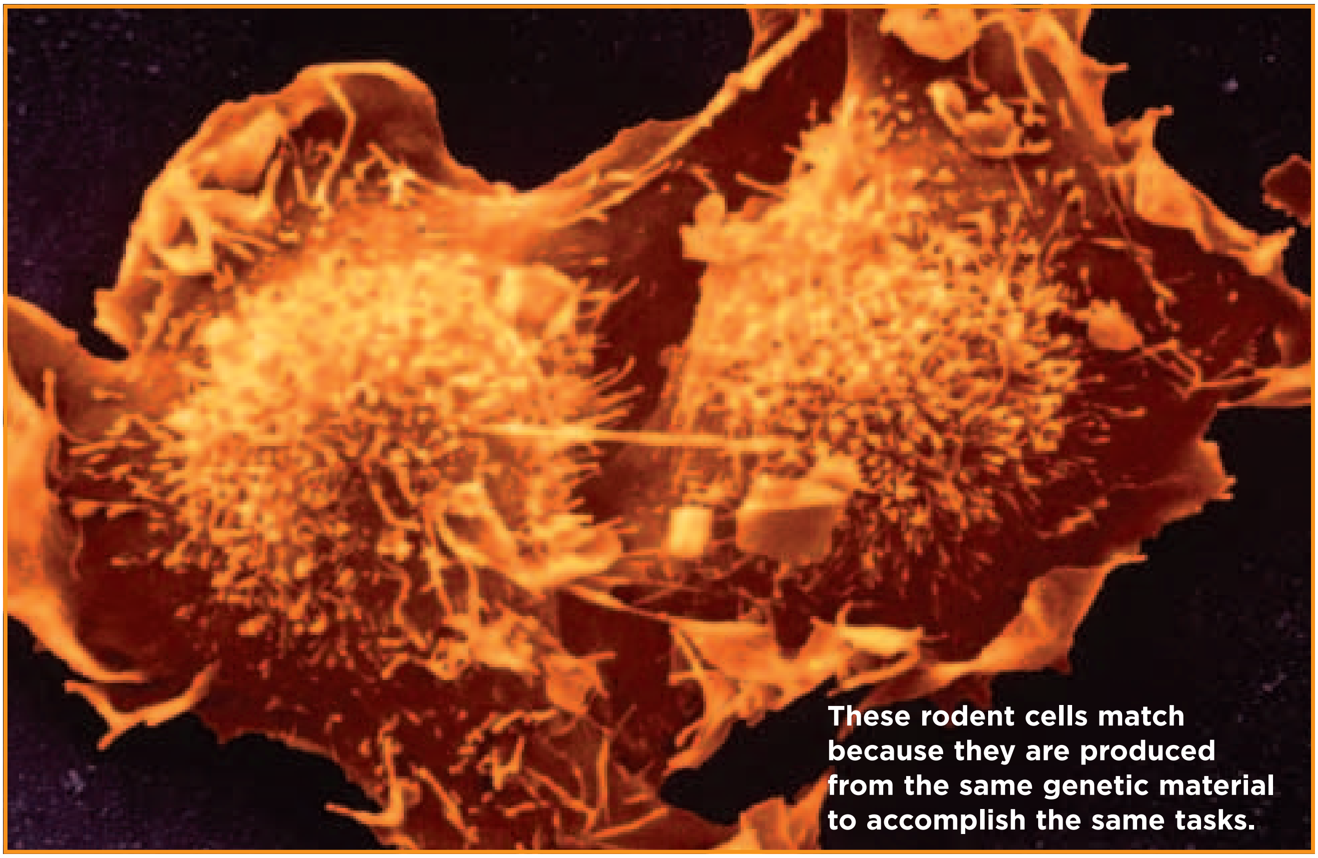
Cancer and the Cell Cycle

Organisms control their cells' growth and division. When mistakes happen, they can cause serious problems. One of these problems is cancer. Cancer occurs when cell growth and division run out of control. Cells divide faster and more frequently than they normally would. This can result in tumors, or clusters of cancer cells. Some tumors can cause life-threatening harm.

Quick Check

Sequence Outline the steps of the cell cycle.

Critical Thinking Which could grow larger: a flat cell or a cube-shaped cell? Explain.



These rodent cells match because they are produced from the same genetic material to accomplish the same tasks.

What is mitosis?

Most human cells contain 46 chromosomes. If a cell simply divided equally in half, each new cell would have only half the chromosomes of the original. This would cause serious problems for most kinds of cells.

Instead, before dividing, a regular cell copies its chromosomes, so that it has a second set. Then, as the cell divides, each new cell receives a nucleus with one full set of chromosomes. This process is called **mitosis** (migh•TOH•sis). At the end of mitosis, two identical cells have been produced.

Mitosis begins in the nucleus of a cell. First, the chromosomes become short and thick. At this stage, the cells develop double chromosomes. Each double chromosome contains both the original and its "twin," or copy. Next, the membrane that surrounds the nucleus disappears. The double chromosomes line up at the center of the cell. Then, the double chromosomes separate and move to opposite ends of the cell. A nucleus forms for each new cell. Finally, two cells form as the original cell splits down the middle.

Mitosis is often described in phases, or stages. However, it is actually a continuous process. The phases describe major events in mitosis. When the cell is not in mitosis, it is in *interphase*, the stage between cell divisions. Most of a cell's time in the cell cycle is spent in interphase.

Mitosis in Plants and Animals

In your body, mitosis takes place whenever body cells divide. Body cells include skin cells, bone cells, white blood cells, and muscle cells. In 1879, a German scientist, Walther Flemming, observed cells in various phases of division by adding a dye and then drawing what he saw through his microscope.

When a body cell begins the process of dividing into two identical cells, a second set of chromosomes forms within the cell. When the cell splits and produces two new cells, each set of chromosomes goes to one of the new cells. Each new body cell then has a full set of chromosomes and is identical to the original cell.

Both plant and animal cells undergo mitosis. However, because plant cells have cell walls, a *cell plate* forms between the two new cells that result from mitosis. The cell plate is like an extension of the cell wall. In animals, the cell membrane pinches in. In both animal and plant cells, mitosis results in two cells, both identical to the original.

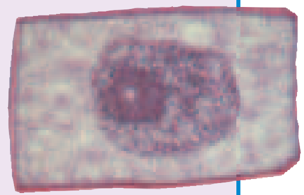
Quick Check

Sequence Outline the phases of mitosis.

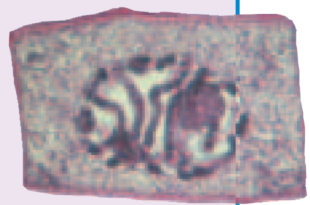
Critical Thinking A dog's body cells have 78 chromosomes. After mitosis is completed, how many chromosomes will each new cell have?

Mitosis

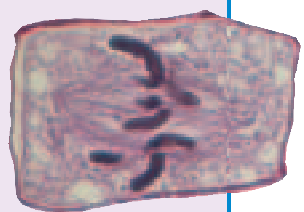
Interphase
The nucleus can be seen clearly. Chromosomes are copied near the end of interphase.



Prophase
Chromosomes become visible. The membrane around the nucleus begins to disappear.

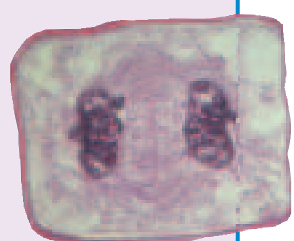


Metaphase
Chromosome pairs line up along the middle of the cell.



Anaphase
Chromosome pairs split apart and begin to move to opposite sides of the cell. The cell begins to stretch.

Telophase
A nuclear membrane forms around each set of chromosomes. The cytoplasm divides. Two new cells are formed. Each new cell then enters interphase.



Read a Diagram

What happens to chromosomes during anaphase?

Clue: Identify the location of the chromosomes.

What is meiosis?

Organisms produce new organisms through reproduction. Single-celled organisms reproduce by cell division. Most animals and plants combine chromosomes from two parents. This process is called sexual reproduction.

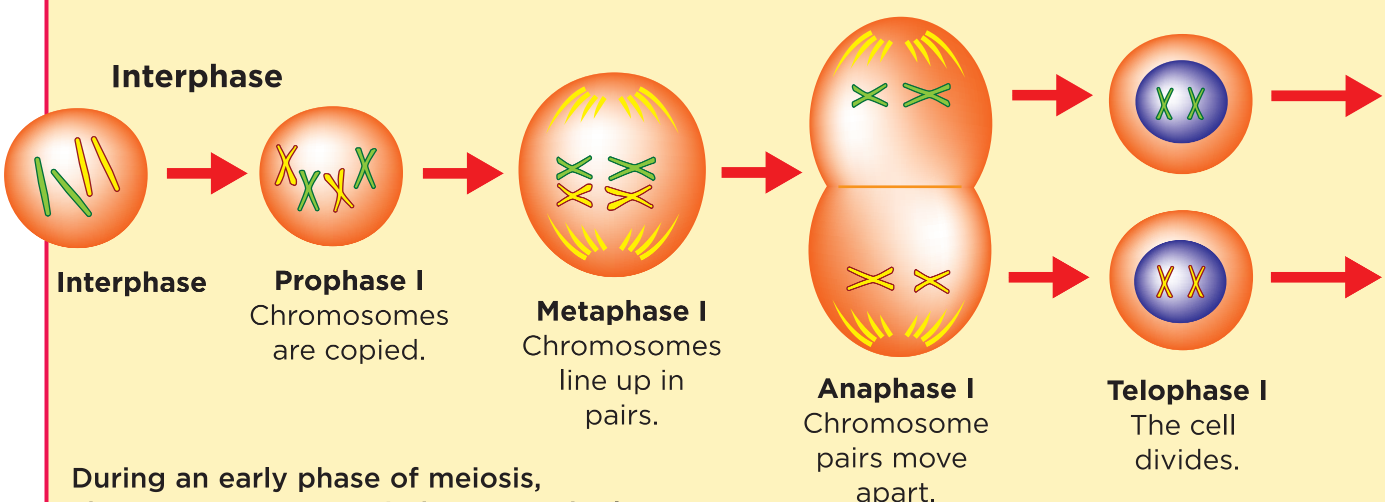
In sexual reproduction, each parent produces a sex cell. The male sex cell is the sperm. It is small and able to move on its own. The female sex cell is the egg. It is usually much larger than the sperm and does not move by itself. These two cells join to form a single cell called the **zygote**. The zygote then develops into a new organism.

Most human body cells have 46 chromosomes. If a sperm cell and an egg cell each had 46 chromosomes, what would happen when they joined? The new cell would have 92—twice as many chromosomes as it should have.

However, zygotes do not actually have twice as many chromosomes as regular cells. This is because sperm and egg cells are produced through a special kind of cell division called meiosis. In **meiosis**, the nucleus of a cell divides twice. The end result of this process is the production of four cells, each with half as many chromosomes as are found in the original cell. Every mature sex cell has only half as many chromosomes as the regular cells of an organism.

Human sex cells each contain 23 chromosomes. As a result of sexual reproduction, these sex cells combine to form a zygote with 46 chromosomes, just like the regular cells of each parent. The offspring, or the organism that results, receives chromosomes from both parents. It therefore receives characteristics and genetic information from both biological parents.

Meiosis

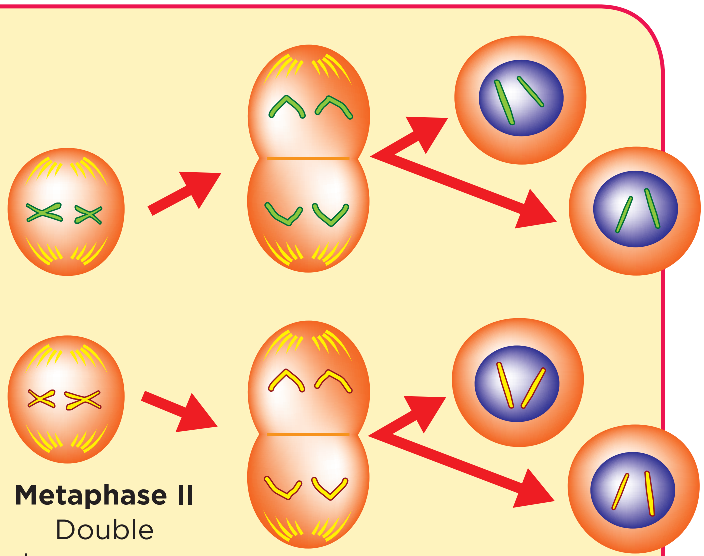


During an early phase of meiosis, chromosomes are copied once. In the latter stages, two cell divisions occur, producing four cells, each with half the number of chromosomes of the original cell.

Comparing Mitosis and Meiosis

In some ways, meiosis is similar to mitosis. Compare the diagram of meiosis below to that of mitosis on page 111. Both processes begin in the nucleus, after chromosomes have been copied. Both result in more cells than previously existed.

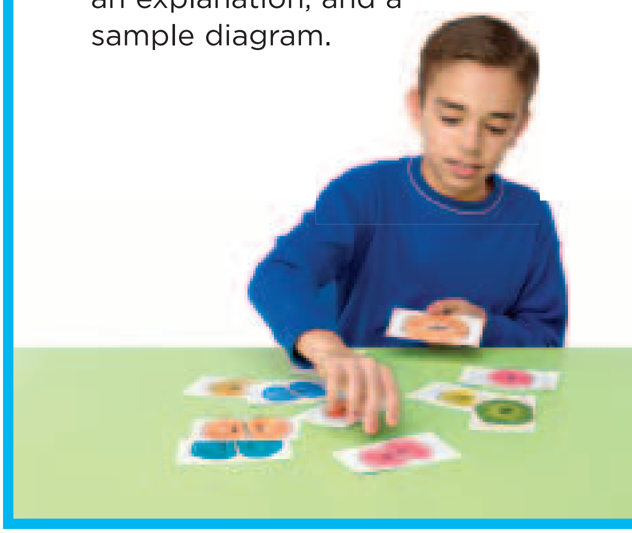
However, there are several notable differences between the two types of cell division. The most significant difference is that mitosis produces cells with the same number of chromosomes as the original cell, but meiosis produces cells with half as many chromosomes as the original cell. In order to accomplish this, there are two cell divisions in meiosis, compared with one in mitosis. The final result of mitosis is two cells, but the final result of meiosis is four cells.



Quick Lab

Mitosis Mania

1. Carefully examine pictures of the various stages of mitosis. Use index cards of previous observations if available.
2. **Compare** Look carefully at each picture, and consider all the phases of mitosis. If pictures are of the same phase, place them together.
3. **Classify** In which grouping does each picture belong? Place each picture in the appropriate category. Be prepared to explain your choice for each picture.
4. **Interpret Data** Working in groups, arrange the pictures according to the phases the cells are in. Write the definition of each phase, an explanation, and a sample diagram.



Quick Check

Sequence Outline the steps in meiosis.

Critical Thinking Why is it important to reduce the number of chromosomes in some cells by half?

How do organisms reproduce?

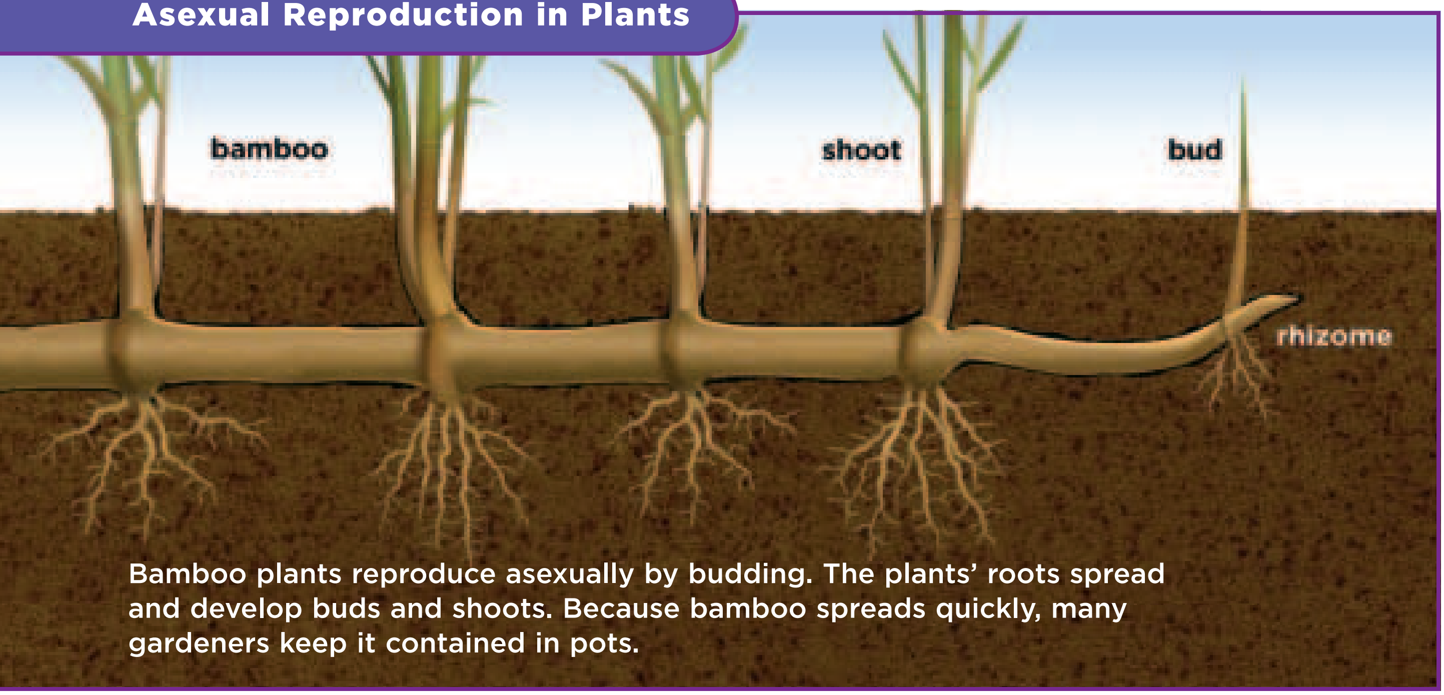
The simplest means of reproduction is asexual reproduction. Asexual reproduction is the production of a new organism from one parent. The offspring is identical to the parent. Asexual reproduction can be an advantage for some organisms. It enables them to increase their numbers quickly.

There are several methods of asexual reproduction. Some organisms reproduce by a process similar to mitosis. Others use a related form of asexual reproduction called budding. An outgrowth, or bud, develops. The bud is a product of cell division. Eventually, the bud breaks off and develops into a new organism.

For some organisms, such as sea stars, a piece that has broken off can sometimes grow into a new organism. This process is known as *regeneration*. Similarly, many plants, such as bamboo, can grow new stems from underground roots. These stems can then grow into complete, individual plants.

Hydras reproduce by a form of asexual reproduction called budding.

Asexual Reproduction in Plants



Bamboo plants reproduce asexually by budding. The plants' roots spread and develop buds and shoots. Because bamboo spreads quickly, many gardeners keep it contained in pots.

Sexual Reproduction

Some organisms can reproduce asexually or sexually. However, most of the more-complex animals reproduce by sexual reproduction.

Fertilization occurs when a sperm cell joins an egg cell. In *external fertilization* the sperm and egg cells come together outside the female's body. Most fish and some amphibians reproduce in this way. Their external fertilization requires a water environment. The sperm and egg cells are released into the water, and the sperm cells swim to the egg cells.

Most fish reproduce sexually by external fertilization.

In *internal fertilization* the sperm and egg cells come together inside the female's body. Reptiles, birds, and mammals reproduce in this manner. Birds and most reptiles lay fertilized eggs, which develop into live young outside the body of the mother. The eggs of most mammals are inside the female's body through their entire development into live young. Because their eggs are more protected, most mammals do not need to release as many eggs as reptiles and birds do.

Regardless of where fertilization occurs, the zygote begins to divide by mitosis. Eventually, from one cell, a new organism develops.

Quick Check

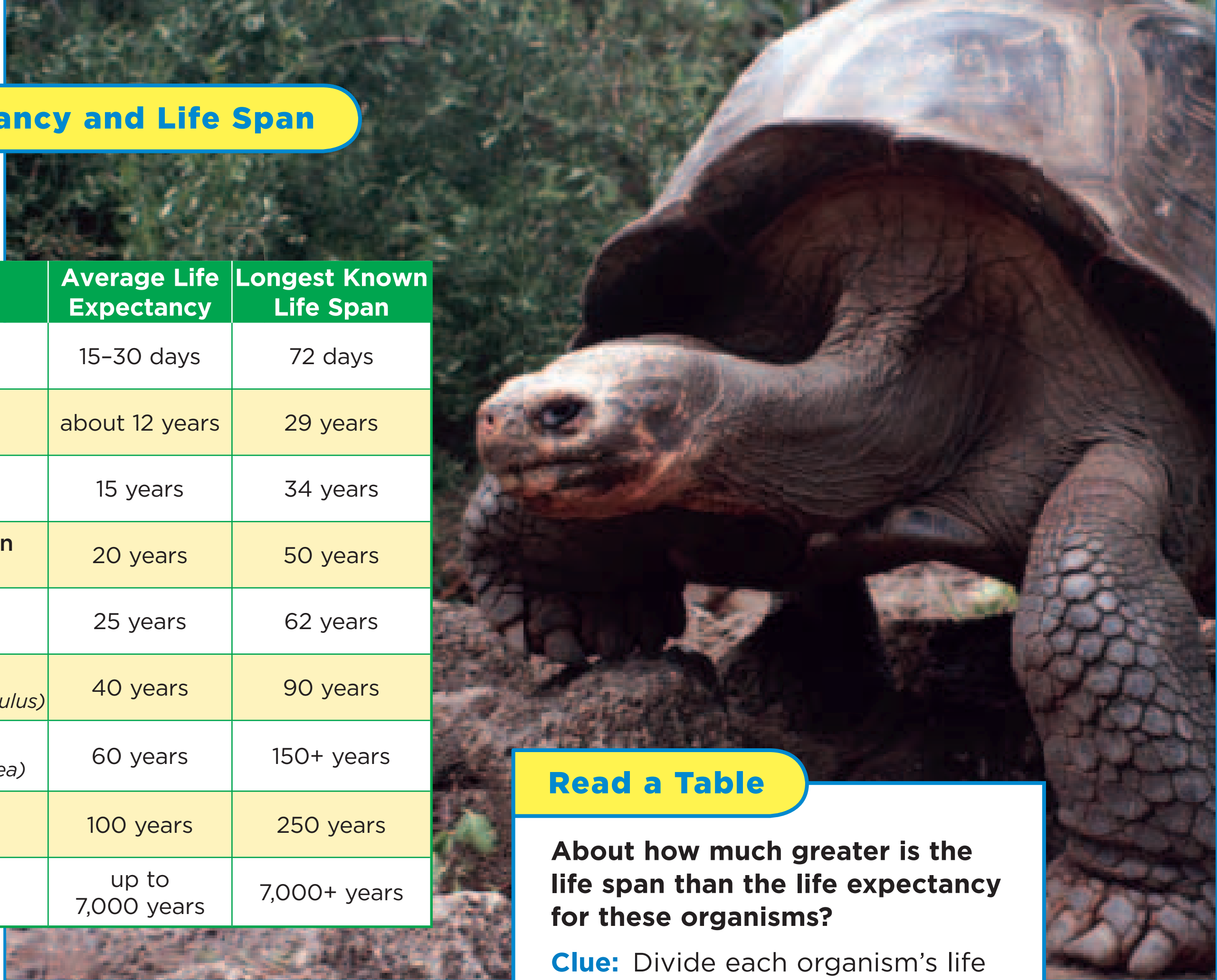
Sequence List the steps by which a bird produces offspring.

Critical Thinking Why is it important to grow plants such as bamboo in containers?

Birds and mammals produce offspring after internal fertilization. ▶

Life Expectancy and Life Span

Organism	Average Life Expectancy	Longest Known Life Span
housefly *(Musca domestica)*	15–30 days	72 days
dog *(Canis familiaris)*	about 12 years	29 years
cat *(Felis catus)*	15 years	34 years
bottlenose dolphin *(Tursiops truncatus)*	20 years	50 years
horse *(Equus caballus)*	25 years	62 years
blue whale *(Balaenoptera musculus)*	40 years	90 years
Marion's tortoise *(Geochelone gigantea)*	60 years	150+ years
sugar maple *(Acer saccharum)*	100 years	250 years
bristlecone pine *(Pinus longaeva)*	up to 7,000 years	7,000+ years



Read a Table

About how much greater is the life span than the life expectancy for these organisms?

Clue: Divide each organism's life span by its life expectancy.

What is a life span?

Just as cells do, organisms have cycles of growth, reproduction, and death. The stages of an organism's growth and development make up its *life cycle*. An animal's life cycle includes birth, youth, reproductive age, old age, and death. The longest period that an organism can live, even under the very best of circumstances, is called its *life span*. An organism's life span is a shared characteristic of its species. For example, annuals are flowering plants with a life span of 1 year. Bristlecone pines are trees that have a life span of more than 7,000 years.

Life expectancy refers to the average amount of time that an individual of a species is likely to live. Depending on conditions, the amount of time an organism lives varies considerably. Environmental factors, such as the amount of food or water available, affect life expectancy. However, these factors do not affect life span. For example, in the United States, the human life expectancy is about 77 years, but the life span of a human is more than 100 years.

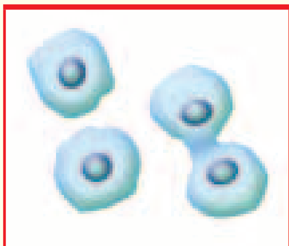
Quick Check

Sequence Diagram the life cycle of a human.

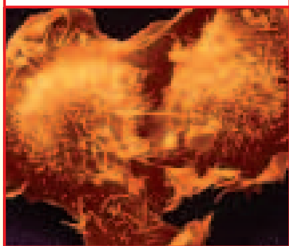
Critical Thinking Besides the availability of food and water, what factors might affect an organism's life expectancy?

Lesson Review

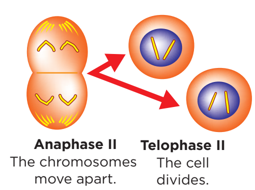
Visual Summary



The **cell cycle** includes cell growth and cell division.

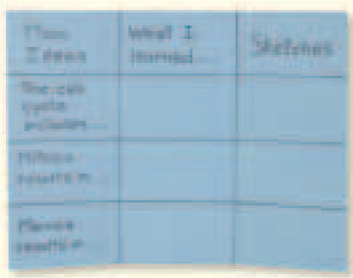


Mitosis is a process of cell division that results in two identical cells.



Meiosis results in four sex cells, each with half the number of chromosomes of the original cell.

Make a FOLDABLES™ Study Guide



Make a Trifold Book. Use the labels shown. Complete the phrases, and include sketches or diagrams that summarizes how each topic relates to cell division.

Think, Talk, and Write

1. **Main Idea** What are two ways in which cells reproduce?
2. **Vocabulary** Fertilization that occurs outside the female's body is called ________.
3. **Sequence** How are the steps of mitosis similar to those of meiosis? How are they different?

   First → Next → Last

4. **Critical Thinking** Why is it an advantage for some organisms to reproduce both sexually and asexually?
5. **Test Prep** **The amount of time an organism can live is its**
   - **A** life span.
   - **B** cell cycle.
   - **C** life expectancy.
   - **D** life cycle.
6. **Test Prep** **How many chromosomes does a human sex cell contain?**
   - **A** 12
   - **B** 23
   - **C** 46
   - **D** 92

Math Link

Calculate Cell Growth

The human body produces an average of about 2.3 million red blood cells every second. How many red blood cells are produced in 1 minute, on average?

Social Studies Link

Research Life Spans

Research human life spans throughout history. How have they changed? What might have caused these changes?

Growing Hybrid Plants

Heirloom plants carry the same traits from one generation to the next. Their seeds have been carefully safeguarded to preserve these traits. Hybrid plants come from crossing two different varieties of plants. Hybrid plants are developed by a special process that combines desirable qualities from both the "mother" plant and the "father" plant.

Let's look at hybrid corn. First, the grower plants two different varieties in rows next to each other. Let's call the first plant A and the other plant B. About 55 days later, each plant has produced a tassel, the male part of the plant, that contains pollen. The grower removes the tassel from plant A. Plant A will be pollinated by plant B, so it doesn't need its own tassel. By day 60, the female part of the corn, the kernels in rows on the ears of corn, has finally formed.

The next step, called cross-pollination, happens naturally. Pollen from plant B is released into the air. It falls on plant A and is absorbed by the kernels.

When the corn plants are harvested, these kernels are used as seeds to grow hybrid corn. The hybrid corn has traits from both plant A and plant B.

Explanatory Writing

Good explanatory writing

- explains or gives information about a process
- presents steps organized in a logical way
- gives clear details that are easy to follow
- uses time-order words or spatial words to make the process clear

Write About It

Explanatory Writing Choose a hybrid plant—a vegetable or a flower. Write an explanation of how hybrids of this plant are made.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Math in Science

How Fast Does a Bacterial Colony Grow?

Though it may seem surprising, an entire colony of bacteria can begin with a single bacterium. One bacterium divides to produce two bacteria. The two bacteria each divide to produce a total of four. The four then divide to produce a total of eight. Each cycle of reproduction is called a generation, and the time it takes for a generation to occur is the generation time. Each generation doubles the colony population. Colonies grow by geometric progression. This process is the exponential growth of a bacterial colony population (P) for a given number of generations (n). Picture yourself as a scientist who experiments with different types of bacteria. Understanding geometric progression will help you predict how fast the bacterial colonies will grow.

Use Geometric Progression

To calculate colony population (P):

- **Observe a known number of bacteria (a), and find the generation time in minutes. You may use the chart below, which lists some generation times.**
- **Find the number of generations (n). Divide the total time in minutes by the generation time.**

  Total time: 1 h + 8 min = 68 min
  E. coli generation time = 17 min
  $n = 68 \div 17 = 4$ generations

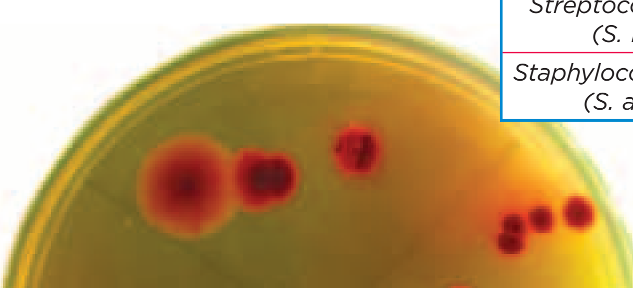
- **Find the total population by using the formula $P = a(2^n)$.**

  If you start with only 1 *E. coli*,
  $P = a(2^n) = 1 \times 2^4 = 16$.
  One *E. coli* will become 16 bacteria after 4 generations, or about 68 min.

Bacteria	Generation Time
Escherichia coli (*E. coli*)	17 min
Streptococcus lactis (*S. lactis*)	26 min
Staphylococcus aureus (*S. aureus*)	30 min

Solve It

1. If you started with 2 *E. coli* bacteria, how many bacteria would be present after 1 h and 25 min?
2. If you started with 1 *S. aureus* bacterium, how many bacteria would be present after 4 h?
3. If you started with 4 *S. lactis* bacteria, how many bacteria would be present after 2 h and 10 min?



Lesson 4

Microorganisms

Look and Wonder

These mites live on the bodies of bees. Other kinds of mites live in carpets, blankets, and furniture. In fact, there are trillions of microscopic organisms all around you. What are microorganisms, and where do they come from? How do they manage to survive?

Explore

Inquiry Activity

What temperatures encourage the growth of yeast?

Form a Hypothesis

What effect does temperature have on the growth of yeast? Write your answer in the form of a hypothesis: "If yeast is grown in warm and cold water, then the yeast will grow better in . . ."

Test Your Hypothesis

1. **Observe** Look closely at a sample of active dry yeast with your hand lens. What do you see? What would help you see more detail?
2. **Experiment** Fill two beakers with 125 mL of warm water (at about 45°C). Add 4 g of sugar to each beaker, and stir gently until the sugar dissolves completely. Label one beaker *Warm* and the other *Cold*.
3. **Use Variables** Place the beaker labeled *Cold* upright in a bowl of ice water. What are the independent and dependent variables being tested in this experiment?
4. Empty one package of active dry yeast into each beaker. Stir the contents of both beakers. After 10 minutes observe the beakers, and describe what you see. In which beaker does there seem to be more activity?

Draw Conclusions

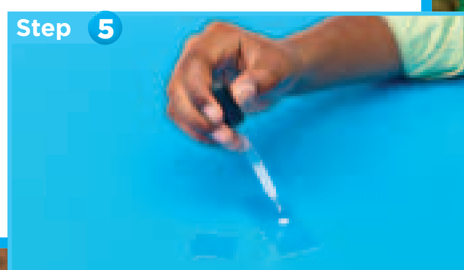
5. **Compare** Take a sample from the center of each beaker. Use the microscope under low and then high power to examine the yeast that is growing. Which sample has more yeast cells?

Explore More

Is yeast able to make its own food, or does it absorb nutrients from its environment? Make an inference, and design an experiment to test it.

Materials

- active dry yeast
- hand lens
- 2 beakers
- graduated cylinder
- warm water
- balance
- sugar
- 2 plastic stirrers
- bowl of ice water
- timer or clock
- 2 droppers
- slides & coverslips
- microscope



Read and Learn

Main Idea

Microorganisms are not visible to the unaided eye and include some fungi, some protists, and most bacteria.

Vocabulary

microorganism, p.122
microbe, p.122
unicellular, p.122
binary fission, p.124
conjugation, p.124
budding, p.125

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Reading Skill

Infer

Clues	What I Know	What I Infer

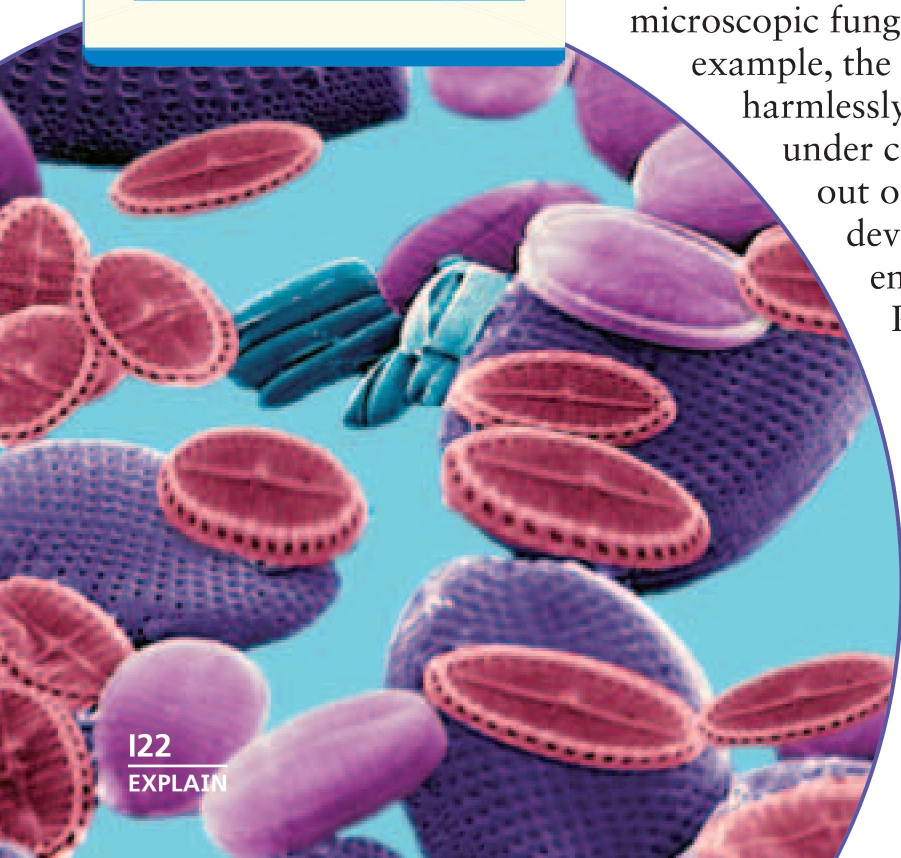
What are microorganisms?

A **microorganism** (migh•kroh•AWR•guh•niz•uhm) is an organism that is microscopic, or not visible to the unaided eye. Another word used to describe these microscopic organisms is **microbe**. Microorganisms can be unicellular or multicellular. **Unicellular** organisms are single-celled organisms, and multicellular organisms have more than one cell. Surprisingly, some unicellular organisms are visible to the unaided eye, and some multicellular organisms are not.

Microscopic Fungi

Microscopic fungi include mold and yeast. Like all other fungi, microscopic fungi cannot make their own food. Instead, they absorb dissolved nutrients from their surroundings. You may be familiar with some fungi. Mold and yeast are used to make foods such as cheese and bread. By 1859 Louis Pasteur had discovered how yeast cells affect bread. Yeast feeds on the starches in flour, producing tiny gas bubbles of carbon dioxide. These bubbles then expand the flour, causing it to rise and take up a greater volume.

Some types of microscopic fungi make antibiotics that are used to cure diseases. However, some microscopic fungi can also cause problems. For example, the fungus *Candida* normally lives harmlessly in and on the body. However, under certain conditions it can multiply out of control. Fungal infections may develop where a warm and moist environment encourages growth. Prime areas include the skin between fingers and the skin between toes. *Candida* causes infections such as athlete's foot.



◀ The varied, detailed shapes of diatoms help these protists float and capture the sunlight they need for photosynthesis.

Microscopic Protists

Most protists are unicellular, microscopic organisms. Protists cannot easily be classified as plants or animals. Plantlike protists, such as euglenas, make their own food. Diatoms, another group of plantlike protists, live in lakes and oceans. They are a major food source in marine ecosystems.

Protists that cannot make their own food often have structures that help them move to obtain food. Some have whiplike tails called *flagella* (fluh•JEL•uh). Others have tiny hairs called *cilia* (SIL•ee•uh) that beat back and forth like oars on a boat. Amoebas have structures called *pseudopods* (SOO•duh•podz), or "false feet," that extend and contract for movement.

Bacteria

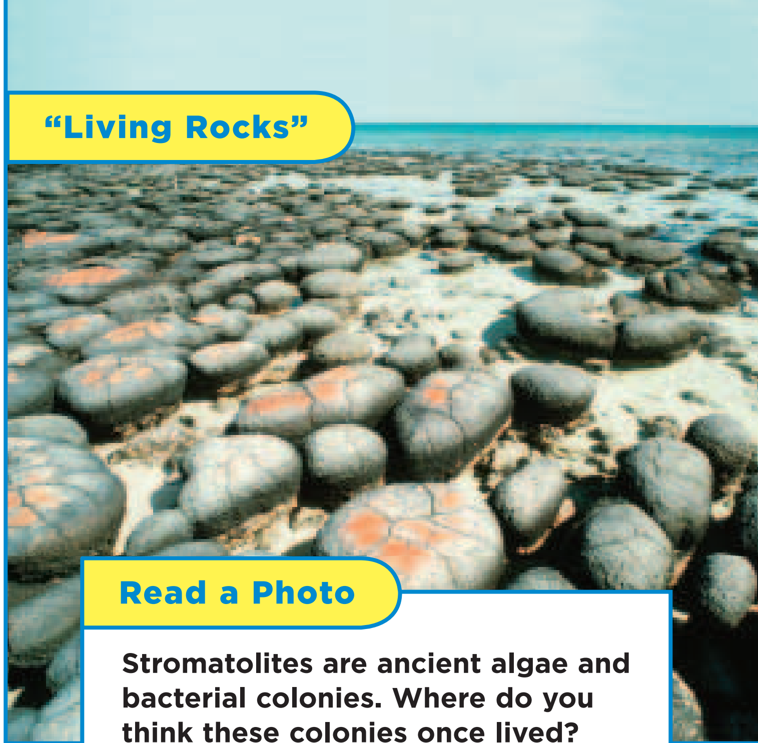
Bacteria are unicellular organisms. Although some kinds of bacteria are harmful, many are not. Bacteria are classified into two kingdoms.

Eubacteria (yew•bak•TIR•ee•uh), or "true bacteria," are the most common bacteria. Some cause disease; others help keep us well. Sphere-shaped *Streptococcus* bacteria cause strep infections. *L acidophilus* bacteria in yogurt are important for good health.

Some bacteria are part of a different kingdom. These archaebacteria (ahr•kee•bak•TIR•ee•uh), or "ancient bacteria," are found in some of the harshest conditions on Earth. Some of these archaebacteria live in hot springs, where temperatures are hot enough to boil water. Some bacteria live in anaerobic, oxygen-free, environments. These environments include areas such as volcanic vents on the ocean floor. Still other types live in the digestive tracts of animals or in very salty locations.

There are many cleaning products that are advertised as antibacterial. While they do combat bacteria that can cause infections, these products can also cause problems. When weaker bacterial strains are killed, only the stronger bacteria are left to reproduce. These stronger organisms can then develop into strains resistant to these antibacterial cleaners.

"Living Rocks"



Read a Photo

Stromatolites are ancient algae and bacterial colonies. Where do you think these colonies once lived?

Clue: Identify the location of these stromatolite remains.

Quick Check

Infer Are archaebacteria likely to be found on your skin? Explain.

Critical Thinking Do you think diatoms live near the surface of lakes and oceans or in deep water? Why?

FACT A teaspoon of topsoil contains more than 1 billion bacteria.

How do microorganisms reproduce?

A few microorganisms can quickly produce populations in the millions. How do they produce such large numbers of organisms so quickly? What gives these species the ability to have survived for billions of years? The answers to these questions are found in the way microorganisms reproduce.

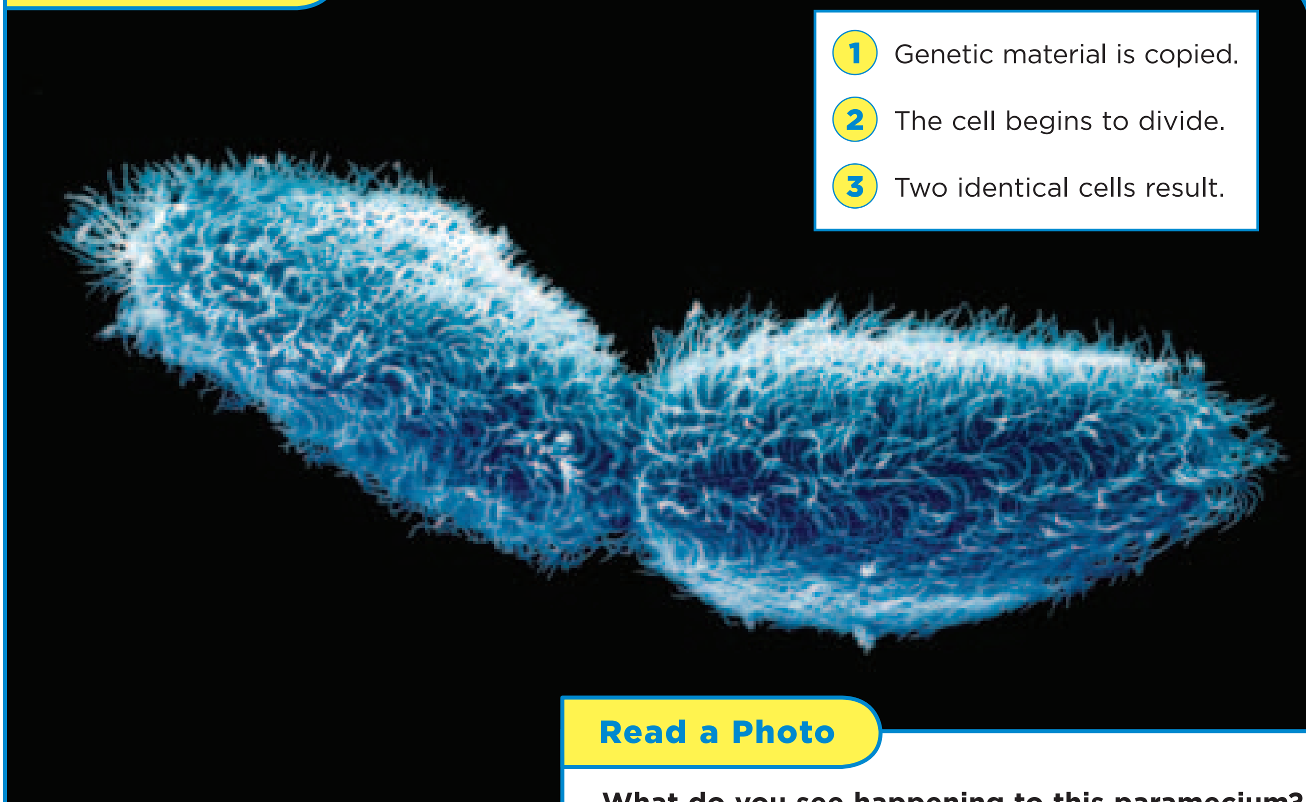
Protists

Most protists reproduce by **binary fission**. Binary fission is a type of asexual reproduction in which the organism divides in two. For example, a paramecium will stretch itself out, make copies of its chromosomes, and divide in half.

Protists may also reproduce by conjugation. **Conjugation** is a form of sexual reproduction in which organisms fuse, or attach themselves to each other, and exchange genetic information. Then they break apart and divide by fission.

Other protists, such as sporozoans, reproduce using spores. *Spores* carry genetic information within a protective membrane. These spores can survive very harsh circumstances until conditions are right for them to grow. Some spores need an organism they can infect in order to grow. This is how microorganisms such as *Plasmodium*—the microorganism that causes malaria—cause disease.

Binary Fission



1. Genetic material is copied.
2. The cell begins to divide.
3. Two identical cells result.

Read a Photo

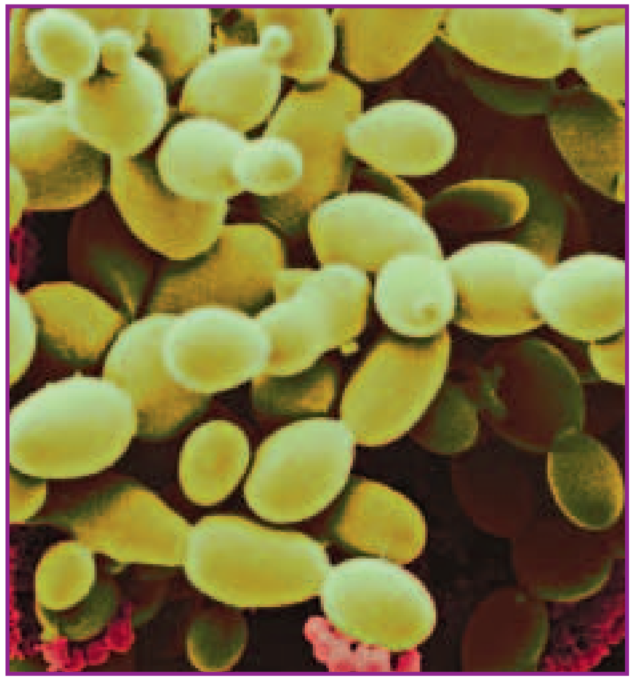
What do you see happening to this paramecium?

Clue: Look at what is occurring in the central area.

Fungi

Some fungi, such as yeast, reproduce asexually by **budding**. A bud first forms as a small growth on the parent cell. As the bud grows, the nucleus in the parent cell divides in two by mitosis. Each of the resulting nuclei has identical genetic information in its chromosomes. One of the two nuclei becomes part of the developing bud. Eventually the bud breaks off and lives as a new, separate organism.

Other types of fungi reproduce by spore formation. Male and female cells fuse to share genetic information and produce spores. These spores are protected inside a coating and are then distributed. If they land in an environment suitable for growth, the spores will develop into adult fungi.



▲ These yeast cells reproduce by budding.

Bacteria

Many bacteria reproduce by binary fission. *E. coli*, the bacteria that live in human intestines, reproduce in this manner. Other bacteria transfer genetic information by conjugation. During conjugation two bacterial cells are connected. Genetic information is then transferred from one cell to the other. This genetic information is then passed on when each bacterial cell divides.

▲ Genetic information passes through the bridge connecting these bacteria as they reproduce by conjugation.

Quick Check

Infer When budding occurs, do you think the new organism resembles the parent? Why or why not?

Critical Thinking How do binary fission and conjugation differ?

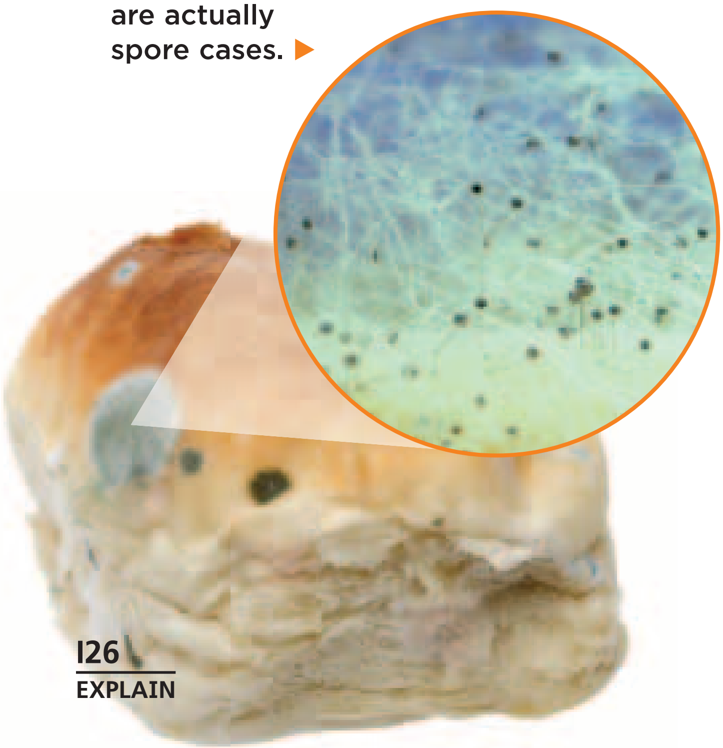
Quick Lab

Mold Growth

1. Moisten a slice of bread so it is damp but not wet. Place it in a clear, sealable plastic bag, and close the bag. Leave the bag in a dark, warm place for several days.

2. **Observe** Using a hand lens, carefully observe the bread. Examine each structure. **Be Careful.** Do not open the bag.
3. **Record Data** Record your observations about the bread. Draw and label what you see. Identify the mold's visible parts.
4. **Interpret Data** What do you think caused the changes to the bread?
5. **Infer** Where do you think the mold that is growing on the bread originally came from?

The black specks at the top of the threadlike hyphae are actually spore cases. ▶



What is bread mold?

Have you ever found black fuzz growing on the surface of a slice of bread? The black fuzz is common bread mold. Mold spores are very tiny. However, when these spores land in a favorable environment, they grow quickly. Warm, moist environments are ideal for mold growth.

Bread mold is made up of tiny filaments called *hyphae* (HIGH•fee) (singular, *hypha*). Just as roots grow out from a plant, hyphae spread out in a tangled mass that can cover a large surface area. Some hyphae anchor the mold to the bread, secrete special chemicals, and absorb nutrients. Bread mold actually lives in its food. The mold releases chemicals into the bread to digest it and then absorbs the nutrients. The chemicals that mold uses to help it digest food are proteins called *enzymes*. Enzymes cause certain chemical reactions to occur faster.

Other hyphae grow upward. These hyphae contain the structures responsible for producing spores. When the spores are fully developed, they are released. This is the asexual part of the mold's life cycle. Sexual reproduction occurs when two hyphae fuse and eventually form a new spore-producing structure.

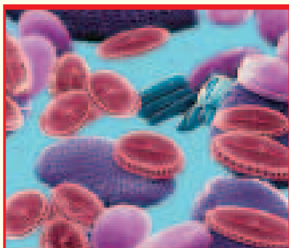
Quick Check

Infer How do you think enzymes help mold digest food?

Critical Thinking How might enzymes be important to activities other than digestion?

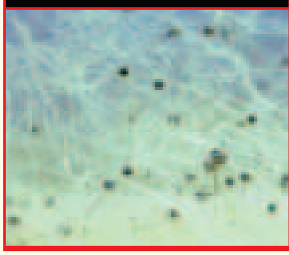
Lesson Review

Visual Summary



Microorganisms, or **microbes**, include some fungi, some protists, and most bacteria. Most are not visible to the unaided eye.

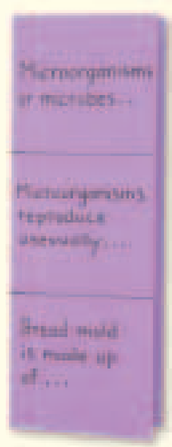
Microorganisms reproduce asexually by **binary fission**, budding, and spore formation. They reproduce sexually by conjugation.



Bread mold is made up of masses of long filaments called hyphae.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, discuss the characteristics of different microorganisms.



Think, Talk, and Write

1. **Main Idea** What is a microorganism? List three examples of microorganisms.
2. **Vocabulary** A form of sexual reproduction in which organisms fuse to exchange genetic information is called ________.
3. **Infer** Why are archaebacteria referred to as "ancient bacteria"?

Clues	What I Know	What I Infer

4. **Critical Thinking** Why is it important for microorganisms to be able to reproduce both sexually and asexually?
5. **Test Prep** **Which of the following is NOT a form of asexual reproduction?**
   - **A** budding
   - **B** conjugation
   - **C** binary fission
   - **D** spore formation
6. **Test Prep** **The filaments that make up common bread mold are called**
   - **A** spores.
   - **B** roots.
   - **C** spindles.
   - **D** hyphae.

Writing Link

Persuasive Writing

Design a Web page defending helpful bacteria. Include a short paragraph explaining the benefits of these important microorganisms. You may add pictures, cartoons, or other visuals.

Health Link

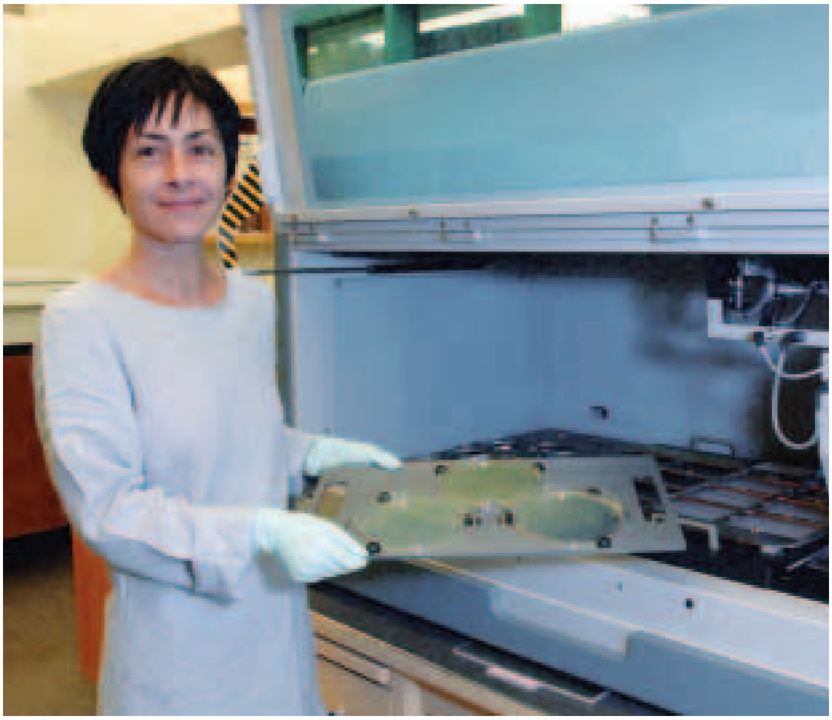
Make a Poster

Investigate both the positive and negative effects of microorganisms on your health. Make a poster presenting the information you discover.

Meet Maria Pia Di Bonaventura

What do museums do when their artwork and other cultural artifacts are being slowly eaten by organisms they can't even see? They turn to scientists like Maria Pia Di Bonaventura at the American Museum of Natural History. Maria Pia is not a detective, but she knows how to unlock mysteries like these, where the main suspects are microorganisms such as fungi and bacteria.

Maria Pia helped an art museum take a microscopic look at several paintings. Paintings made of wood, ink, oils, and canvas can be perfect environments for some microorganisms to grow in. You may not be able to see the microorganisms with your eyes, but they give themselves away by their green, yellow, and blue tints and the black markings that they leave behind.



Maria Pia is a microbiologist. That is a scientist who studies microorganisms.

To study the microorganisms that are making their home in the art, Maria Pia first takes a sample of them. Back in the lab, Maria Pia focuses on the fungi. She grows them to find out more about their DNA. The DNA provides the information that Maria Pia uses to determine the species of the fungi. The different species respond to different treatments, so after she identifies a species, she can figure out the best way to protect the paintings from even more damage.

Growing fungi damaged this painting.

Fungi don't just live on paintings. They live in all kinds of environments on our planet—in the tropical rain forests and the cold tundras, in the rivers and the oceans, and even in deserts! Maria Pia is interested in investigating their amazing diversity—there are over 100,000 species of fungi, and more are being discovered all the time. In fact, the world's largest known organism is thought to be a fungus weighing more than 100 tons, about the weight of an adult blue whale!

Write About It

Main Idea and Details

1. Why do museums ask for help from scientists like Maria Pia Di Bonaventura?
2. How does Maria Pia's work help protect works of art and other artifacts?

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

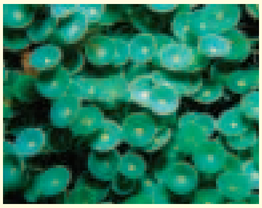
Main Idea and Details

- Look for the question or problem being discussed.
- Think about how the details all relate to one another.

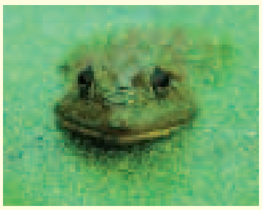
American Museum of Natural History

CHAPTER 2 Review

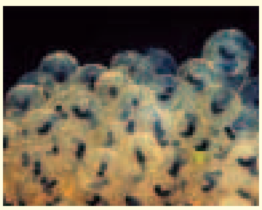
Visual Summary



Lesson 1 All living things are made up of one or more cells.



Lesson 2 Cells are made up of different structures that work together to conduct life processes.



Lesson 3 Cells reproduce by cell division.

Lesson 4 Microorganisms are not visible to the unaided eye and include some protists, some fungi, and most bacteria.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.

Vocabulary

Fill each blank with the best term from the list.

budding, p. 125
cellular respiration, p. 101
element, p. 90
fertilization, p. 115
microbe, p. 122
organ, p. 88
passive transport, p. 98
zygote, p. 112

1. The joining of an egg and a sperm is called ________.
2. A group of two or more types of tissue that work together to carry out one specific function is a(n) ________.
3. Osmosis and diffusion are types of ________.
4. A bacterium is an example of a kind of microscopic organism, or ________.
5. The cell that forms after a sperm joins an egg is a(n) ________.
6. A form of asexual reproduction observed in yeast is ________.
7. The process by which cells convert molecules such as glucose into usable energy is called ________.
8. A pure substance made up of only one kind of atom is a(n) ________.

Skills and Concepts

Answer each of the following in complete sentences.

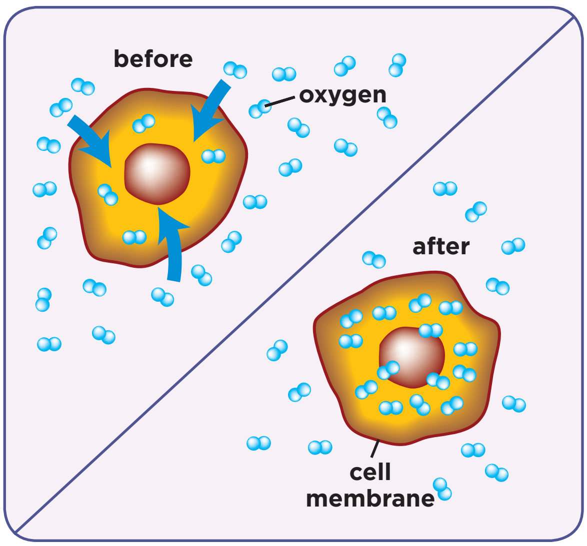
9. Summarize What happens during cellular respiration?

10. Explanatory Writing Explain how mitosis makes it possible for a cell to divide into two genetically identical cells.

11. Observe How can you observe unicellular organisms?

12. Critical Thinking You notice that your friend uses antibacterial hand soap in her home. Are you concerned? Justify your answer.

13. Interpret Data What type of passive transport is taking place in the diagram below?



The Big Idea

14. What do all living things have in common?

Performance Assessment

Where's the Bread?

Your goal is to determine the best place to store bread to prevent mold growth.

What to Do

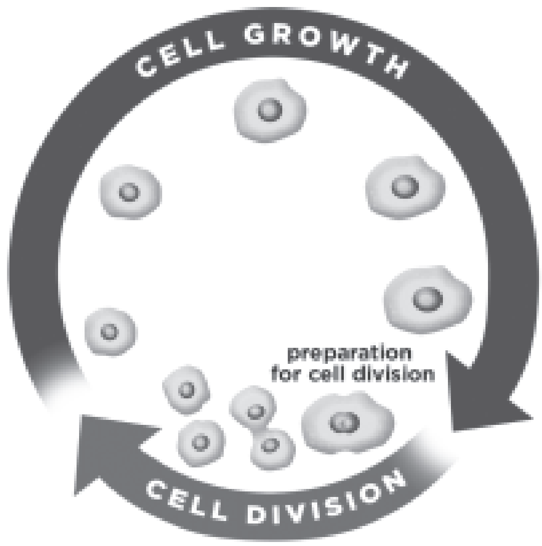
1. Seal three pieces of bread in three different sealable plastic bags. Put each bag in a different dark place, each with a different temperature.
2. Predict which slice of bread will develop the most mold growth. Observe the bags daily for a week. Record your observations in a data table.

Analyze Your Results

▶ Which slice of bread showed the most mold growth? Where is the best place to store bread to prevent mold growth?

Test Prep

1. What processes are shown here?



A fertilization

B photosynthesis

C growth and mitosis

D meiosis

Emergency Medical Technician

The phone rings, and emergency medical technicians are dispatched to the scene. These men and women never know what they may encounter—a car accident, the birth of a baby, or a child injured from a fall. However, they do know that people's lives depend on their quick and competent reactions. At the scene, emergency medical technicians assess the situation and then provide emergency care until the patient is transported to the hospital. What does it take to join this elite group? Requirements vary from state to state, but a high-school diploma, formal training, and certification, as well as a strong desire to help others, are all necessary.

▲ Emergency medical technicians are often the first to respond to an emergency.

▼ Geneticists help people and the environment through their research.

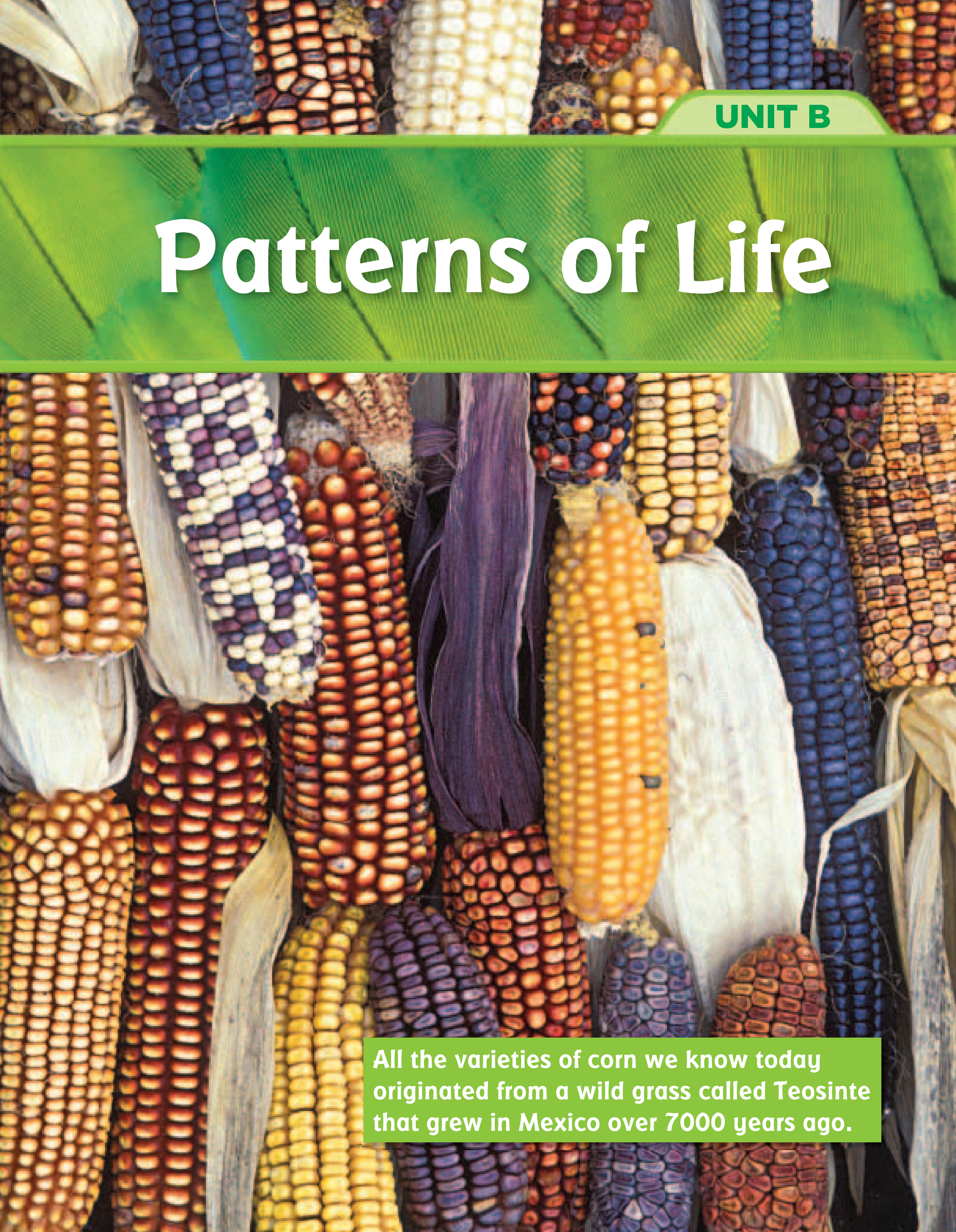
Geneticist

There is no time like the present to work in the field of genetics. Research in genetics has led to exciting discoveries in medicine, agriculture, and environmental science. The information that geneticists find gives people with genetic disorders hope for the future. Genetic advances in agriculture introduce new ways to provide food for increasing world populations. There are many specialized branches of genetics, but most people in the field are involved in research. To be on the forefront of discovery, you could begin by earning a bachelor's degree in genetics. Advanced degrees are often required to specialize in the field. Rapid developments in genetics make continuing education part of the job.

LOG ON e-Careers at www.macmillanmh.com

UNIT B

Patterns of Life



All the varieties of corn we know today originated from a wild grass called Teosinte that grew in Mexico over 7000 years ago.

TROUBLE ON THE TABLE

by David Bjerklie

Some people find genetically altered superfoods hard to swallow.

For thousands of years, farmers improved their crops by patiently crossbreeding plants that had good traits. They took pollen from the sweetest melon plants and added it to the flowers of plants that produced the biggest melons to produce new plants with melons that were both sweet and big. However, crossbreeding does not always work. Even when it does, it can take decades to get good results.

Now, thanks to advances in gene science, there are amazing shortcuts. Genes are the instructions inside cells that help determine what a living thing looks like: its size, its shape, and countless other traits. Using the new tools of genetic engineering, scientists can take a gene from one living thing and put it directly into another plant or animal. That way, says John Mount, professor of agriculture at the University of Tennessee, "you can make changes more precisely in a much shorter period of time."

from ***Time for Kids***

Are we making monster food?

Not everybody is convinced that pumping up our food with foreign genes is a good idea. Many people say these genetically modified, or GM, foods may end up harming the environment and humans. They fear that plants with new genes forced into them will accidentally crossbreed with wild plants and produce pesticide-resistant superweeds. They also say GM foods could carry genes that trigger allergies or other side effects. Already, there is evidence that some GM corn crops may be harmful to the caterpillars that turn into monarch butterflies.

"We are rushing headlong into a new technology," warns Ronnie Cummins of the Organic Consumers Association. "We are courting disaster if we don't look before we leap."

So far, GM foods have not harmed anyone. Most genetic researchers believe that if troubles do crop up, they will be manageable. "We're not talking killer tomatoes here," says Norm Ellstrand, a University of California geneticist.

As the battle goes on, will we continue to see GM food on our tables? "I hope so," answers Allison Snow, an ecologist at Ohio State University. "Even though I have concerns, I think it would be silly not to use this technology. We just have to use it wisely."

Write About It

Response to Literature This article discusses genetically modified foods. What are some of the issues related to the use of these foods? What do you think about them? Write an essay explaining your point of view about GM foods. Provide details to support your argument.

–Journal Write about it online at **www.macmillanmh.com**

CHAPTER 3

Genetics

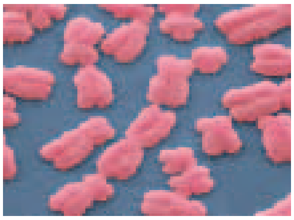
The Big Idea

How do organisms pass on characteristics to their offspring?

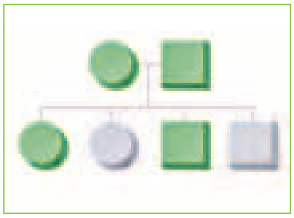
leopard with cub

Key Vocabulary

chromosome One of the threadlike structures in the nucleus of a cell that contain directions for the cell's activities. (p. 152)



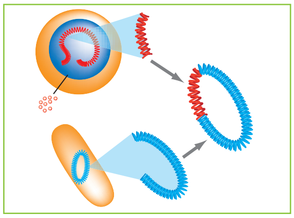
X and Y chromosomes Chromosomes that determine a person's sex. (p. 153)



pedigree A chart that traces the history of traits in a particular family. (p. 154)

DNA Deoxyribonucleic acid, a long, complex molecule that controls heredity. (p. 162)

geneticist A scientist who studies how heredity works. (p. 164)



gene-splicing Adding the genes from one organism to the genes of another organism. (p. 165)

More Vocabulary

inherited trait, p.140

heredity, p. 140

genetics, p. 141

acquired trait, p. 141

hybrid, p. 142

dominant trait, p. 143

recessive trait, p. 143

gene, p.144

genotype, p. 153

phenotype, p. 153

carrier, p. 155

genetic disorder, p. 156

genome, p. 163

genetic engineering, p. 164

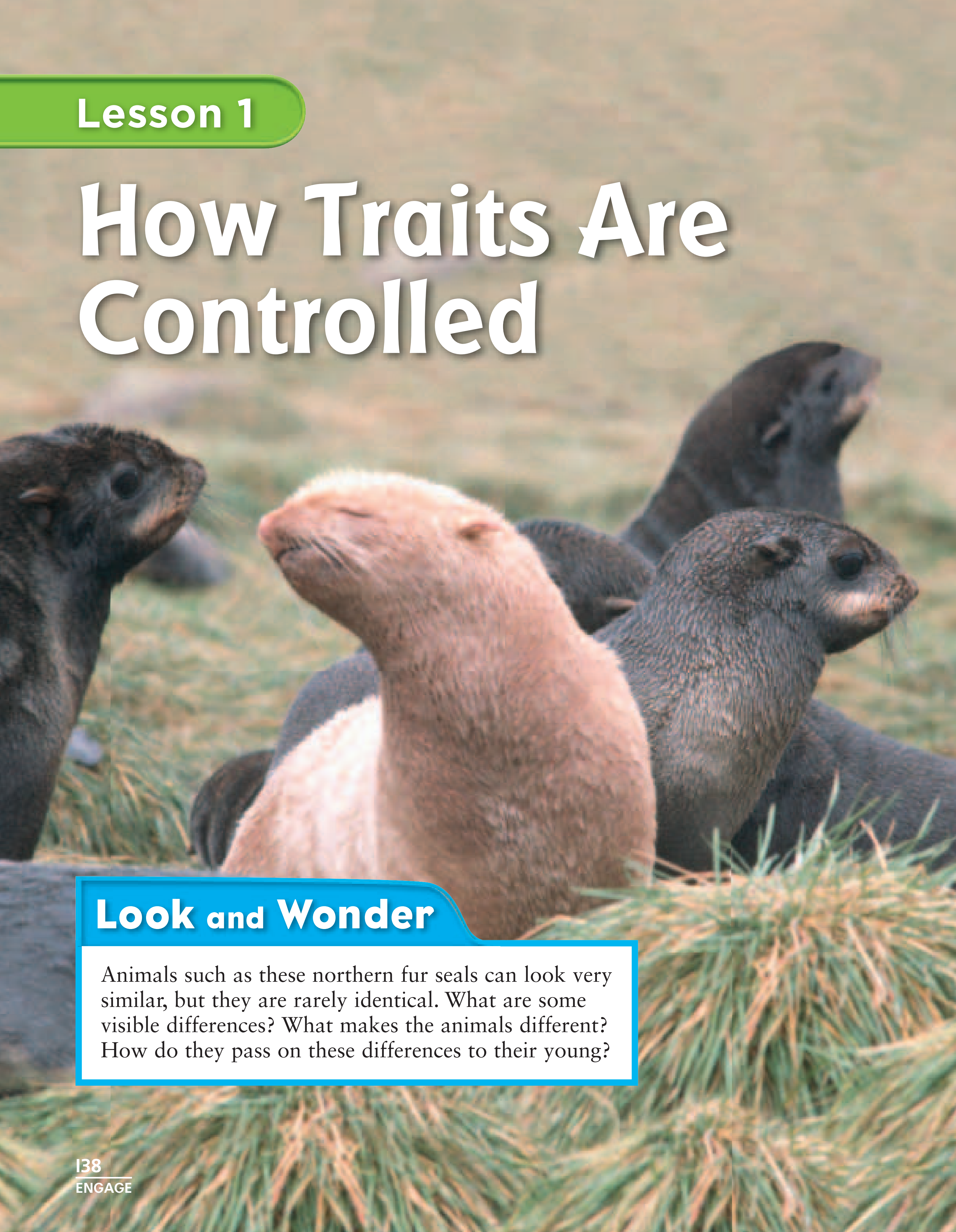
clone, p. 165

variation, p. 172

mutation, p. 172

natural selection, p. 174

antibiotic, p. 176



Lesson 1

How Traits Are Controlled

Look and Wonder

Animals such as these northern fur seals can look very similar, but they are rarely identical. What are some visible differences? What makes the animals different? How do they pass on these differences to their young?

Explore

Inquiry Activity

Which inherited traits are dominant?

Make a Prediction

Yellow corn produces yellow corn, and purple corn produces purple corn. Is this always true? What happens when yellow corn and purple corn are crossed? The corn appears to be 100 percent purple! However, it is not really the same as its purple parent plants. What would happen if these new purple ears of corn were crossed? What percent of the corn kernels would be purple? Write your answer in the form of a prediction: "If purple ears of corn, each with a yellow parent and a purple parent, are bred together, then the percent of purple kernels in the offspring will be . . ."

Test Your Prediction

1. **Record Data** Look closely at the ear of purple-and-yellow corn. Row by row, count any purple kernels on your ear of corn, and record your answer. Then count any yellow kernels on your ear of corn. Record your answer.
2. **Use Numbers** Write the ratio of purple kernels to yellow kernels. Use a calculator to simplify your ratio to the lowest fraction.

   $$\text{ratio} = \frac{\text{purple kernels}}{\text{yellow kernels}}$$

3. **Use Numbers** On the board, add the class totals for purple kernels and yellow kernels. Find the average number of each color. Write this as a ratio of purple kernels to yellow kernels.

Draw Conclusions

4. **Interpret Data** Which kernel color appears more often? How does the ratio for your ear of corn compare with the ratio for the class total?
5. **Infer** Which color seems to be the more likely color for corn? Why do you think so much of the corn that we eat is yellow, not purple?

Materials

- ear of purple-and-yellow corn
- calculator

Explore More

Do other corn qualities occur in a similar ratio? Repeat this experiment with another trait, such as white and yellow kernels. Compare your results to those of others in your class.

Read and Learn

Main Idea

Inherited traits are passed from parents to offspring.

Vocabulary

- **inherited trait**, p.140
- **heredity**, p.140
- **genetics**, p.141
- **acquired trait**, p.141
- **hybrid**, p.142
- **dominant trait**, p.143
- **recessive trait**, p.143
- **gene**, p.144

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Reading Skill

Fact and Opinion

Fact	Opinion

These puppies display many features that resemble those of their mother.

What is heredity?

In a factory, you can see how workers assemble items such as cars or computers. What about people? How are features passed from parents to their children?

Living things usually tend to look like their parents. Parents pass some of their features, or inherited traits, to their offspring. **Inherited traits** are characteristics that are passed from parent to offspring. For example, dogs pass fur color to their puppies. Inherited traits in humans include height, eye color, dimples, freckles, and the shapes and sizes of fingers and toes. The passing of inherited traits from parents to offspring is known as **heredity**.

▶ Physical features are just some of the traits children inherit from their parents.

Genetics

Genetics is the study of heredity. Sometimes scientists debate whether a trait is genetic. What does this mean? An organism's traits do not all come from heredity. For example, zebra finches can sing from an early age, without ever learning or practicing. This is an inherited trait. However, the song of the young finch changes as the bird gets older. After it hears other birds singing, its own songs become more complex. The ability to sing a more complex song is an **acquired trait**, a trait influenced by experience or the environment.

The environment influences acquired traits in many ways. The amount of water a plant receives influences its height. Nutrition affects how large a kitten grows. Practice may help a musician gain musical skills.

Acquired traits are not passed on to an organism's offspring. Suppose that you cut branches from a tree. Doing so would not affect the traits that the tree passes on to its offspring, and the tree's offspring would still develop branches. Today, we take knowledge like this for granted. However, there was a time in the past when many scientists did not realize that this was true.

Quick Check

Fact and Opinion "Acquired traits are the more important traits." Is this a fact or an opinion? Explain.

Critical Thinking What is the importance of acquired traits?

FACT Scientists are uncertain whether some traits, such as math skills, are inherited, acquired, or both.

Acquired Traits and Inherited Traits

This cat inherited its physical characteristics from its parents.

Flamingos are born with white feathers. This flamingo acquired its coloring from eating food high in beta-carotenoid pigments.

Read a Photo

Which animal shows an inherited trait? An acquired trait?

Clue: What are some of the individual traits you notice on these animals?

What did Mendel do?

In the 1800s, an Austrian monk named Gregor Mendel discovered the basic rules that explain how traits are passed from parents to offspring. Today, many consider Mendel to be the founder of genetics.

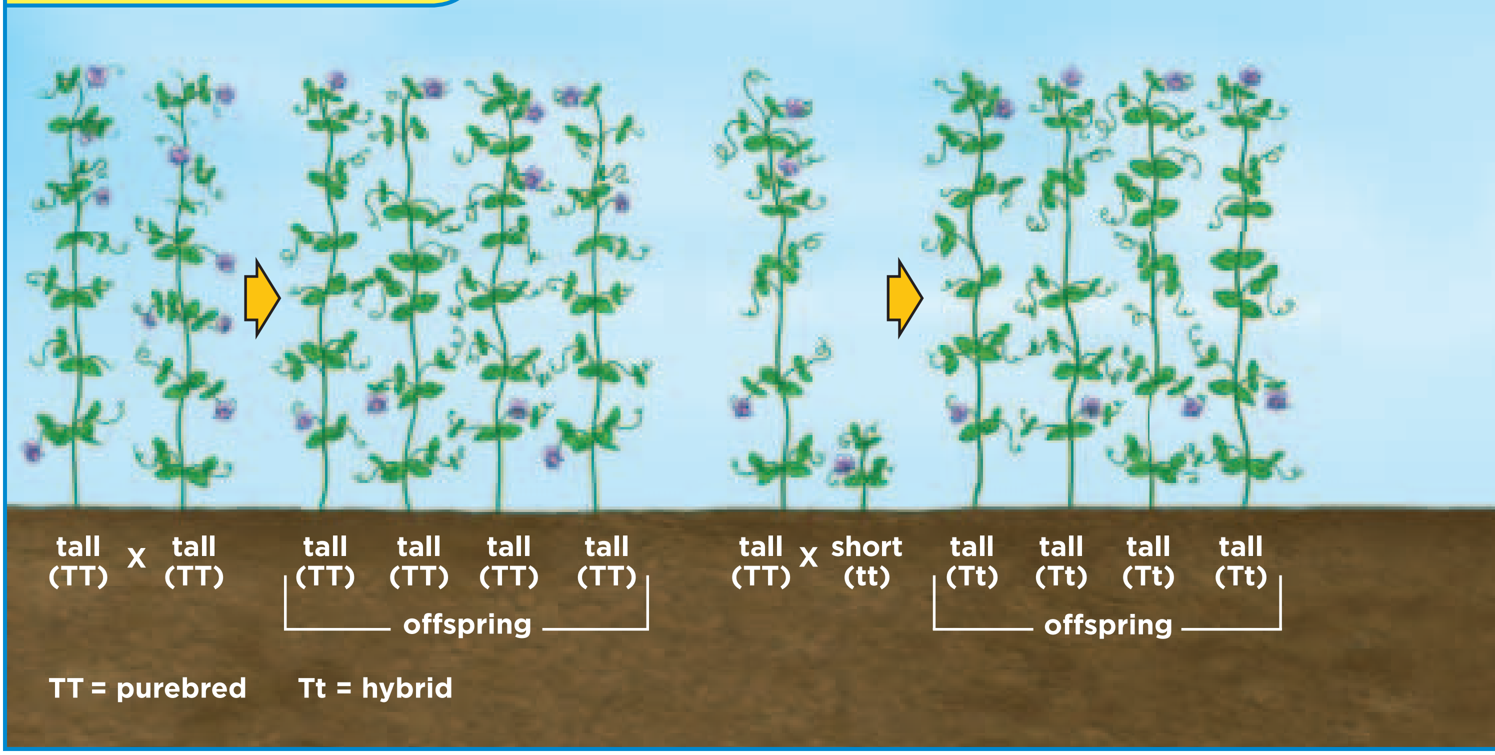
In 1856, Mendel took charge of the gardens at his monastery. In these gardens, he experimented with pea plants to study how traits were passed from parents to their offspring. Mendel studied the inheritance of seven separately inherited traits.

Mendel began his experiments by selecting pea plants that had been bred to always express the trait he was studying. Organisms that always produce offspring with the same traits are known as *purebred*. For example, a purebred tall pea plant will only produce tall offspring.

Next, Mendel crossed tall pea plants with short pea plants. This cross produced **hybrids**, organisms that have inherited two different forms of the same trait, one from each parent. In this case the hybrid offspring each received a tall and a short form for the trait of height. Surprisingly, when Mendel looked at the hybrids from this cross, every one of them was tall. Why were all the offspring tall? What happened to the short trait?

Mendel asked these same questions. He believed that the trait for shortness must have been present but that it had somehow been hidden. He tested this hypothesis in a second experiment. Mendel allowed the hybrids to self-pollinate. The offspring included both tall plants and short plants.

Mendel's Experiments

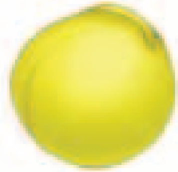
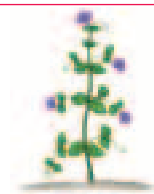
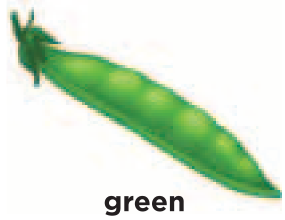


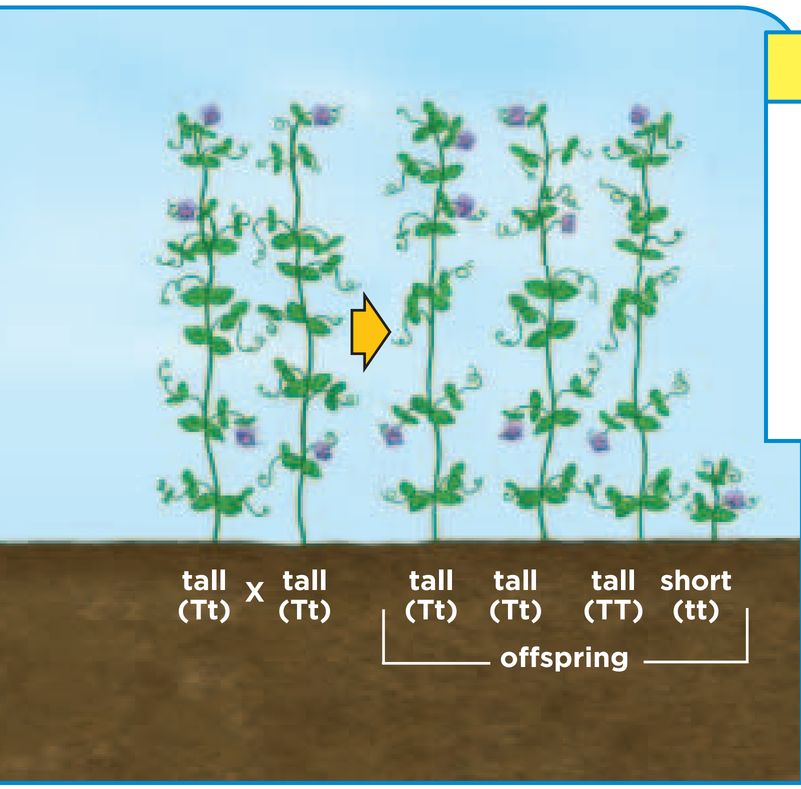
Dominant and Recessive Traits

Mendel hypothesized that the presence of the tall form prevented the short form from appearing. He called the tall form the **dominant trait**, which meant that it masked the other form of the trait for height. If a plant had both a tall and a short form of the trait, it grew tall. This was because inheriting even one dominant form caused the dominant trait to appear. Mendel called the short form the **recessive trait**, or the hidden form of the trait. Having one copy of the short trait did not make a plant short. However, if a plant had two copies of this recessive trait, the plant grew short. He called the different forms of each trait *factors*.

In Mendel's experiments, each trait he tested showed the same pattern. Recessive traits would disappear for a generation and could then reappear in a later generation.

Pea-Plant Traits

Dominant Form	Recessive Form
 smooth	 wrinkled
 purple	 white
 tall	 short
 green	 yellow



Read a Diagram

There are tall pea plants that produce short offspring. Are they purebred plants or hybrids? Explain.

Clue: Which tall plants are able to cross and produce a short offspring?

LOG ON *Science in Motion* Watch plants produce offspring at www.macmillanmh.com

Quick Check

Fact and Opinion "Green peas taste better than yellow peas." Is this a fact or an opinion? Explain.

Critical Thinking How could purple corn plants produce yellow offspring?

Why is Mendel's work important?

Through his observations, Mendel made a connection that no one else had made. Mendel realized that pea plants had two factors for each trait he studied. He saw that one factor came from the female plant and the other factor came from the male plant. Today, we call Mendel's factors *genes*. A **gene** is the portion of a chromosome that controls a particular inherited trait.

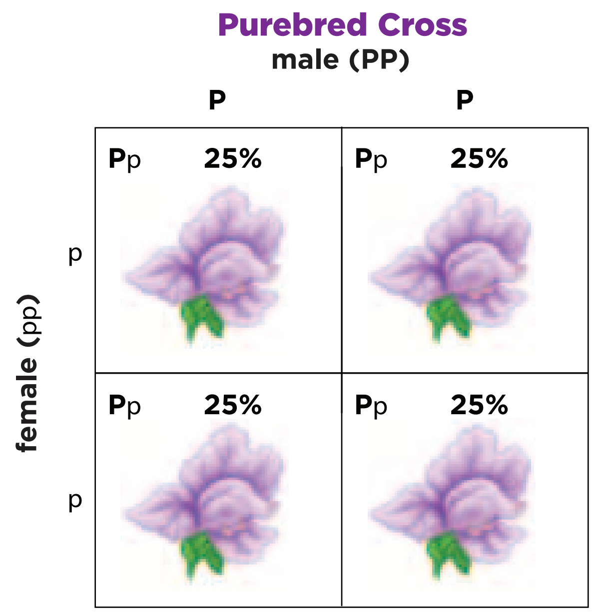
Heredity does not always follow the clear patterns that Mendel found in the seven pea-plant traits he studied. However, in many cases, Mendel's methods can be used to predict the offspring from crossing two organisms.

Predicting Traits

Mendel used mathematics to further understand the patterns of heredity that he observed. In his data, Mendel saw an interesting pattern, which he expressed as a ratio. A ratio expresses the relationship that exists between two numbers.

Mendel found that, on average, two hybrid parents produced three offspring showing the dominant factor for every one showing the recessive factor. This is a 3:1 ratio, and it occurs in crosses between organisms that carry both the dominant and recessive genes for a particular trait.

Punnett Squares



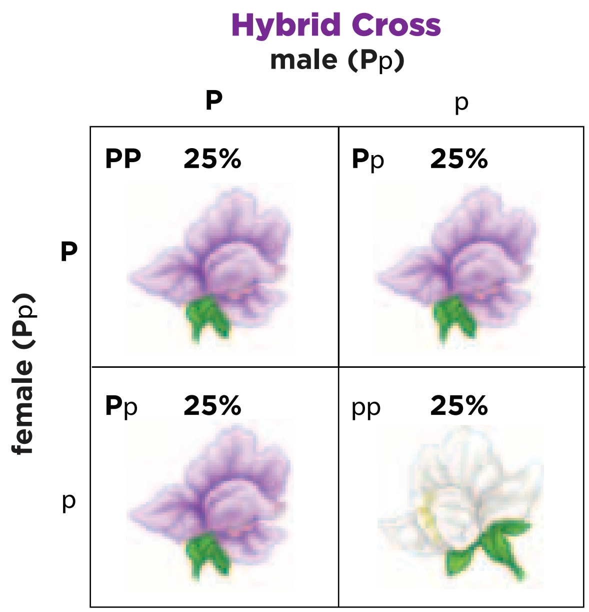
Purebred purple (PP) and white (pp) pea plants produce all hybrid plants, with one form of each color factor (Pp).

Punnett Squares and Probability

Punnett squares predict the possible outcomes of genetic crosses. Letters represent different genes. For the flower color of a pea plant, an uppercase *P* represents purple flowers, the dominant form of the trait. A lowercase *p* represents white flowers, the recessive form.

To make a Punnett square, divide a large square evenly into four smaller squares. The female's genes are written outside down the left, and the male's genes are written outside along the top. The results of a cross between them are found by carrying the letters downward and across into the boxes.

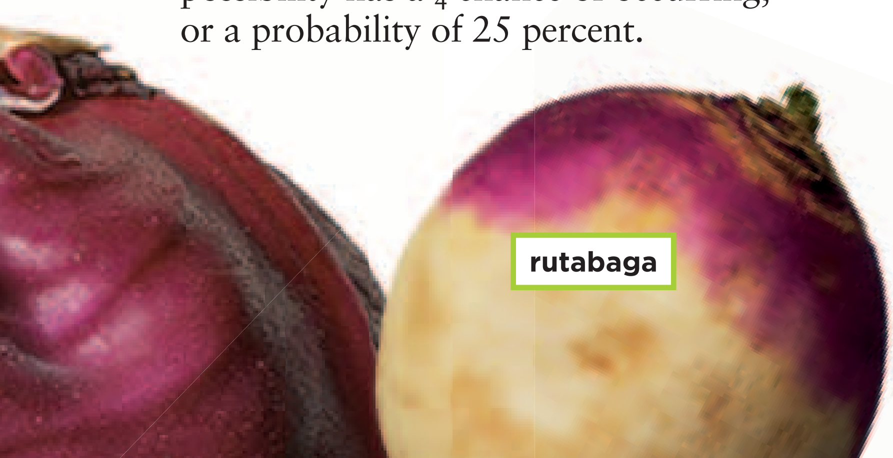
▶ These vegetables all belong to the cabbage family. Because they are closely related, they can be crossed.



On average, hybrid pea plants produce offspring in a 3:1 ratio of purple to white.

The probability of each type of offspring can be determined from these results. *Probability* is the likelihood of an event. However, it is not a certainty that the event will occur. For example, if you flip a coin, there is an equal chance of getting heads or tails. The chance that it will come up heads is $\frac{1}{2}$, or a probability of 50 percent.

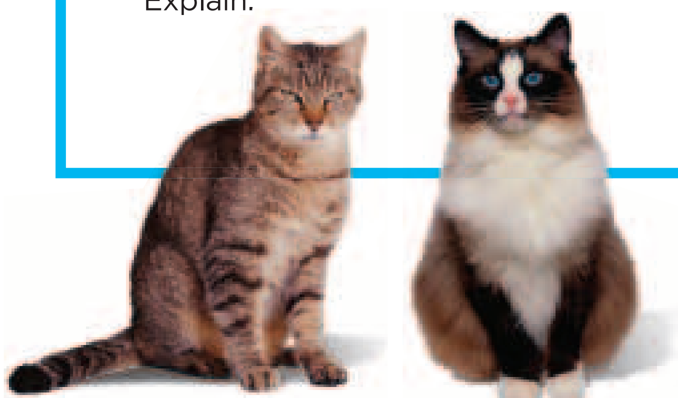
The possible outcomes of a two-coin toss are similar to those of a genetic cross. There are two possible genes for a trait. Each parent gives an offspring one of its two genes. Since there are four ways the factors can combine, each possibility has a $\frac{1}{4}$ chance of occurring, or a probability of 25 percent.



Quick Lab

Predicting Cat Traits

1. In cats, short hair (S) is dominant over long hair (s). Which genes will a short-haired hybrid cat have?
2. **Make a Model** Use the sides of two coins to represent heredity for this trait. Let heads represent the dominant trait and tails represent the recessive trait.
3. **Record Data** Flip the coins together for the male cat, and write down its genes. Record *S* or *s* for each coin flip. Then flip the coins for the female cat.
4. **Use Numbers** Make a Punnett square for these two cats. What is the possible ratio of short-haired to long-haired offspring?
5. **Predict** If you begin with hybrid cats, how often will you get a purebred offspring for this trait? Explain.



Quick Check

Fact and Opinion "A ratio is a mathematical relationship." Is this a fact or an opinion? Explain.

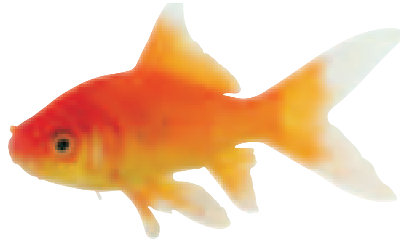
Critical Thinking If you flipped a coin three times and got tails each time, what would be the probability of getting heads on the fourth try? Explain your answer.

What is selective breeding?

People have long noticed that certain organisms have desirable traits. For example, some food plants are more drought-resistant than others, and some animals are stronger than others. Organisms that show desirable traits are selected to produce offspring.

Mating certain organisms in order to promote offspring with desirable traits is called *selective breeding*. Selective breeding has been used to alter the characteristics of crops and livestock. It also is responsible for many varieties of household pets, such as dogs and cats. Members of an animal species with similar traits are part of a group called a *breed*. Breeds have distinctive features because of many generations of selective breeding.

From Gray Carp to Goldfish



Hundreds of years ago, fish with unusual colors such as gold, black, and yellow were discovered in the lakes and rivers of China. Scientists believe that these fish were colorful forms of a normally gray fish called carp. The Chinese enjoyed keeping these colorful fish in their ponds and mated the fish in various combinations. The carp were bred over many generations and later came to be known as goldfish. Today, there are many breeds of goldfish.

Quick Check

Fact and Opinion "Goldfish were bred to display many different colors." Is this a fact or an opinion? Explain.

Critical Thinking How could Mendel's discoveries provide valuable information for selective breeding?

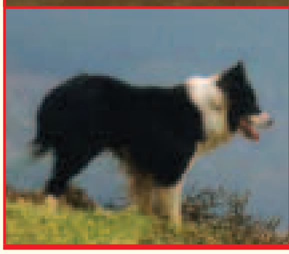
The border-collie dog breed has been herding livestock for hundreds of years.

Lesson Review

Visual Summary

Heredity is the passing of traits from parents to offspring.

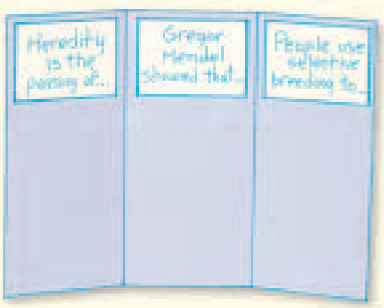
The experiments of Gregor Mendel showed that some traits are **dominant** and others are **recessive**.



People use **selective breeding** to produce organisms with desirable traits.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add additional information about how traits are controlled.



Think, Talk, and Write

1. **Main Idea** How did Mendel explain heredity in pea plants?

2. **Vocabulary** An organism that has inherited two different forms of a trait is a(n) ________.

3. **Fact and Opinion** "Fur color in puppies is an inherited trait." Is this statement a fact or an opinion?

Fact	Opinion

4. **Critical Thinking** How can a trait disappear in one generation and then reappear in a later generation?

5. **Test Prep** **The "factors" that Mendel described are**
   - **A** genes.
   - **B** dominant traits.
   - **C** recessive traits.
   - **D** hybrids.

6. **Test Prep** **If a purebred tall pea plant were crossed with a purebred short pea plant, the offspring would be**
   - **A** 100 percent tall pea plants.
   - **B** 100 percent short pea plants.
   - **C** 50 percent tall pea plants.
   - **D** 25 percent short pea plants.

Math Link

Calculate Probability

Black fur color (F) is dominant over white fur color (f). If a hybrid black dog is mated with a white dog, what is the probability of their producing a puppy that is black? Use a Punnett square.

Health Link

Investigate Genetic Disorders

Research a genetic disorder, such as hemophilia or cystic fibrosis. Find out how the disorder is inherited, what symptoms it produces, and how it is treated.

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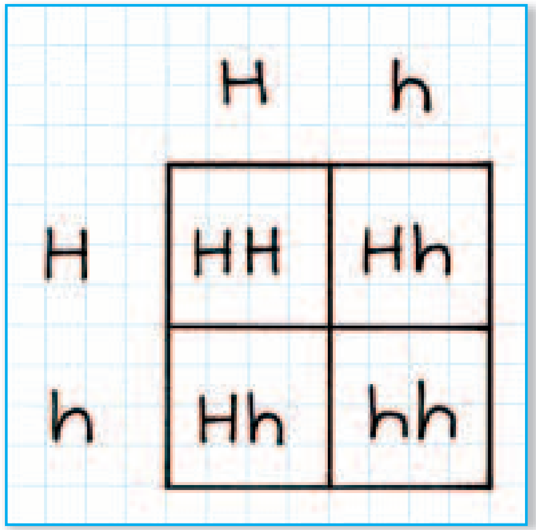
Focus on Skills

Inquiry Skill: Use Numbers

Many traits are determined by just two genes, one from each parent. Each parent passes on one of two genes that may be either dominant or recessive. Knowing this helps scientists predict the probability that a form of a trait will be inherited. How do scientists make these predictions? They **use numbers** by calculating data from Punnett squares.



▶ Learn It

When you **use numbers**, you count, add, subtract, multiply, or divide to explain data. For example, the Punnett square at right shows the possible hairlines that a child might inherit if his or her parents each had a combination of a dominant, pointed-hairline gene (H) and a recessive, straight-hairline gene (h).

The probability of the child's having HH genes is 25 percent. There is a 50 percent probability of the child's having Hh genes. This means there is a 75 percent probability that the child will have a pointed hairline. At the same time, there is a 25 percent probability that the child will have a straight hairline (hh). It is possible that both parents could pass on the recessive gene to their child. In this activity, you will find the probability that a child will inherit the ability to roll the tongue.

▶ Try It

Materials **masking tape, 2 pennies, marker**

1. Apply masking tape to both sides of each penny. Write *R* (able to roll) on the head side of each penny and *r* (unable to roll) on the tail side.
2. Make a Punnett square with *Rr* at the top and *Rr* down the side. Make a chart like the one shown, with one possible combination from your Punnett square at the top of each column.
3. Flip the two coins. Record the results on your chart by making a tally mark under the combination shown on the coins. Flip the coins and record the results a total of ten times. Record the total number of marks in each column, and **use numbers** to figure out the percents for each possible combination.

▶ Apply It

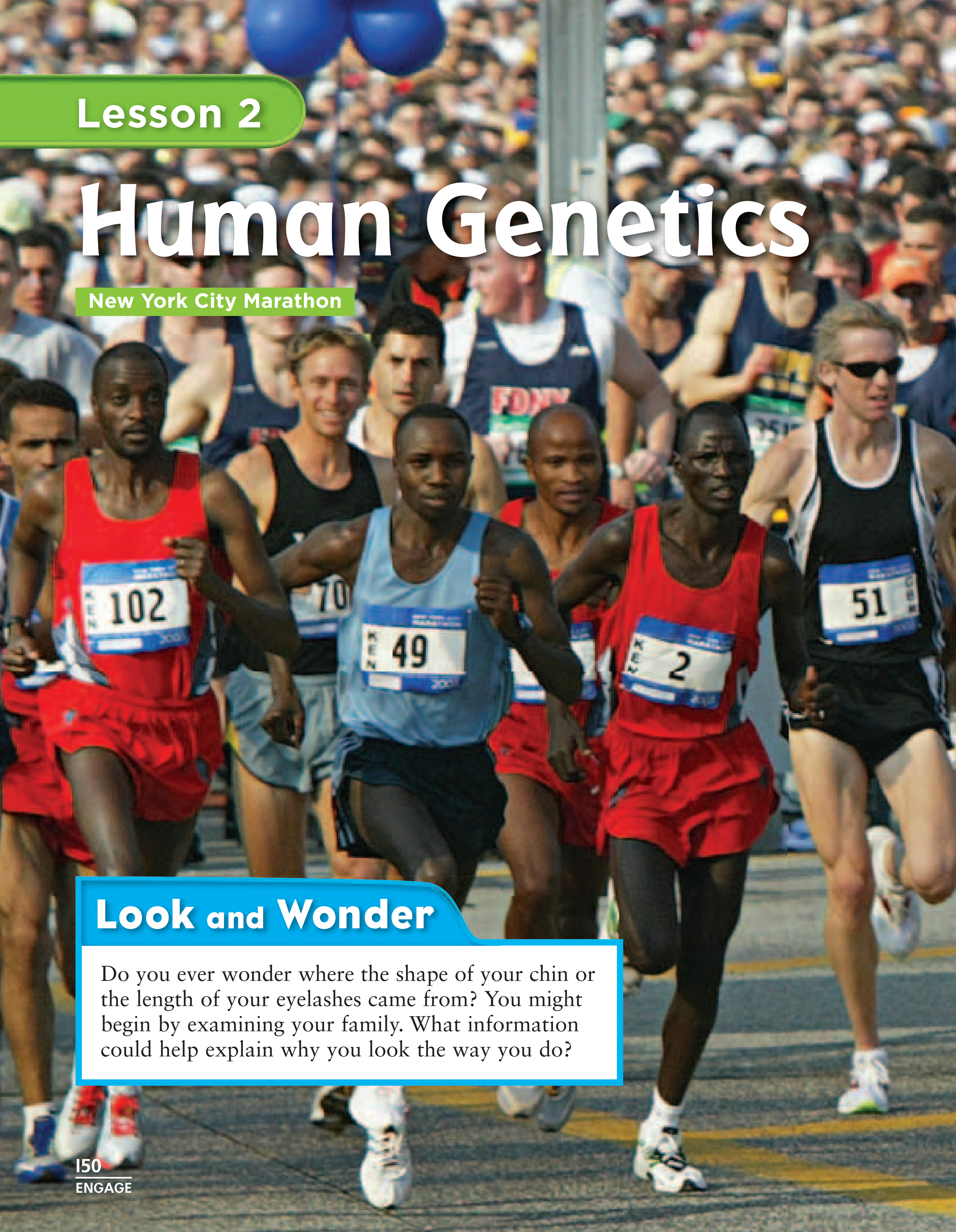
1. According to your Punnett square, what is the probability that a child will inherit the ability to roll the tongue?
2. How many times out of ten did you actually get a combination that gives a child the ability to roll the tongue?
3. How many times out of ten did you actually get a combination of two recessive genes (rr) for tongue rolling?
4. Now find the probability that a child will inherit one of these other traits that are passed on by parents:
   - long eyelashes (dominant) or short eyelashes (recessive)
   - unattached earlobes (dominant) or attached earlobes (recessive)
   - dimples (dominant) or no dimples (recessive)
5. Decide what gene combination you wish each parent to have. Then make a Punnett square using the letter combinations. What is the probability that the child will inherit that trait?
6. Now label your coins with those new combinations, repeat the activity, and record your results. **Use numbers** by calculating your actual statistics.

	RR	Rr	rr
toss 1			
toss 2			
toss 3			
toss 4			
toss 5			
toss 6			
toss 7			
toss 8			
toss 9			
toss 10			
probability	____-in-10 or ____%	____-in-10 or ____%	____-in-10 or ____%

Lesson 2

Human Genetics

New York City Marathon



Look and Wonder

Do you ever wonder where the shape of your chin or the length of your eyelashes came from? You might begin by examining your family. What information could help explain why you look the way you do?

Explore

Inquiry Activity

What are some common inherited traits?

Make a Prediction

How can you tell which traits are dominant when gathering data from many different individuals? Write your answer in the form of a prediction: "If I check a group of individuals for the frequency of different traits, then . . ."

Test Your Prediction

1. **Observe** Have a partner check you for each trait listed below. Record which traits you have.
2. **Observe** Reverse roles with your partner, and repeat step 1.

Type of Trait	Column A	Column B
Freckles	no freckles	freckles
Tongue Rolling	unable to roll edges	able to roll edges
Shape of Hairline	not pointed	pointed in the middle
Chin Shape	not indented	indented in the middle
Thumb	straight	hitchhiker's
Eyelash Length	short	long
Earlobes	attached	unattached

3. **Communicate** Tally your results in a classroom chart that lists all the traits.

Draw Conclusions

4. **Interpret Data** Plot the data from the classroom chart on a bar graph. Based on the data, which column lists the dominant traits?
5. **Classify** Of the traits on the chart, how many dominant and recessive traits do you have?
6. **Infer** Why is it important to gather data on many individuals before deciding which traits are dominant? Are dominant traits always more common? Explain your answer.

Materials

- calculator

Explore More

Find the percent of each trait in the class. The percent is a way of telling the frequency of a trait—how often the trait appears. Research dominant traits in humans. Are dominant traits more frequent in all groups of people?

Read and Learn

Main Idea
Information contained in the genes from each parent results in an individual's inherited traits.

Vocabulary
chromosome, p. 152
genotype, p. 153
phenotype, p. 153
X chromosome, p. 153
Y chromosome, p. 153
pedigree, p. 154
carrier, p. 155
genetic disorder, p. 156

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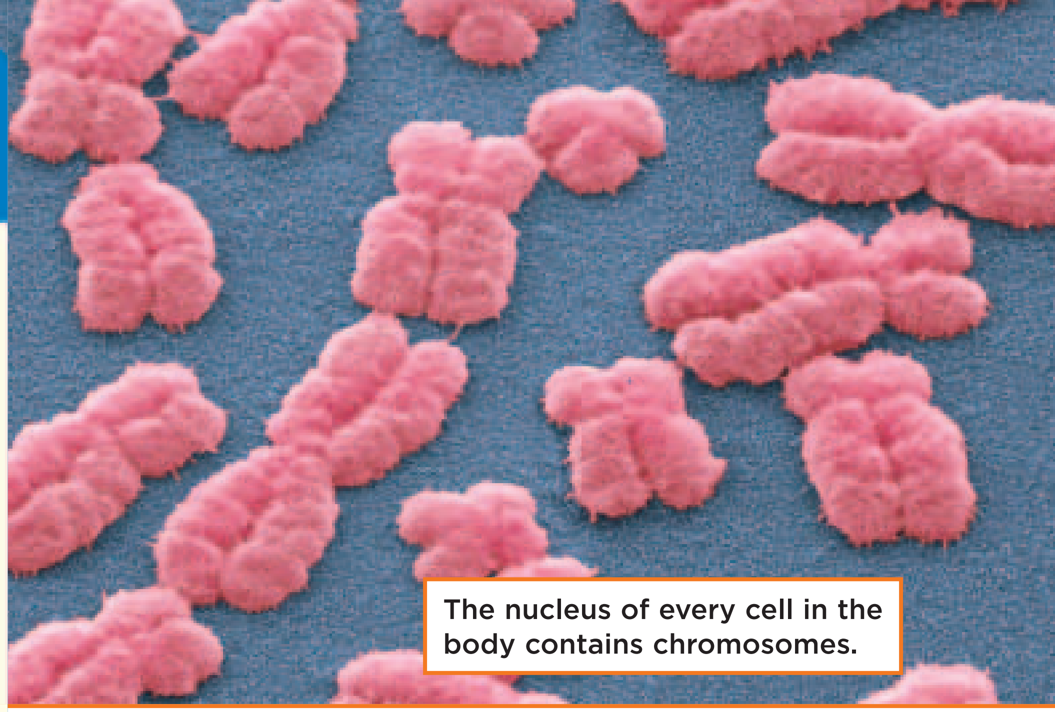
Reading Skill
Main Idea and Details

Main Idea	Details

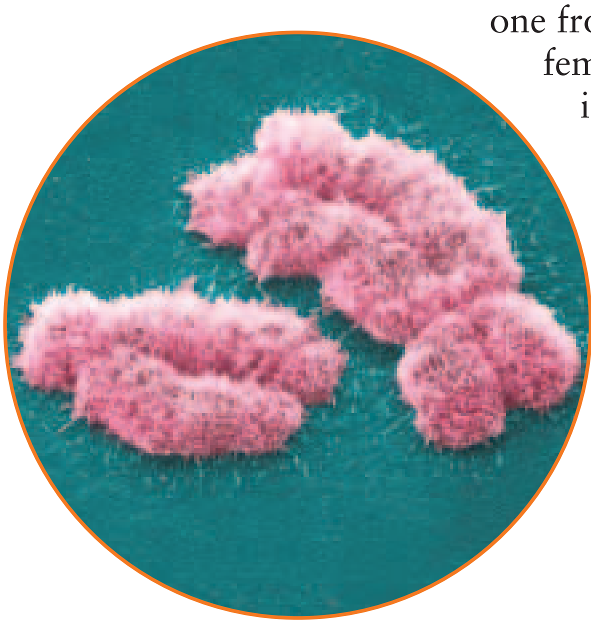


The nucleus of every cell in the body contains chromosomes.

What are genes?

Genes, the basic units of heredity, control traits. Genes are arranged along the length of a chromosome (KROH•muh•sohm) in a cell's nucleus. **Chromosomes** are threadlike structures in the nucleus that contain directions for cell activities. When a cell divides, chromosomes transfer these directions to the new cells.

Almost all human cells contain 23 pairs of chromosomes, or a total of 46 chromosomes. Most chromosome pairs have two copies of the same gene. Each organism produced by sexual reproduction receives two genes for a given trait, one from the male parent and one from the female. In Mendel's garden-pea experiment, information about the traits he studied was found in specific locations on specific chromosomes. For example, the peas' pod color had two gene types—one for green pods and one for yellow pods. The hybrid cross received a different gene type from each parent.



The Y chromosome is smaller and carries fewer genes than the X chromosome.

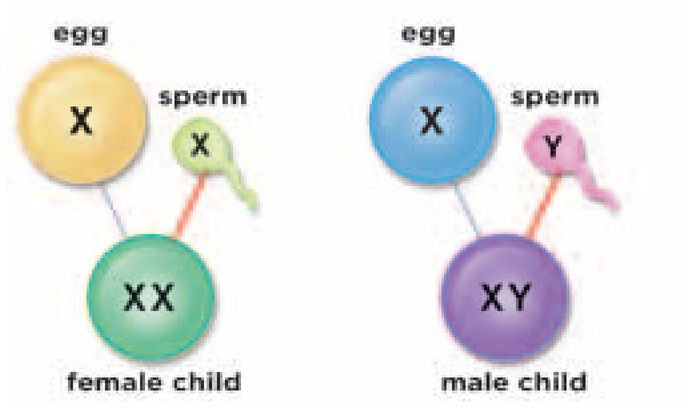
An organism that receives a gene from each parent for a trait may have two dominant genes, two recessive genes, or one dominant gene and one recessive gene. This determines the organism's **genotype** (JEE•nuh•tighp), all the genes that are inherited by an organism. The way in which an organism expresses, or shows, its traits is the organism's **phenotype** (FEE•nuh•tighp). Unless the organism receives two recessive genes for a trait, the dominant gene is expressed in the phenotype. For example, in a pea plant with a genotype for a hybrid of green and yellow pea pods, the phenotype would be green, since green is dominant.

Sex Chromosomes

In 1910, American scientist Thomas Hunt Morgan observed that female fruit flies had chromosome pairs in which both chromosomes were the same shape. He also observed that male fruit flies had one chromosome pair in which the two were differently shaped. This observation led to the discovery of the **X chromosome** and **Y chromosome**, the two sex chromosomes that determine *gender*, or whether an organism is male or female.

In humans, offspring that receive two X chromosomes, one from each parent, are female. Offspring that receive an X chromosome from the female parent and a Y chromosome from the male parent are male. Eggs always contain X chromosomes, so the offspring's gender is determined by whether the sperm cell contains an X chromosome or a Y chromosome. There is a 50 percent probability that offspring will be male and the same probability it will be female.

Sex Chromosomes



Read a Diagram

Which parent determines the gender of a human offspring?

Clue: Which sex cell contributes a Y chromosome?

The sex chromosomes carry genes for many traits, not just gender. Some genes, for *sex-linked traits*, are found on one sex chromosome but not the other. Color blindness is a sex-linked trait. Men are seven times more likely to be color-blind. This is because men inherit just one X chromosome, which is where the gene is found. Men who inherit color blindness in their genotype do not have another X chromosome from which normal sight can develop. These men are therefore color-blind.

Quick Check

Main Idea and Details What do chromosomes do?

Critical Thinking Why are the chances of having male offspring or female offspring equal?

What is a pedigree?

People inherit genes for traits, not the traits themselves. For example, scientists have identified three individual gene pairs that affect eye color. Two of the gene pairs are on chromosome 15, and one gene pair is on chromosome 19. All three gene pairs play a role in determining a person's eye-color phenotype.

For each gene pair in your cells, one gene is inherited from each parent. You could pass on a copy of one of these two genes to your children.

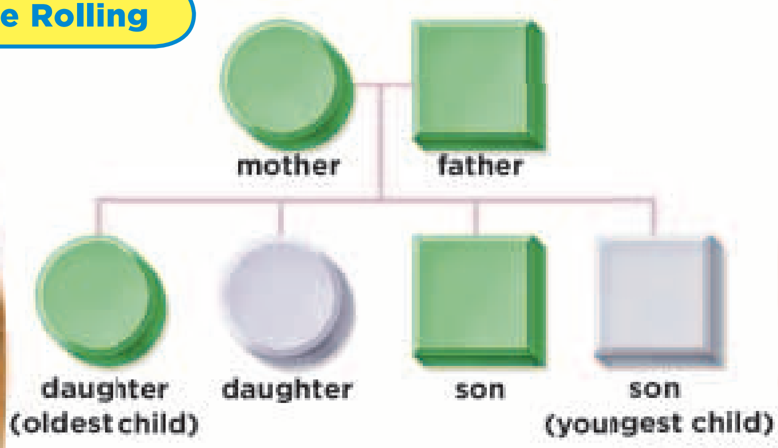
The shape of your earlobes is determined genetically. If your earlobes are unattached, then you possess at least one dominant gene for this trait. A person needs two recessive genes to have attached earlobes.

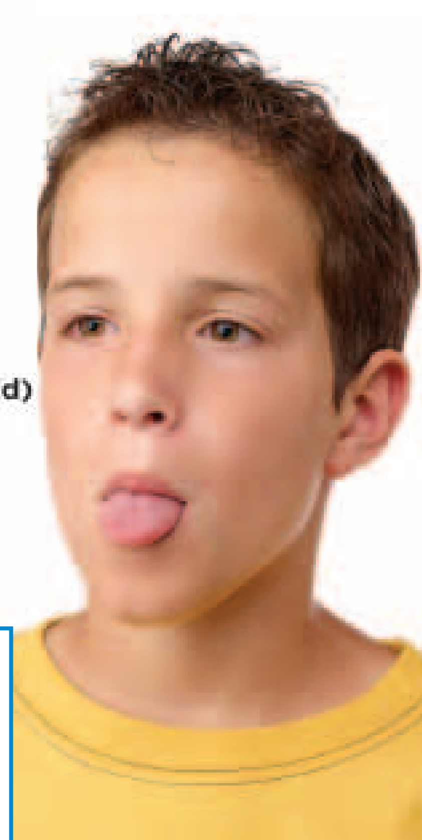
Many traits are either dominant or recessive. If you have short eyelashes, you have two recessive genes for that trait. If you have long eyelashes, you have either two dominant genes or one dominant gene and one recessive gene.

Families often show patterns of inheritance. A **pedigree** is a chart that traces the history of a trait within a particular family. It shows which family members expressed the dominant trait in their phenotypes and which expressed the recessive trait. A pedigree can also trace genetic disorders in families.

Pedigrees can take a variety of forms, but they all function in a similar way. The charts use symbols to identify family members and the expression of a particular trait.

Pedigree for Tongue Rolling





Key

Can roll edges of tongue (dominant trait)

Cannot roll edges of tongue (recessive trait)

Read a Diagram

Are either of these children the youngest or oldest of their siblings?

Clue: Identify whether they can roll their tongues. Then find their places on the chart.

▲ The unattached earlobe is the dominant trait. The attached earlobe is recessive.

A pedigree reads as follows:

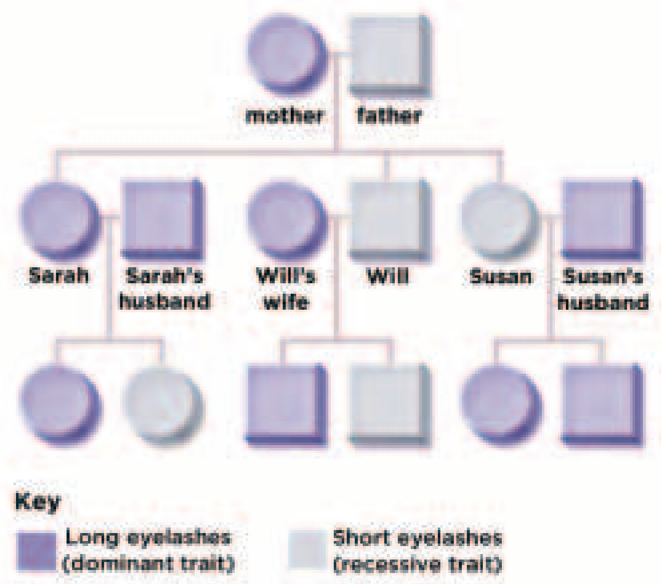
- Circles represent females; squares represent males.
- A square and a circle connected by a horizontal line represent male and female parents. A vertical line connects parents to their offspring.
- A horizontal line connects the children in a family. The oldest child is always on the left, and the youngest is on the right.
- Darker-shaded circles or squares stand for individuals who show the particular trait that is being studied.
- Lighter-shaded circles or squares stand for individuals who do not express that trait.

In the pedigree for tongue rolling, both the mother and the father are able to roll their tongues. Of the four children, two can roll the tongue, and two cannot. Because the gene for not rolling is recessive, you can infer that both parents must be carriers of the non-rolling gene. A **carrier** is one who has inherited the gene for a particular trait but does not express that trait.The trait is part of the individual's genotype but not his or her phenotype.

Quick Lab

Pedigrees

1. **Observe** Study this pedigree for eyelash length. Which family members have short eyelashes?
2. **Infer** The trait for short eyelashes can skip a generation and then reappear. What does this tell you about Sarah's genes for this trait?
3. **Infer** What can you infer about the genes of Sarah's husband regarding this trait?
4. **Communicate** Choose a trait that is expressed in some family members, perhaps your own. Draw a pedigree showing the occurrence of this trait in the family members.



Quick Check

Main Idea and Details What information can you learn from a pedigree?

Critical Thinking What does a darker circle on a pedigree represent?

What disorders are inherited?

Genetic disorders are conditions caused by mutations, or changes, in a gene or set of genes. One example occurred in the family of England's Queen Victoria. The queen carried the gene that causes hemophilia, a disorder in which blood does not clot properly. The queen did not have hemophilia herself, but one of her sons and a few of her grandsons and great-grandsons did. Hemophilia is a condition caused by a recessive, sex-linked gene.

Another genetic disorder that affects the blood is sickle-cell anemia. Normal, disk-shaped red blood cells carry oxygen throughout the body. Sickle-cell anemia causes red blood cells to be inflexible and shaped like sickles, or half-moons. Since cells like this cannot move freely through blood vessels, the body receives less oxygen.

In some genetic disorders, whole chromosomes or parts of chromosomes are missing, duplicated, or changed. For example, Down syndrome occurs when a child inherits an extra copy of one chromosome in pair 21. People with this disorder may have mild to severe mental disabilities and other health problems. Fortunately, many people with Down syndrome lead happy, productive lives.

There are many different genetic disorders. Some people who have them are not even aware of it. With the rapid growth of knowledge in the field of genetics, more of these disorders can be diagnosed early and treated.

Quick Check

Main Idea and Details What is a genetic disorder?

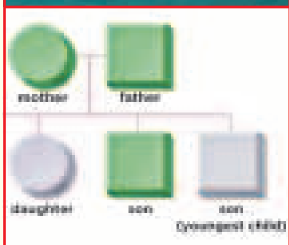
Critical Thinking How could Queen Victoria not have hemophilia herself yet pass it on to a son and several of her grandsons and great-grandsons?

Down syndrome occurs in 1 out of every 800 births.

Lesson Review

Visual Summary

Genes are the basic units of heredity and control inherited traits.



Pedigrees are charts that show patterns of inheritance for particular traits.

Genetic disorders are conditions caused by gene mutations, such as copies or omissions of chromosomes.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the phrase and provide supporting details.

Think, Talk, and Write

1. **Main Idea** Dominant and recessive genes determine people's inherited ________.
2. **Vocabulary** A person who inherits the gene for a particular disorder but does not express that disorder himself or herself is a(n) ________.
3. **Main Idea and Details** Explain how a recessive trait is passed on to offspring.

Main Idea	Details

4. **Critical Thinking** A couple has four sons. What is the probability that their next child will be a boy? Explain your reasoning.
5. **Test Prep** **Which combination of chromosomes will produce a male offspring?**
   - **A** two X
   - **B** one X, one Y, and one Z
   - **C** two Y
   - **D** one X and one Y
6. **Test Prep** **Which genetic disorder causes misshapen red blood cells?**
   - **A** hemophilia
   - **B** Down syndrome
   - **C** sickle-cell anemia
   - **D** color blindness

Writing Link

Explanatory Writing

Write a letter to Gregor Mendel explaining what the "factors" he identified in his experiments really are and how they transfer traits from one generation to the next.

Art Link

Design a Pedigree

Pedigrees can be beautiful pieces of art. Design a pedigree for your family or a fictional family, tracing an inherited trait of your choice. Make the chart both attractive and accurate.

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THE DANGERS OF ANTIBIOTICS

To the Editor:

As a scientist and a doctor, I feel that Americans are using antibiotics too often and for the wrong reasons. I want to warn people about the dangers of overusing these drugs.

Antibiotics can be harmful, because they keep the immune system from getting stronger. People who take antibiotics too often may get sick more easily. This is especially true for children.

The way antibiotics make you better is by killing bacteria living in your body. However, antibiotics kill good bacteria as well as bad bacteria. This can lead to serious illnesses, especially in older people.

Most importantly, antibiotics help breed "superbugs." The antibiotic drugs kill off the weaker bacteria first. The stronger bacteria can develop a resistance to the drug and multiply in the body. Without competition from the other bacteria, they reproduce rapidly. Then only the strongest antibiotic can kill them. Some scientists predict that we will soon have bacteria that no antibiotic will be able to kill. This would be a very dangerous situation. People could die from everyday infections.

Doctors should prescribe antibiotics only when they are really necessary. Patients should not ask for antibiotics if some other medicine can help them. Let's keep antibiotics working by using them in a smart, responsible way.

Dr. Christine Anderson

Persuasive Writing

Good persuasive writing

- clearly states an opinion on a specific topic
- uses convincing reasons and arguments
- organizes reasons in a logical order
- usually saves the strongest argument for last
- includes opinion words

Write About It

Persuasive Writing Do some online research and find more information about the dangers of overusing antibiotics. Write a one-minute public-health announcement to be broadcast over your local radio station. Give reasons that people should limit the amount of antibiotics that they use. Save your most important reason for last.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

We all want antibiotics to remain effective against bacteria, so we must not overuse them.

Math in Science

How Can You Analyze Traits?

A pedigree is one way of showing a family's traits. The chart uses square symbols to represent male family members and circles to represent female family members. Filled-in shapes represent family members who show a particular trait, and empty shapes indicate those who do not show the trait.

The pedigree below includes two parents and five children. It shows which family members have freckles. Freckles are a dominant trait, so the shapes for those family members are filled in.

Fractions and Percents

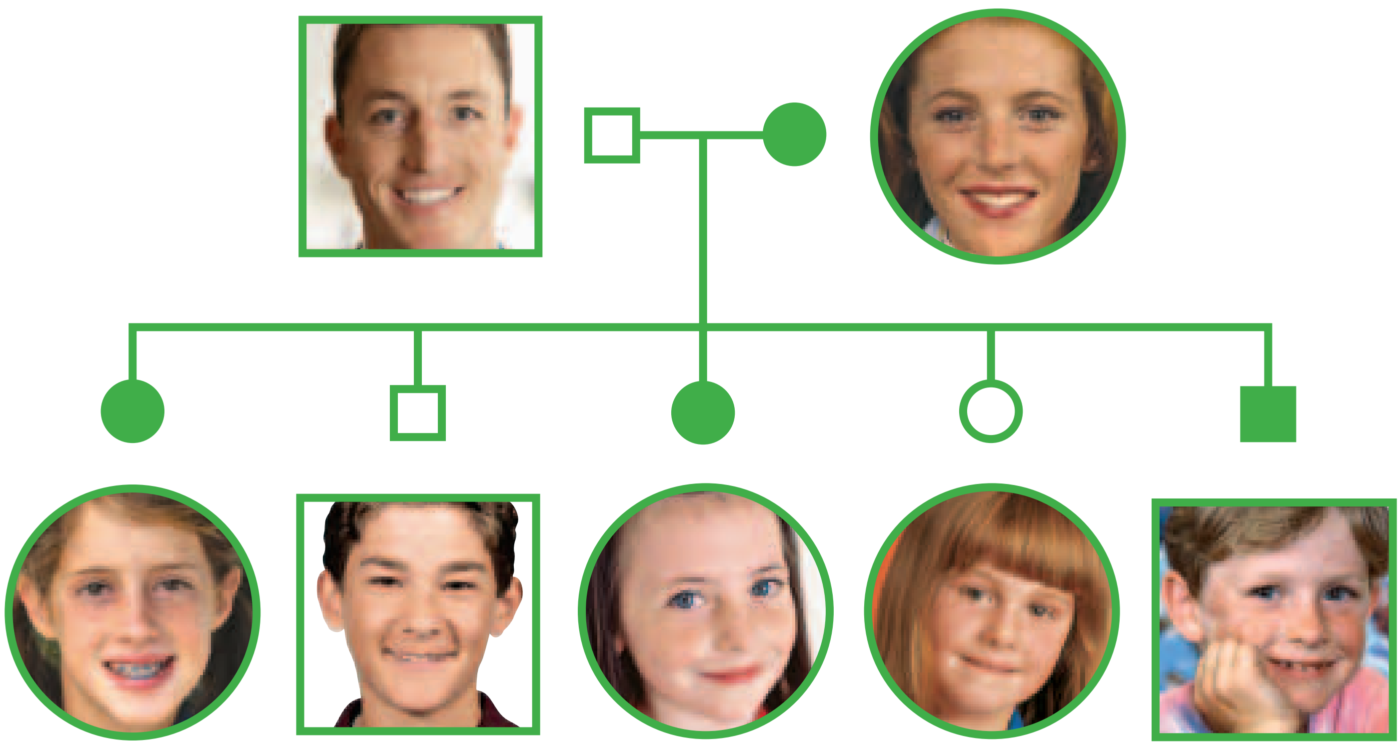
To convert a fraction to a percent,

- divide the numerator by the denominator

  $\frac{3}{5} = 0.6$

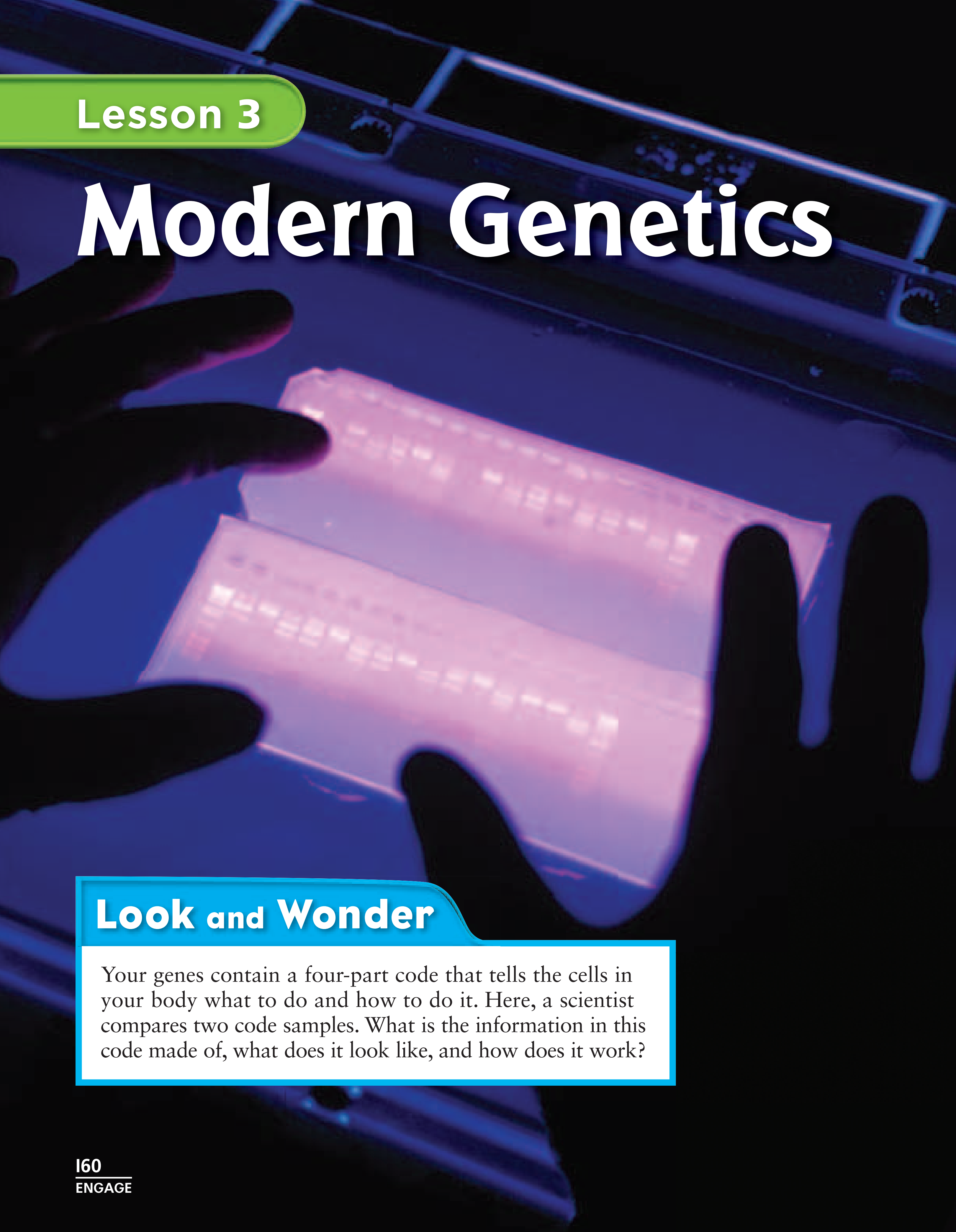
- then multiply by 100

  $0.6 \times 100 = 60\%$



Solve It

1. What is the ratio of children with freckles to children without freckles?
2. What percent of the children have freckles?
3. How many people in the family have freckles? What percent of family members do they represent?



Lesson 3

Modern Genetics

Look and Wonder

Your genes contain a four-part code that tells the cells in your body what to do and how to do it. Here, a scientist compares two code samples. What is the information in this code made of, what does it look like, and how does it work?

Explore

Inquiry Activity

How does a four-part code work?

Purpose

Chromosomes are made up of genes. Each gene contains part of the code that controls various traits. How are these codes put together? Use puzzle pieces to make a model of this genetic code. The letters of the puzzle pieces represent the four types of substances that cells use to record and transfer information.

Procedure

1. **Make a Model** Gather some genetic puzzle pieces together. Arrange your puzzle pieces so that each of them fits together with another piece. Then put all of them together. Use colored pencils to draw a copy of how the pieces in your model fit together.
2. **Observe** Can you assemble the pieces in a different way? How many different models can you make? Which parts fit together, and which parts do not? Explain why they do or do not fit.
3. **Communicate** How are your models like those of other students? How are they different?

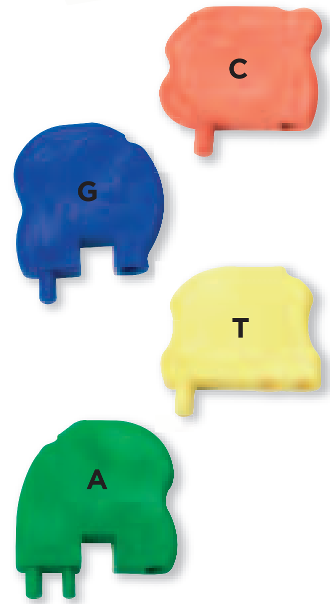
Draw Conclusions

4. **Experiment** Develop a simple way of showing the arrangement of the pieces without actually drawing the assembled pieces. How does your method work?
5. **Interpret Data** What is the main difference among the ways that you assembled the puzzle?
6. **Infer** How might the different ways of assembling the puzzle be used as a code?

Explore More

Make a fifth puzzle piece. Label it *U*. How would you shape the piece so it could link horizontally to piece A and still be part of the puzzle? If you shaped piece U this way, would one of the original four have to be left out? If one would be left out, which one would it be? Try it, and share your findings with the class.

Materials



- genetic puzzle pieces
- colored pencils

Read and Learn

Main Idea

DNA is the genetic material in genes and chromosomes that offspring inherit from their parents. It determines traits and provides instructions for cell operations.

Vocabulary

DNA, p.162
genome, p.163
genetic engineering, p.164
geneticist, p.164
gene splicing, p.165
clone, p.165

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Reading Skill

Fact and Opinion

Fact	Opinion

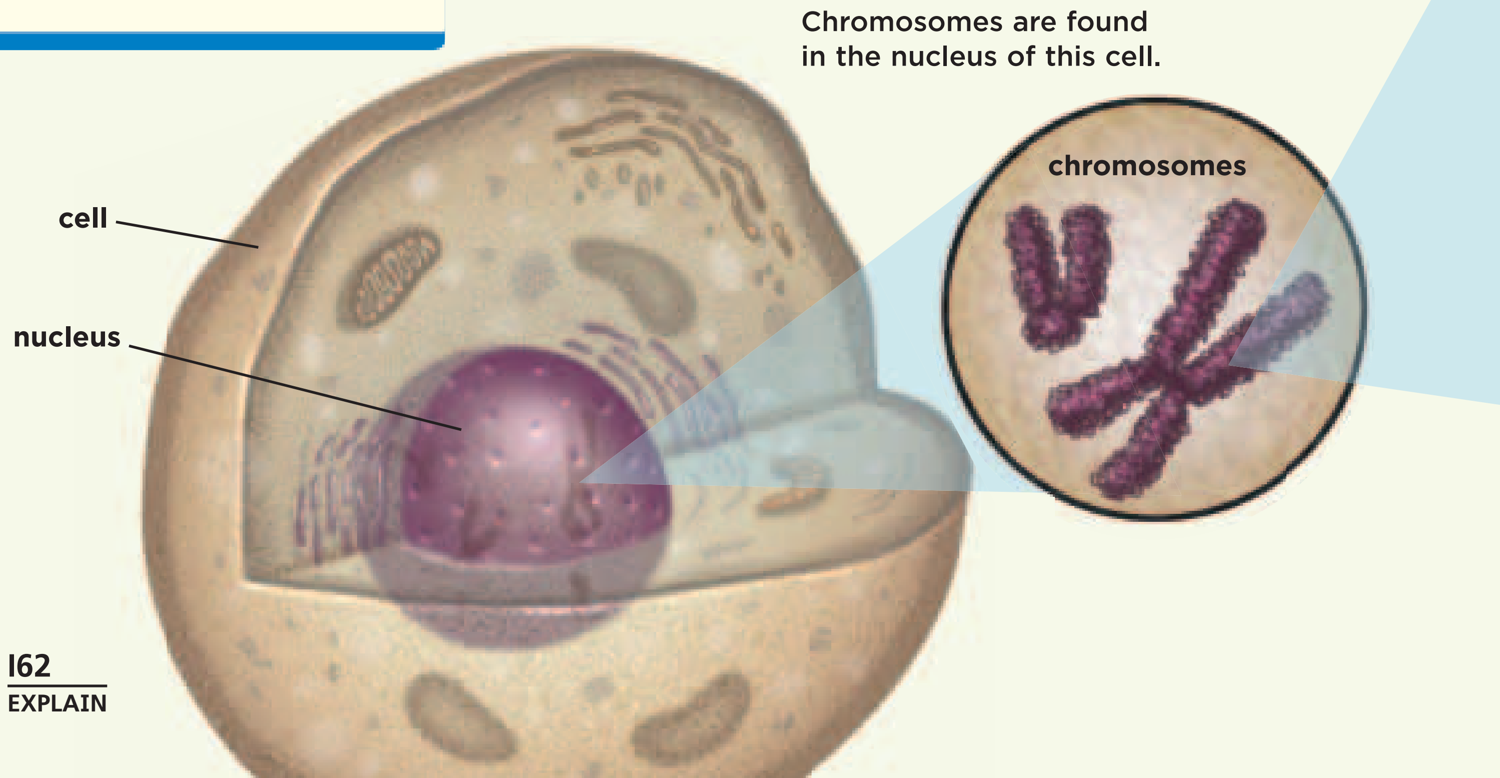
What is DNA?

In 1869, three years after Gregor Mendel's work was published, Johann Friedrich Miescher isolated a chemical substance he called *nuclein*. This later became known as nucleic acid. The discovery of nucleic acid led to the discovery of DNA. **DNA**, or deoxyribonucleic acid, is a long, complex molecule that contains the genetic code of an organism.

In 1953, James Watson and Francis Crick discovered DNA. The molecule itself looks like two long spirals connected together, forming a twisted ladder. The shape of DNA is called a *double helix* (HEE•liks). Watson and Crick determined that each rung of the double helix was made up of a pair of chemicals they called *bases*. There are four different bases found in DNA: cytosine (C), guanine (G), thymine (T), and adenine (A).

Like jigsaw-puzzle pieces, bases connect together in specific ways. Each base bonds only with its own specific match. Adenine bonds with thymine, and guanine bonds with cytosine. The sides of the double helix are made of sugars and phosphates. The bond between each base pair holds the two sides together.

Genes and DNA



A strand of DNA resembles a twisted ladder or spiral staircase.

Read a Diagram

In what part of this cell is DNA found?

Clue: Follow the DNA to its point of origin.

Genetic Code

DNA is the genetic code that determines the function of each cell. Each gene is a short section of the long DNA molecule that makes up the whole chromosome. The order of the base pairs in DNA is what determines genetic characteristics, and that order is the same in all the cells found in an individual organism.

Controls are in place within the DNA to ensure that each gene is expressed in the correct tissue. For example, these controls make sure that corneal tissue grows only where your eyes belong and that nails grow only on your fingers and toes. When cells divide during mitosis, an identical set of chromosomes is produced. This means that a copy of the DNA molecule is made with exactly the same order of base pairs as the original.

The DNA of any particular species is different from the DNA of every other species. A **genome** (JEE•nohm) consists of all the DNA that makes up an organism. The base pairs, A-T and G-C, are repeated millions or even billions of times. The human genome is made up of about 3 billion base pairs. Variations in the number and order of these base pairs cause all the genetic differences found in Earth's organisms.

Quick Check

Fact and Opinion "DNA contains a genetic code." Is this statement a fact or an opinion?

Critical Thinking How are the four bases that make up DNA similar to an alphabet?

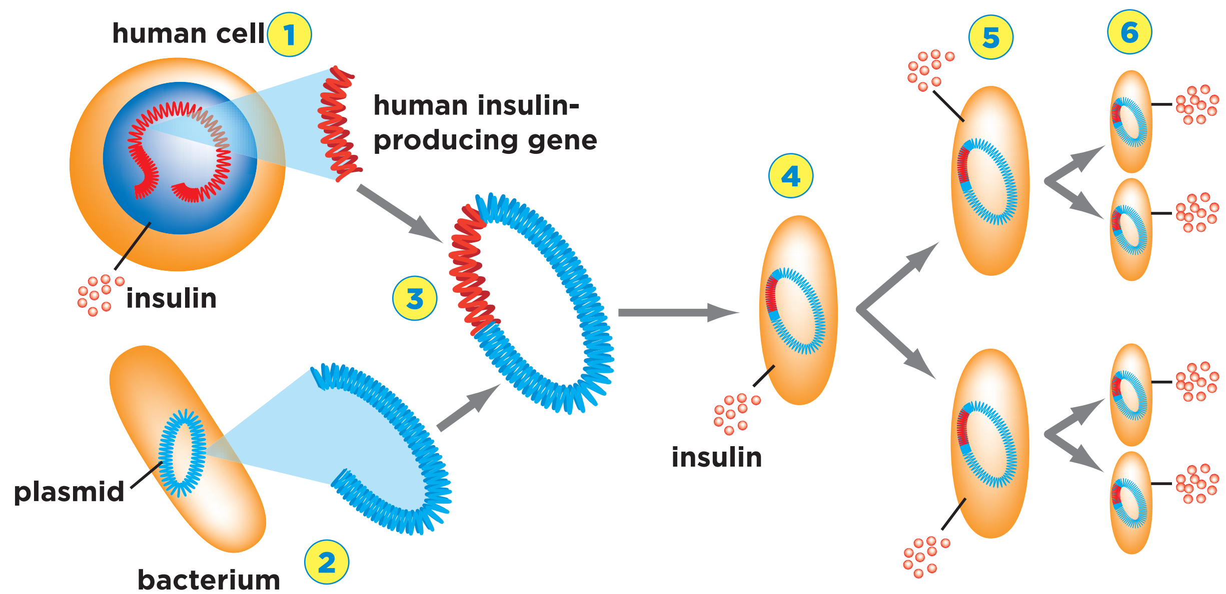
What is genetic engineering?

In 1973, scientists Stanley Cohen and Herb Boyer first transferred DNA from one species to another. The process is called genetic engineering. **Genetic engineering** is a way of intentionally changing a genetic sequence in DNA so that a particular trait is produced.

A **geneticist** is a scientist who studies how heredity works. Geneticists use their knowledge in many innovative ways. For example, genetic engineering has made it easier to clean up oil spills. Now, bacteria can be genetically engineered to produce substances that break down oil particles. When applied directly to an oil spill, these genetically altered bacteria can break some of the oil down into harmless, nontoxic substances.

Genetic engineering can also produce crops that are able to withstand extreme weather conditions. Barley plants each have a gene that controls the traits that determine the plant's strength, height, and resistance to drought. If this gene is injected into wheat, rice, or soybeans, it could produce a crop that is strong enough to survive a drought.

Gene Splicing



1 A human insulin-producing gene is identified.

2 Plasmid DNA of an *E. coli* bacterium is cut by special chemicals.

3 The gene for insulin production is spliced into plasmid DNA.

4 The plasmid DNA is then inserted into the *E. coli* bacterium, and therefore the bacterium can produce human insulin.

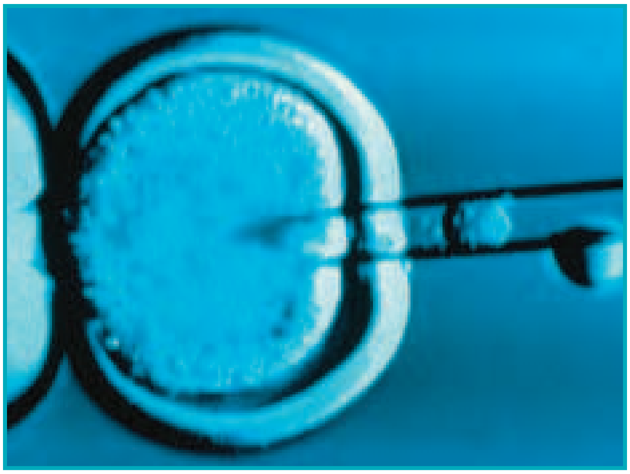
5 Insulin-producing *E. coli* bacteria pass this trait on to offspring.

6 Large amounts of human insulin are produced by many genetically engineered *E. coli* bacteria.

Read a Diagram

What characteristic do bacteria share with humans after this process?

Clue: What can the bacteria do now that they could not do before?



▲ To clone a sheep, scientists inject a complete nucleus into an egg.

Gene Splicing

Gene splicing takes genes from one organism and adds them to the genes of another organism. Geneticists use chemicals to cut out the part of the gene that is to be transferred. It is then combined with the *plasmid*, a small, circular structure of genetic material found in bacteria. The DNA from another organism is inserted, or spliced, into the plasmid. Gene splicing is used to produce drugs and medicines. Insulin, a substance needed by diabetics, is produced in bacteria through gene splicing.

A **clone** is an organism that receives all of its DNA from one parent and is genetically identical to that parent. In 1996 Scottish scientist Ian Wilmut led a team that took a body cell from an adult female sheep and transferred it to an egg with the nucleus removed. The egg divided into a ball of cells as if it had been naturally fertilized, and it was placed inside a sheep to develop. The end result was a lamb named Dolly. Dolly's DNA was identical to the DNA of the adult sheep from which the body cell was taken.

Quick Lab

Researching Genetically Engineered Crops

1. Read some information about genetically engineered crops.
2. **Record Data** Fold a piece of paper into three panels. In the center panel, list all the facts you have collected. On the left panel, list all the positive, or favorable, opinions about genetically engineered crops. On the right panel, list all the negative, or unfavorable, opinions you found.
3. **Communicate** Compare the facts to the two groups of opinions. How do you feel about genetically engineered crops? Share your researched facts with a partner.
4. **Draw Conclusions** Present your opinion to the class. Support your opinion with facts and quotes from your research.

Quick Check

Fact and Opinion "Genetic engineering is an exciting field of science." Is this statement a fact or an opinion?

Critical Thinking Is a clone completely identical in every way to its parent?

What are genetically engineered crops?

In recent years, there has been a significant increase in the production of genetically engineered crops. In fact, about 80 percent of processed food in your local supermarket contains some genetically engineered ingredients.

Genetically engineering crops can have many benefits. Crops can be modified in ways that increase productivity and nutrient content. People may then be able to grow food more efficiently, without using more land. Genetic engineering can also be used to produce crops that are better able to resist disease, weeds, and harmful insects. This could reduce the need for pesticides and other potentially dangerous chemicals. A great deal of research is still needed if we as a society are to enjoy all these advantages.

One example of modern genetic engineering in agriculture is Bt corn. *Bt corn* is corn grown from cells injected with a gene from bacteria that produce Bt toxin. Bt toxin is poisonous to insects and pests such as the European corn borer, which destroys corn by digging through the stem and causing it to fall over. When the modified corn cells reproduce, the bacterial gene is part of the information that the corn cells pass on to their offspring.

Quick Check

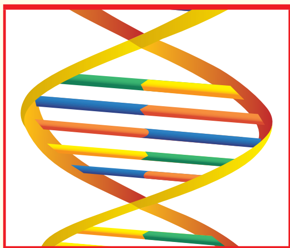
Fact and Opinion "Genetic engineering is used to improve many foods." Is this a fact or an opinion?

Critical Thinking What would be the benefits of being able to produce more crops without using more land?

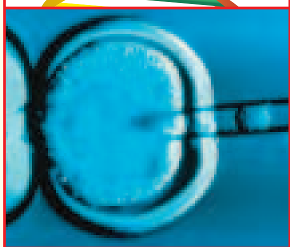
The European corn borer damages about 40 million tons of corn each year.

Lesson Review

Visual Summary



DNA is a long, complex molecule that contains a genetic code.

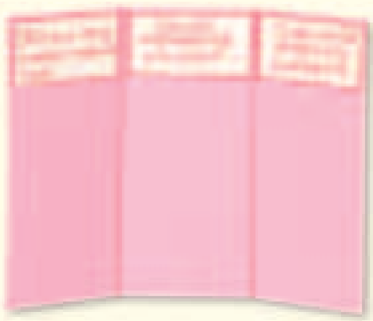


Genetic engineering is a way of changing an organism's DNA to produce a particular trait.

Crops can be **genetically modified** to increase productivity, improve nutritional value, and resist diseases and pests.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add details for each genetics topic.



Think, Talk, and Write

1. **Main Idea** The genetic material in genes and chromosomes is ________.
2. **Vocabulary** When geneticists cut genes from one organism and insert them into the DNA sequence of another organism, the process is called ________.
3. **Fact and Opinion** "Bt corn is corn that has been genetically modified." Is this statement a fact or an opinion? Explain your answer.

Fact	Opinion

4. **Critical Thinking** How might genetically engineered crops help people in harsh climates?
5. **Test Prep** **How are DNA bases paired?**
   A U-T and A-G
   B G-T and C-A
   C A-G and C-T
   D A-T and C-G
6. **Test Prep** **A clone receives all of its DNA from**
   A gene splicing.
   B genetically engineered crops.
   C one parent.
   D two parents.

Writing Link

Persuasive Writing

Research some of the arguments for and against cloning. Write a one-page paper stating your opinion. Provide evidence to support your position.

Social Studies Link

Make a Time Line

Scientists constantly build upon the ideas of others. Research some of the scientists who have made advances in modern genetics. Make a detailed time line of their discoveries.

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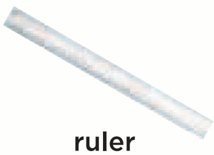
Be a Scientist

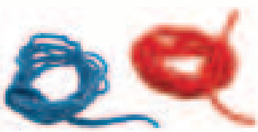
Materials

construction paper


ruler


scissors

⚠ **Be Careful.**


red and blue yarn


glue stick

Structured Inquiry

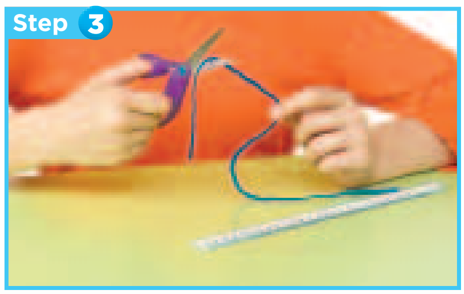
How do scientists genetically engineer bacteria to produce insulin?

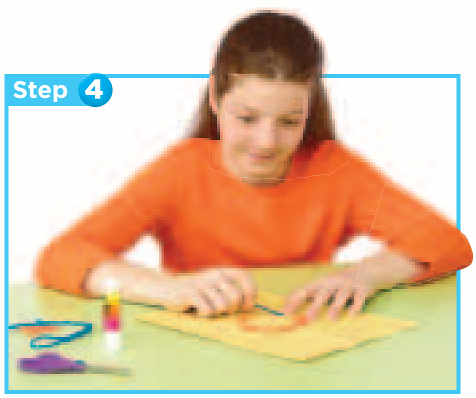
Form a Hypothesis

Genetic engineering is intentionally changing DNA so that a gene will produce a specific trait. Geneticists have changed genes in plants to make the plants larger, heartier, or tastier. They have also changed genes in bacteria so that these cells can produce chemicals used in medicines and for other applications. For example, the gene that produces insulin in humans has been added to bacteria so that the bacterial cells produce insulin. The insulin is needed by people who have diabetes. This type of insulin is better for people than the types previously used. How can you model genetic engineering? Write your answer in the form of a hypothesis: "If a gene from a human is added to, or replaces, a piece of bacterial DNA, then the model of this genetic engineering will look like . . ."

Test Your Hypothesis

1. Draw a large circle on a piece of construction paper. This will represent the bacterial cell.
2. Cut a 12 in. piece of red yarn, and tie the ends together to make a circle. This will represent the bacterial DNA. Glue down half of the DNA to the middle of your bacterial cell.
3. Cut a 2 in. piece of blue yarn to represent the human gene for producing insulin. The scissors you cut with represent chemicals used to cut DNA at specific points.
4. Cut a 2 in. section from the "bacterial DNA," and replace it with the "human gene," gluing the yarn at both ends.





Draw Conclusions

5. **Infer** Genetic engineering must be done in a clean room and under very strict conditions. Why do you think this is necessary?

6. **Infer** Why would scientists be interested in putting the human insulin-producing gene into bacterial DNA?

Guided Inquiry

How are genetically engineered seeds different from wild seeds?

Form a Hypothesis

Farmers use many genetically engineered plants that grow faster or better in certain conditions. What differences are there between wild seeds and genetically engineered seeds? Write your answer in the form of a hypothesis: "If a plant is genetically engineered, then there will be measurable differences in the seeds, such as . . ."

Test Your Hypothesis

Design an experiment to determine the differences between wild and genetically engineered radish seeds. Write out the materials you will need and the steps you will follow. Record your observations.

Draw Conclusions

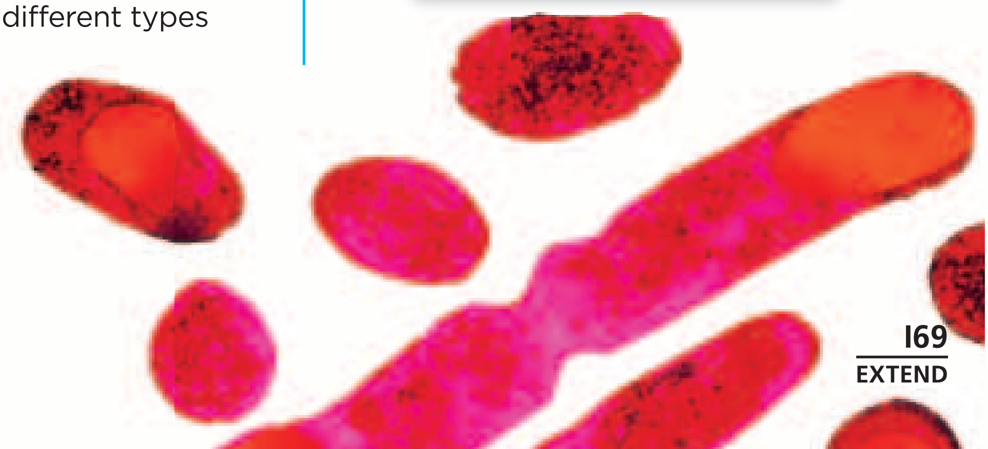
Did your results support your hypothesis? Why or why not? What differences did you see between the two different types of seeds?

Open Inquiry

What else can you learn about genetic engineering? For example, what are some differences in how genetically engineered plants grow? Design an experiment to answer your question. Write your experiment so that another group could complete the experiment by following your instructions.

Remember to follow the steps of the scientific method.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions



Insulin-producing bacteria are a result of genetic engineering. ▶

Lesson 4

Genetic Change over Time

Look and Wonder

Have you ever noticed how many different types of organisms live on Earth? Some variations, such as those of this giant anteater, help an organism survive and reproduce. How might these different variations occur?

Explore

Inquiry Activity

How do variations help animals survive?

Form a Hypothesis

How might you explain variations among animals of a single species? What are some factors that may have contributed to the changes within the species? Write your answer in the form of a hypothesis: "If there are variations within a species, then . . ."

Test Your Hypothesis

1. **Observe** The photographs at right show finches found on the Galápagos Islands, a group of islands in the Pacific Ocean. Think like a scientist. Study the differences among the beaks of the birds shown here, and write detailed notes about them. You may want to include sketches as well.
2. **Infer** In your notes, make a column with a list of the traits you observed. Next to each trait, write a possible explanation for how it might help a bird survive and reproduce.
3. Research each bird to see where it lives and what it eats. Include this information in your notes.
4. **Infer** Use your observations and notes to propose an explanation for how these variations might have occurred.

Draw Conclusions

5. **Communicate** How do you think the variations occurred? Share your ideas with a partner.
6. **Infer** Some of the finches live on different islands. How might geography have influenced the variations among these birds?

Explore More

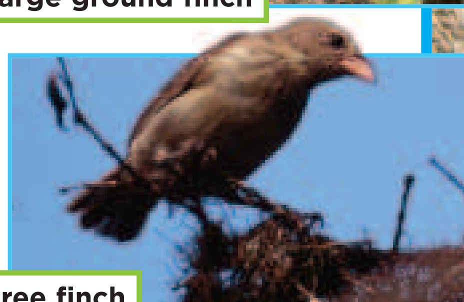
Research variations among organisms of another species. What types of features can you find? How might these features help the organisms survive?

Materials

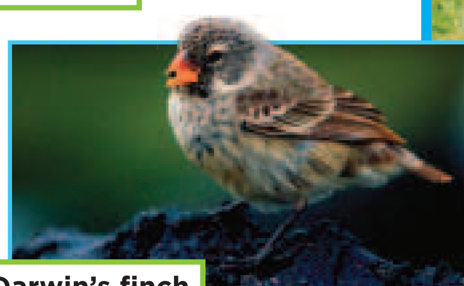
- paper
- pencil

woodpecker finch

large ground finch



tree finch



Darwin's finch

Read and Learn

Main Idea

Genetic variations and environmental factors have led to great diversity among living things.

Vocabulary

variation, p.172
mutation, p.172
natural selection, p.174
antibiotic, p.176

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Reading Skill

Cause and Effect

Cause	→	Effect
	→	
	→	
	→	
	→	

What are variations?

On December 27, 1831, Charles Darwin, a British naturalist, boarded the H.M.S. *Beagle* for a journey around the world. In the fall of 1835, the ship reached the Galápagos Islands. There, Darwin made important observations of different finch species. Darwin's studies of these birds helped him recognize genetic variations. The 13 species of finches he saw in the Galápagos Islands were all similar in size, color, and habits. However, their beaks were different in size and had shapes ranging from very thick to very fine. Still, Darwin thought the finches might all have come from one common ancestor.

Darwin noticed that each species of finch was very well suited to its particular environment. For example, the different beak types enabled the finches to eat particular kinds of seeds and insects. Each beak type was a **variation**, or a difference among members of the same species that enables individuals to better survive and reproduce. Such differences are caused by changes in an organism's genetic makeup. A **mutation** is a change in an organism's DNA. Such a change can occur because of an error in mitosis or meiosis. Changes can also occur when genes combine during sexual reproduction.

The Galápagos Islands are home to many unique species, such as these marine iguanas.

Darwin's Finches

Read a Diagram

What type of food might the large ground finch of the Galápagos Islands feed on?

Clue: Beak types allow finches to eat particular types of food.

Variations for Survival

Darwin's finches can all be traced back to a single species. How can the variations among the beaks of these birds be explained? When the original species arrived at the Galápagos Islands, some of the birds likely became separated and flew off to different islands. On each island different types of food were available. If thick-shelled seeds were a major food source on one island, birds with thick beaks would be the ones best suited to eat them. These birds would be the most likely to survive and reproduce there. Later populations of birds on that island would have thick beaks. If insects were the main food source on another island, then the birds with narrow, grasping beaks would be more likely to survive and reproduce there.

Darwin's finches demonstrate how variations can favor certain animals over others. The beaks of the two populations of birds would remain different, as long as the two finch species did not produce offspring with each other. Variations can help a species survive. This means that a variation can help individuals in a species live long enough to successfully reproduce. The trait will then be passed on to the next generation. What if a variation does not favor survival? In that case, the individuals are less likely to reproduce and pass on the trait.

Variations also occur in plants. Many varieties of plants are well suited to live in particular climates. Some plants from dry climates have very shallow roots that grow near the surface of the soil. This allows them to capture much of the rain that falls. Other plants have roots that extend deep into the ground. In both plants and animals, variations can help species in their struggle for existence by enabling individual organisms to survive and reproduce.

Quick Check

Cause and Effect How do the finches of the Galápagos Islands demonstrate variations?

Critical Thinking How are variations passed down through generations?

What is natural selection?

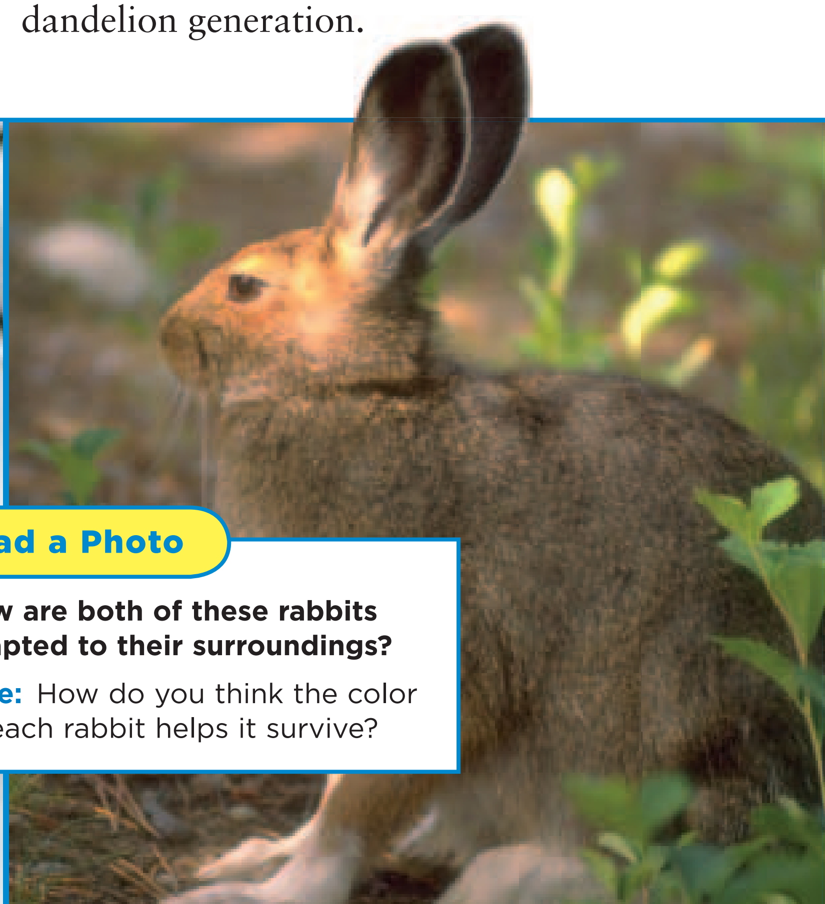
Consider a dairy farmer with a herd of cows. What if one of the cows produced much more milk than the others? When it was time to breed the animals, which cow do you think the farmer would be most likely to choose? The farmer would probably select the cow that produced the most milk. The farmer's goal in this selective breeding would be to have more cows that also produced greater amounts of milk.

Nature has its own selection process. All living things compete for food, water, sunlight, space, and other resources. The organisms that are best able to obtain food and escape from predators survive and reproduce. To ensure that their species continue, most organisms produce more offspring than their environments can support. This increases competition for resources such as food, water, sunlight, and space. This higher number of offspring also increases the probability that variations will occur.

Natural selection occurs when the organisms that are best suited to their environments survive and reproduce successfully. This process is sometimes called the "survival of the fittest."

Think about dandelion seeds. In spring, the air sometimes seems to be filled with dandelion seeds. What if all the dandelion seeds from the parent plant fell to the ground and grew? The competition for water, nutrients, sunlight, and space would be so fierce that many young plants would not survive. However, this is not what happens. Instead, feathery dandelion seeds are set adrift in the wind. Some seeds will not land in conditions favorable for growth. Even if a seed does land in a favorable spot and begins to grow, it may be eaten, pulled up, or otherwise destroyed. Despite the large number of seeds produced, relatively few survive. The seeds that do grow and survive pass their genetic information to the next dandelion generation.

Color Adaptations



Read a Photo

How are both of these rabbits adapted to their surroundings?

Clue: How do you think the color of each rabbit helps it survive?

Dandelions produce many seeds to ensure that some survive.

Living things often have other traits that enable them to survive. Many of these traits are also produced by genetic variations. For example, on the Galápagos Islands, only the finches with larger and stronger beaks could crack the seeds with the toughest shells. These strong-beaked birds mated with other strong-beaked birds and passed this trait to their offspring.

Animals whose fur or skin color blends into their surroundings are much more likely to hide from or escape their predators than are animals that are more noticeable. This ability to blend in is called *camouflage*. Camouflage also allows both predators and prey to move about, unnoticed, to obtain food and other resources.

Other organisms may have bright coloring that makes them quite noticeable. Vivid coloring can serve many purposes. In some species, coloring may warn predators that an organism is dangerous, tastes bad, or is poisonous. In other species, bright coloring can be a way to attract a mate.

FACT The strongest and the fastest are not always the organisms that survive.

Quick Lab

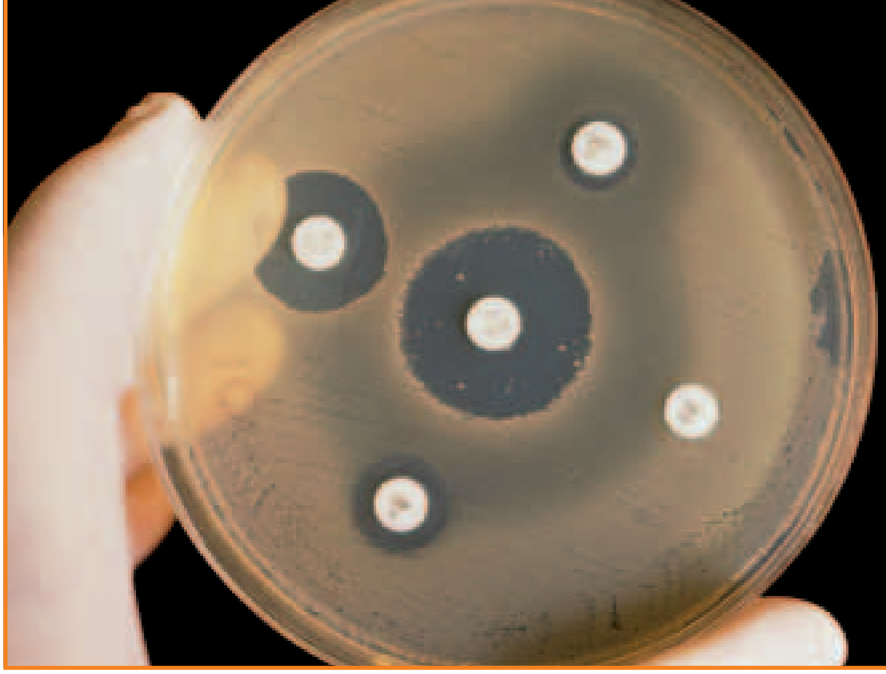
Deep-Sea Creatures

1. What types of creatures might you encounter in the deep ocean?
2. **Infer** Working in small groups, make a list of features that would help an organism survive deep in the ocean. Explain the benefit of each trait.
3. **Make a Model** Design your own deep-sea creature, and draw a picture of the organism. Label all the traits from your list. Describe how each trait would help the creature survive and reproduce.
4. Read about some of the unusual creatures that live in the ocean.
5. **Classify** Compare your creature to actual, known ocean organisms. Where might your creature fit if it were classified as a new discovery?

Quick Check

Cause and Effect How can an animal's coloring affect its chances of survival?

Critical Thinking How does natural selection compare to selective breeding?



Some strains of bacteria are sensitive to antibiotics, and others are resistant. The diameters of the clear rings show how effective the samples of antibiotics were.

What is bacterial resistance?

Natural selection does not just happen to the organisms we can see. Natural selection also occurs among microorganisms, the organisms that we can only see under a microscope. While microorganisms such as bacteria can be helpful in some situations, they can also cause diseases. For example, various bacteria cause ear infections, strep throat, and various forms of pneumonia and meningitis.

In 1928, Sir Alexander Fleming discovered penicillin, the first antibiotic. An **antibiotic** kills disease-causing bacteria without harming the host. There are thousands of antibiotics, and more than 100 are widely used in modern medicine.

The problem is that some bacteria are more difficult to kill than others. In certain cases, doctors find that they must try different types or larger doses of antibiotics to treat an infection effectively. Sometimes antibiotics do not work at all against a particular type of bacteria. These bacteria are *resistant*.

When a patient is treated for a bacterial infection, antibiotics may not kill all the bacteria in the first few doses. This is particularly true when patients stop taking the antibiotic before completing the full course of medicine prescribed by the doctor.

Which bacteria do you think could survive an attack by antibiotics? Only the bacteria that are most resistant to the antibiotic survive. When these bacteria then reproduce, they pass their antibiotic-resistant genes on to the next generation of bacteria. Once this occurs, people are more likely to be infected by resistant bacteria. The result is that, over time, all antibiotics have gradually become less effective at fighting bacterial infections.

Quick Check

Cause and Effect What causes bacterial resistance?

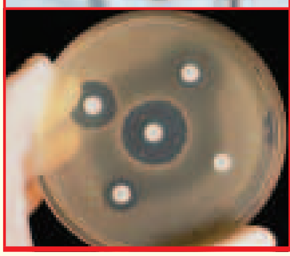
Critical Thinking How can people help prevent bacterial resistance?

Lesson Review

Visual Summary

Variations are differences among members of the same species. The causes of these differences may be genetic or environmental.

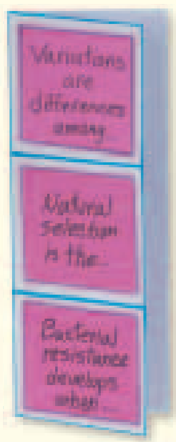
Natural selection is the survival and successful reproduction of the organisms best suited to their environment.



Bacterial resistance develops when antibiotics do not kill all the bacteria they are used to treat.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. On the inside of each tab, complete the phrase and provide supporting details.



Think, Talk, and Write

1. **Main Idea** How does natural selection relate to the survival of the fittest?

2. **Vocabulary** The diversity of living things is due to ________.

3. **Cause and Effect** Why would failing to finish taking a prescription of antibiotics contribute to bacterial resistance?

Cause	→	Effect
	→	
	→	
	→	
	→	

4. **Critical Thinking** What might happen if some lions were better hunters than other members of the pride?

5. **Test Prep** **Which of these is a process, occurring over time in nature, that results in the survival of the fittest?**
   - **A** an antibiotic
   - **B** genetic engineering
   - **C** a variation
   - **D** natural selection

6. **Test Prep** **If all dogs could be traced back to a common ancestor, the gray wolf, then short-haired dogs would be a**
   - **A** spore.
   - **B** camouflage.
   - **C** variation.
   - **D** behavior.

Writing Link

Narrative Writing
Think about what it might have been like if you had sailed along with Charles Darwin on-board the H.M.S. *Beagle*. Write a journal entry about discoveries you and Darwin might have made.

Health Link

Public-Service Message
Do research to gather additional information about bacterial resistance. Then prepare a public-service message about the dangers of using antibiotics incorrectly.

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Meet Joel Cracraft

New Guinea is a large island just to the north of Australia. In its forests live some of the most spectacular and colorful birds in the world—so beautiful, in fact, that they are called birds of paradise.

Joel Cracraft, a scientist at the American Museum of Natural History, researches these birds. There are more than 90 kinds of birds of paradise on New Guinea. Joel is investigating why there are so many and how they are related. To do this he analyzes their DNA and studies where they live.

Geography plays an important role in the way new species evolve. Birds of paradise do not fly far from home, so the birds on New Guinea have little or no contact with birds on the small, surrounding islands. Furthermore, even the birds on New Guinea itself may not come into contact with each other. For example, New Guinea's central, high mountain range is divided by deep river valleys. This prevents populations living on isolated mountaintops from ever meeting.

Joel is an evolutionary biologist. That is a scientist who studies the history of changes in organisms.

Like all organisms, birds pass their characteristics down to the next generation through genes. Over time, these genes change. For example, females tend to choose the most colorful males as mates. More-colorful males mate more frequently, so their genes are selected and passed down to future generations more often than those of less-colorful males. Random mutations (changes in the makeup of genes) also occur. A mutation may change a characteristic such as size, color, or feather type. If these changes help a bird survive, then those new genes will be passed down to the bird's offspring.

Over millions of years, all these factors—isolation, selection, and mutation—influence the way a group of birds evolves. Eventually, the group may even become a new species, with its own coloring, plumage, and behavior.

Joel studies the DNA of all the different kinds of birds of paradise. The genes in the DNA tell him how the groups are related, and this helps him understand how new species have come to be.

Fact and Opinion

- Facts are based on true information.
- Opinions express a personal preference or point of view.

Write About It
Fact and Opinion

1. What opinion does the writer express in this statement: "In its forests live some of the most spectacular and colorful birds in the world"?
2. "There are more than 90 kinds of birds of paradise on New Guinea." Is this statement a fact or an opinion?

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American Museum of Natural History

CHAPTER 3 Review

Visual Summary

Lesson 1 Inherited traits are passed from parents to offspring.

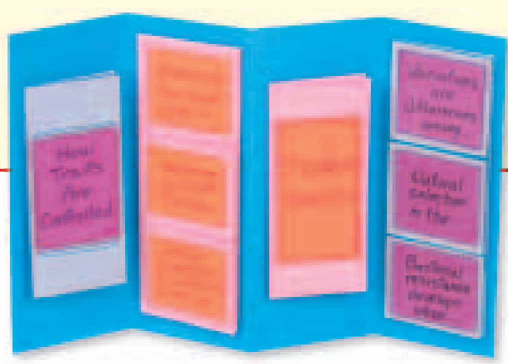
Lesson 2 Information contained in the genes from each parent results in an individual's inherited traits.

Lesson 3 DNA is the genetic material in genes and chromosomes that offspring inherit from their parents.

Lesson 4 Genetic variations and environmental factors have led to diversity among living things.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

acquired trait, p. 141	**inherited trait**, p. 140
clone, p. 165	**mutation**, p. 172
genome, p. 163	**phenotype**, p. 153
genotype, p. 153	**variation**, p. 172

1. All of the DNA of an organism is its ________.

2. A genetic difference among individual members of the same species is a(n) ________.

3. A parent and its ________ are genetically identical.

4. The way an organism's genes are expressed is its ________.

5. Offspring receive a(n) ________ from their parents.

6. A characteristic that is influenced by experience or the environment is a(n) ________.

7. A change in an organism's DNA is called a(n) ________.

8. Each individual has a(n) ________, or a set of inherited genes for a certain trait.

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Skills and Concepts

Answer each of the following in complete sentences.

9. Cause and Effect What causes a genetic variation to occur?

10. Persuasive Writing Suppose that a local university has received money to conduct research. Write a letter to persuade the university to spend the money on researching genetic disorders.

11. Use Numbers A scientist crossed two tall pea plants. Both were hybrids. The cross produced 324 seeds. How many of the seeds would you expect to grow into short plants? (Hint: Use a Punnett square.)

12. Critical Thinking How can pedigrees help scientists studying gene inheritance?

13. Infer How can the genetic variation shown help the rabbit survive?

14. How do organisms pass on characteristics to their offspring?

Performance Assessment

Be a Gene Detective!

Your goal is to identify genetic traits.

What to Do

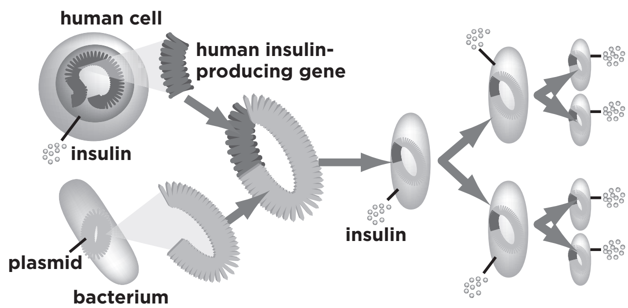
1. Conduct a survey asking 20 people you know about a trait. For example, you might ask them whether they can roll their tongues or what their eye colors are. Record your data in a table or chart.
2. Research statistics on the trait you have chosen. Find out how often the trait appears in the general population.

Analyze Your Results

- Compare your survey data to the information you have gained through your research. How does it match up? Do the percentages of people with your trait reflect a 3:1 ratio? Why or why not?

Test Prep

1. Look at the diagram below.



What process is taking place?

A crossing

B breeding

C gene splicing

D animal cloning

CHAPTER 4

Ecosystems

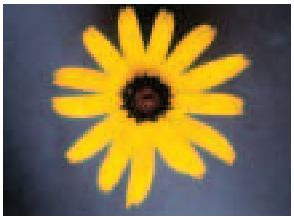
The Big Idea

How do organisms exchange energy and nutrients in an ecosystem?

Kingfisher dives for fish in Switzerland.

Key Vocabulary

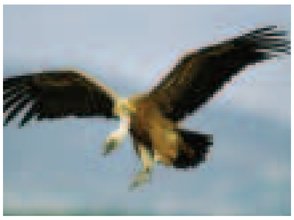
food chain
A model of how the energy in food is passed from organism to organism in an ecosystem. (p. 198)



producer
An organism that uses the Sun's energy to make its own food through photosynthesis. (p. 198)

decomposer
Any organism that breaks down dead plants and animals into simpler materials that enrich the soil. (p. 199)

predator
A living thing that hunts and kills other living things for food. (p. 201)



scavenger
A meat-eating animal that feeds on the remains of dead animals that it did not hunt or kill. (p. 201)

energy pyramid
A model that shows how energy flows through a food chain. (p. 202)

More Vocabulary

ecosystem, p. 186

population, p. 187

community, p. 187

biotic factor, p. 187

abiotic factor, p. 187

symbiosis, p. 190

competition, p. 192

niche, p. 192

consumer, p. 199

food web, p. 200

climate, p. 208

biome, p. 208

limiting factor, p. 222

threatened, p. 224

endangered, p. 224

extinct, p. 224

biodiversity, p. 225

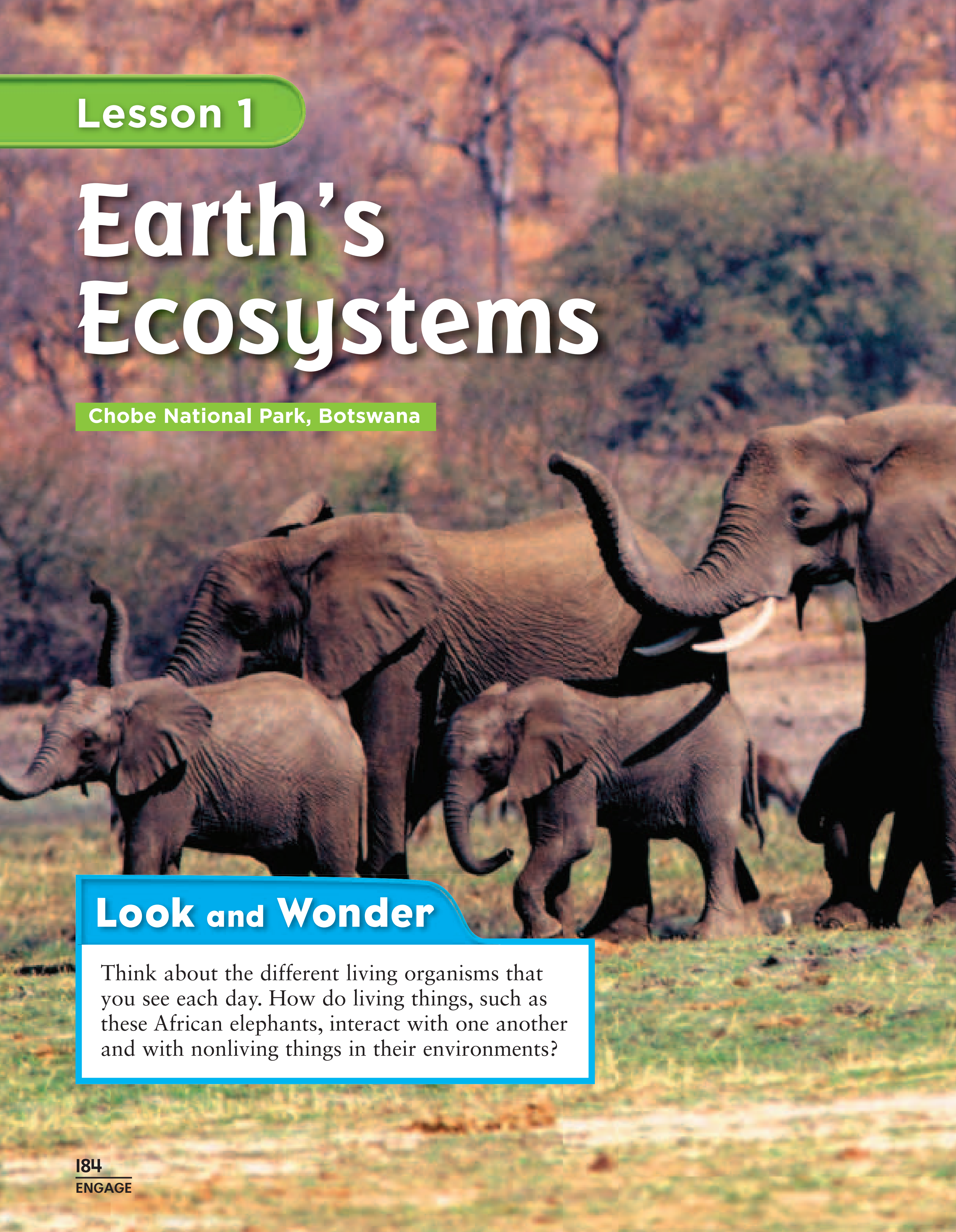
succession, p. 226

pioneer community, p. 227

climax community, p. 227

Lesson 1

Earth's Ecosystems



Chobe National Park, Botswana

Look and Wonder

Think about the different living organisms that you see each day. How do living things, such as these African elephants, interact with one another and with nonliving things in their environments?

Explore

Inquiry Activity

How does sunlight affect life in an ecosystem?

Form a Hypothesis

How does the amount of sunlight affect the number and types of organisms living in a small area? Write your answer in the form of a hypothesis: "If an area receives more sunlight, then . . ."

Test Your Hypothesis

1. **Experiment** With your teacher select two areas on or near your school grounds to study. Choose one area that receives full sunlight and another that receives very little sunlight. Use a meterstick to mark off a 2 m by 2 m plot in each area with stakes and string.
2. **Use Numbers** Measure the air temperature at ground level and at 1 m above ground level in each area. Record your observations.
3. **Observe** Use graph paper to record the locations of the living things in each area. What kinds of organisms do you see? Look closely at the ground.
4. **Classify** Use field guides to help you identify the organisms you found.

Draw Conclusions

5. **Interpret Data** Compare your observations of the two areas. How do the temperatures differ? Which area contains more living things? Did your observations support your hypothesis? Based on your data, what statement can you make about the effect of sunlight on an ecosystem? Did any other variables affect your results?

Explore More

How do you think the amount of water in an ecosystem affects living things? Form a hypothesis, and design a procedure to test it. Try it and share your results with your class.

Materials

- meterstick
- small stakes
- string
- thermometer
- graph paper
- field guides

Step 2

Step 3

Read and Learn

Main Idea
Ecosystems include living and nonliving things that interact.

Vocabulary
ecosystem, p. 186
population, p. 187
community, p. 187
biotic factor, p. 187
abiotic factor, p. 187
symbiosis, p. 190
competition, p. 192
niche, p. 192

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Reading Skill
Main Idea and Details

Main Idea	Details

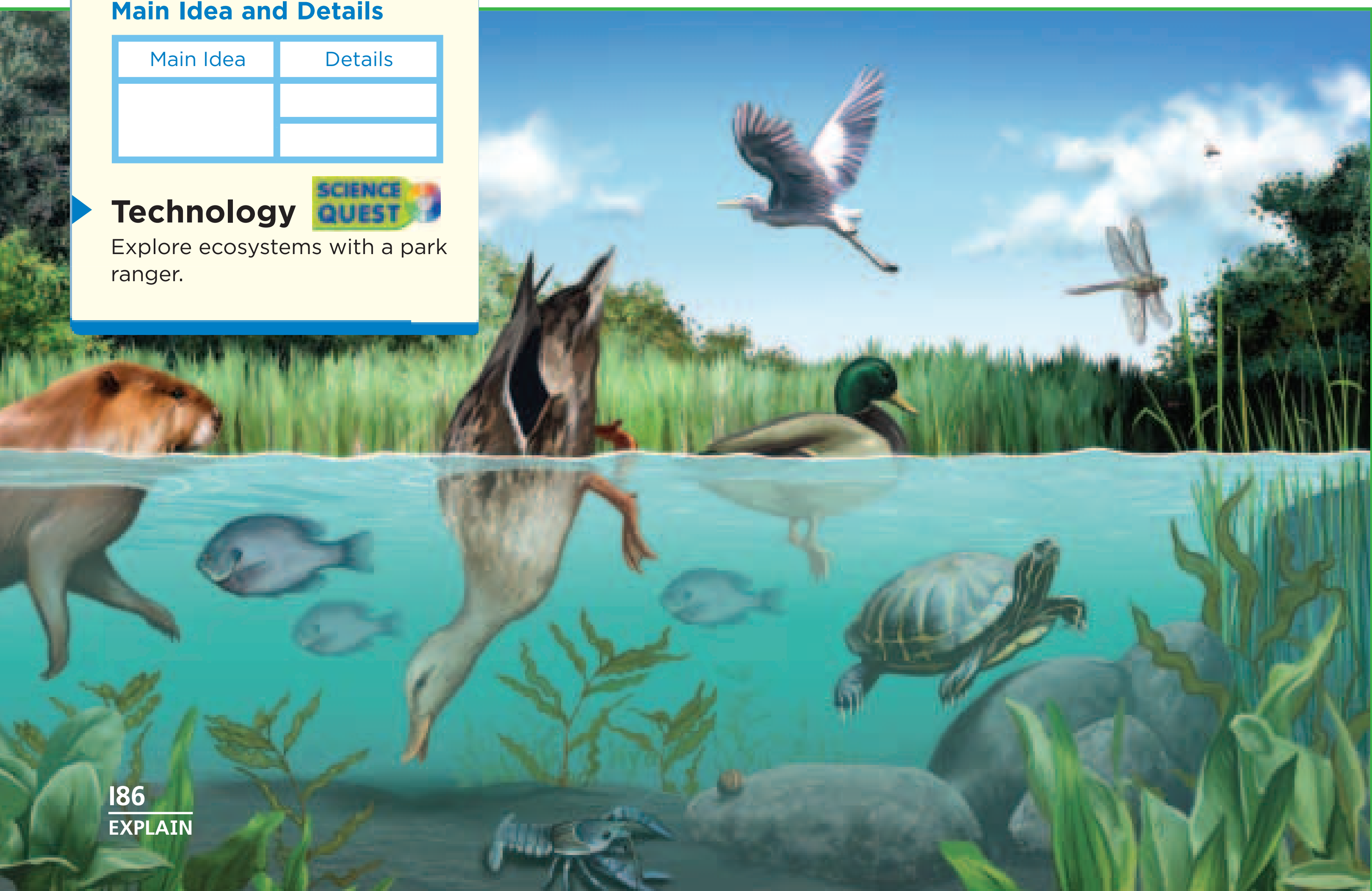
Technology
SCIENCE QUEST
Explore ecosystems with a park ranger.

What makes up an ecosystem?

A *system* is a group of things that work together as a whole. Our bodies contain many different organ systems. Planets are part of a solar system. In each case, the system is made up of parts that interact closely and affect one another.

The living things and nonliving things in an area make up an **ecosystem**. These things interact with their environment and with one another in a number of ways. For example, you depend on grocers for food, on your teachers for an education, and on stores for clothes and other necessities. All living things need water and nourishment to survive, and they all depend on their environments for the basic requirements of life.

Organisms depend on one another and on their environments for the nutrients they need. Notice how the living things and nonliving things in this pond environment affect the ecosystem. ▼



Parts of an Ecosystem

All organisms of the same kind that live in a particular area make up a **population**. For example, the zebras living on an African savanna in Tanzania make up a population. Different ecosystems support different types of populations. Some populations of species are unique to a particular habitat. You would not find polar bears in Africa or a cactus at the South Pole. If populations do not have adaptations that enable them to survive in their ecosystems, they may disappear from the area or die out.

An ecosystem contains many populations. All the populations that live together in the same place make up a **community**. For example, populations of perch, frogs, turtles, algae, trees, and other organisms that live in or near a pond make up a pond community.

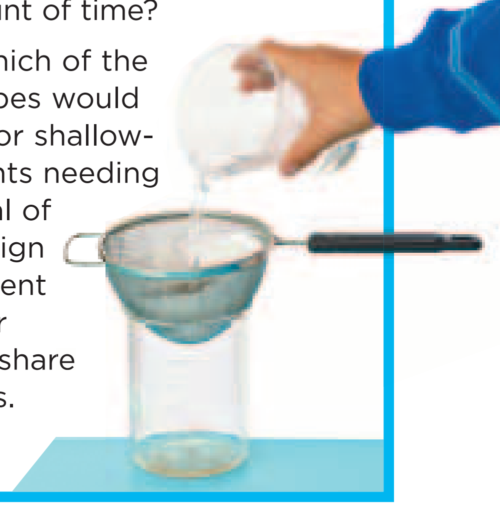
The influence of various living things on an ecosystem are known as **biotic factors**. The effects of the nonliving parts of an ecosystem, such as water, minerals, sunlight, air, and soil, are **abiotic factors**. Abiotic factors determine which kinds of organisms can live in a particular area.

Together, the biotic and abiotic factors in an ecosystem help determine the sizes of the populations that live there. What if a drought reduced the number of plants growing in a forest area? The deer population might decrease because of a lack of food. What would then happen to the coyotes that fed on the deer? Scientists measure biotic and abiotic factors in an ecosystem to calculate the ecosystem's health and productivity.

Quick Lab

Properties of Soil

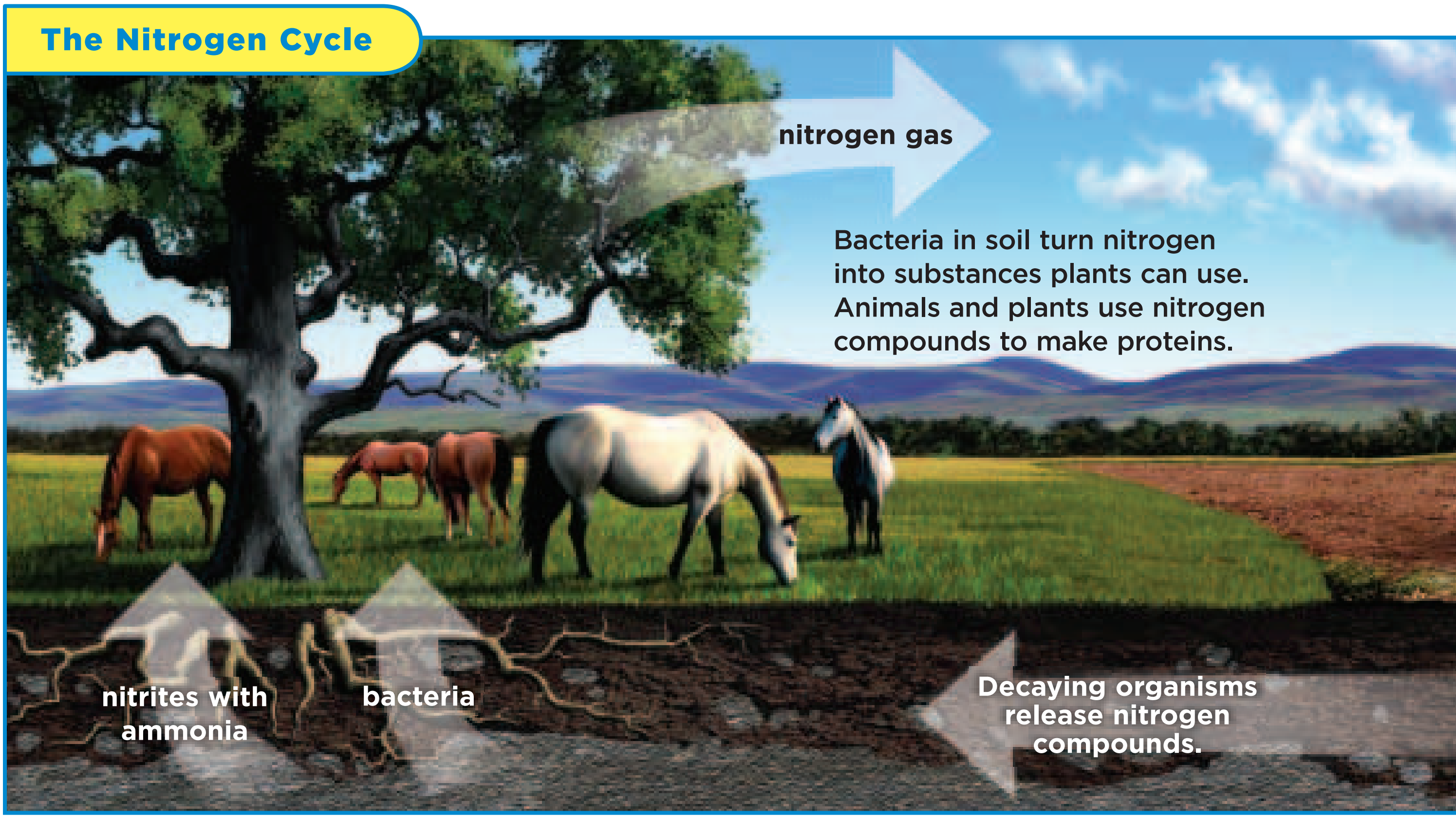
1. **Experiment** Place a small amount of soil in a filter-lined strainer. Set the strainer on top of a beaker. Repeat this setup for a sample of a different type of soil, but use the same amount.
2. **Use Variables** At the same time, pour an equal amount of water into each of the soil samples. Watch both setups carefully for the same amount of time. What are the dependent and independent variables in this experiment?
3. **Measure** Which soil sample allowed more water to pass through in the same amount of time?
4. **Predict** Which of the two soil types would be better for shallow-rooted plants needing a great deal of water? Design an experiment to test your idea. Then share your results.



Quick Check

Main Idea and Details What makes up an ecosystem?

Critical Thinking Describe the ways in which a system in your community depends on the interaction of many of its parts.



What are cycles in an ecosystem?

A *cycle* is a series of events that happen in the same order over and over again. The environment constantly recycles itself. In nature, substances such as air, rock, and water are recycled. As long as natural cycles function normally, these substances never run out. The health of Earth's ecosystems depends on these cycles.

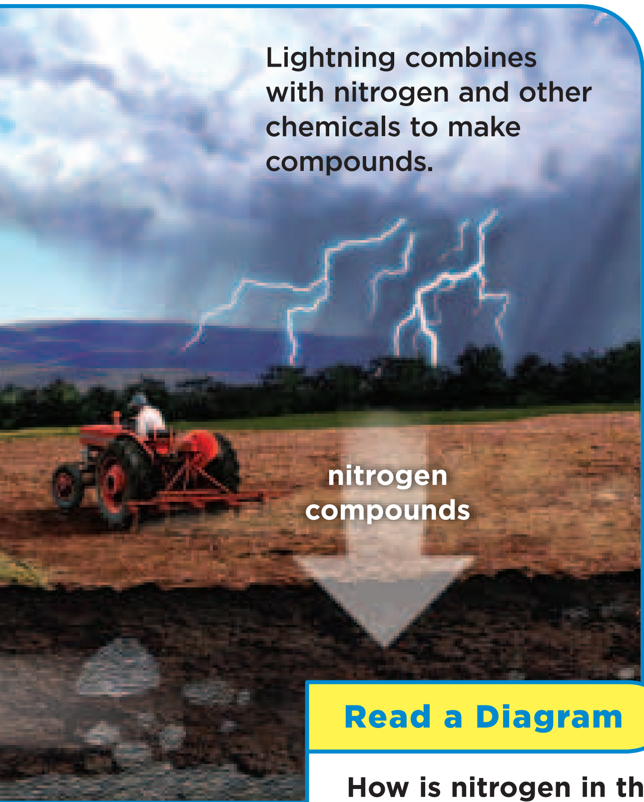
The Water Cycle

Living things need water in order to survive. Plants absorb water through their root systems. They use the water to make food through photosynthesis and to transport nutrients. Animals drink or absorb water as well. Their bodies use water to excrete wastes from their systems.

Ecosystems with lots of water tend to have many different types of organisms. Most of Earth's water is in the oceans. Water on Earth's surface evaporates, condenses, and forms clouds. The water in clouds then returns to the surface as precipitation. Water also cycles through living organisms. For example, when you exhale, your breath releases water vapor. You can see this vapor condense into water droplets if you breathe on a mirror or window.

Plants release water, too. Water exits the leaves of a plant during transpiration. This process can produce clouds of water vapor around tall trees in the rain forest. These clouds, in turn, contribute to the regular rainfall that gives the rain forest its name.

FACT Falling raindrops are shaped not like teardrops but like spheres, flattened as they travel through the air toward the ground.



Read a Diagram

How is nitrogen in the air replaced?

Clue: Find the arrow showing the release of nitrogen gas.

The Oxygen-Carbon Dioxide Cycle

Because the atmosphere of early Earth probably contained no breathable oxygen, life as we know it today could not have existed. Early photosynthetic organisms used water, carbon dioxide, and energy from the Sun to make their own food. Over time, the oxygen released as a waste product of photosynthesis gradually built up in the atmosphere.

When you breathe, you take in oxygen and release carbon dioxide. Activities such as burning fossil fuels also release carbon dioxide. Plants take in a portion of carbon dioxide from the air to use during photosynthesis.

The Nitrogen Cycle

About 78 percent of the atmosphere is nitrogen, but the nitrogen is not in a form that organisms can use. Nitrogen must be "fixed," or combined with other substances, to be used by plants.

Bacteria living in the soil, usually attached to plant roots, change nitrogen into forms plants can use. This process is called *nitrogen fixation*. Plants absorb nitrogen-containing substances through their roots. Legumes, the plant family that includes beans, peanuts, and peas, have colonies of nitrogen-fixing bacteria attached to their roots. The bacteria constantly provide usable forms of nitrogen for the plants.

Through nitrogen fixation, nitrogen is taken from the air and changed, but how does nitrogen return to the air? When animals and plants die and decay, living plants absorb some of the nitrogen-containing substances that are released by the decaying organisms. Other substances containing nitrogen are broken down by bacteria in the soil. The bacteria then release nitrogen gas back into the air.

Like both the water cycle and the oxygen–carbon dioxide cycle, the nitrogen cycle is essential to all Earth's ecosystems.

Quick Check

Main Idea and Details What roles do plants and animals play in the oxygen-carbon dioxide cycle?

Critical Thinking What role do certain types of bacteria play in the nitrogen cycle?

What kinds of interactions exist in an ecosystem?

A relationship between two kinds of organisms that lasts over time is called **symbiosis** (sim•bigh•OH•sis). Symbiosis can take many forms. Sometimes one organism benefits at the expense of another organism. At other times, one organism benefits, but the other is unaffected. There are also cases in which both organisms benefit.

Parasitism

How would you feel if someone took something from you? In nature this type of interaction occurs often. In a *parasitic* relationship, an organism of one species benefits at the expense of an organism of another species. The organism that benefits from the relationship is called a parasite, and the organism that is harmed is called a host.

Many species of wasps are parasitic. Parasitic female wasps lay their eggs in the bodies of other insects or spiders. As the young wasps develop, they feed on the host. Eventually, this kills the host. In time the young wasps are able to survive on their own. They then emerge from the host and complete their life cycle.

However, most parasites do not kill their hosts. The sea lamprey (LAM•pree) is a fish that uses its mouth to attach itself to the sides of other fish. The lamprey carves a hole in the host with its sharp teeth and sucks out some of the host's blood. Both fish may live for a long time this way.

Parasites can affect humans as well. Trichinas are worms that live in the muscle tissue of some pigs. When meat from an infected pig is not fully cooked, the parasitic worms may survive. If people then eat this undercooked meat, the worms may invade their muscle tissue and cause a painful disease called trichinosis (trik•uh•NOH•sis).

Commensalism

When one organism benefits without harming the other, there is a *commensalistic* (kuh•men•suh•LIS•tik) relationship. One species may use another for transportation, shelter, or some other purpose. Clownfish use sea anemones for protection. The stinging cells on the tentacles of sea anemones do not harm clownfish, so they protect these fish from predators.

The remora (ri•MAWR•uh) is a fish that attaches itself to sharks and other large fish. The remora receives protection from predators, and it feeds on scraps from the larger fish's meal. The larger fish is neither harmed nor helped by the presence of the remora.

◀ Wasp eggs laid on a tomato hornworm feed on the hornworm until they are ready to hatch.

Fish Floss

Read a Photo

How is this relationship between the fish and the hippopotamus mutualistic?

Clue: What benefit does each organism appear to receive?

Mutualism

A *mutualistic* (myew•chew•uh•LIS•tik) relationship benefits both participants. Interactions in the nitrogen cycle provide an example of mutualism. The bacteria that grow on the roots of legumes obtain nutrients from the plants. The plants can then build proteins using the fixed nitrogen produced by the bacteria. Both participants help each other survive, and each benefits from the presence of the other. Mutualism is a positive form of symbiosis, because the relationship benefits both species.

Another example of mutualism is found in coral reefs. Millions of tiny coral polyps produce coral skeletons with the help of unicellular algae. The algae produce food for the coral polyps, and the coral skeletons provide shelter for the algae.

Various species of "cleaner fish" display mutualism when providing a service to larger fish and other animals. These cleaner fish eat parasites or dead skin off larger fish. Larger fish provide a nourishment source and protect the cleaner fish from enemies. Divers have found cleaning "stations" where larger animals line up to let these smaller animals clean them off. Both types of animals benefit from this relationship.

Quick Check

Main Idea and Details How does mutualism differ from commensalism?

Critical Thinking In what ways might a parasite benefit from its host?

How do organisms compete and survive in an ecosystem?

An ecosystem can support only so many living things. There are limited amounts of food, water, sunlight, shelter, and other resources. As a result, organisms struggle against one another to obtain what they need to survive. This struggle is competition. **Competition** is the attempt by organisms to obtain a resource that is available in a limited supply.

Each species has a different **niche** (nich), or role in the community. The niche of a particular species includes what the species eats as well as what eats the species. Each species has adaptations that help it survive in its own particular niche. For example, animals that eat plants normally have teeth that are good for grinding fibers. Animals that eat meat often have claws and teeth that are good for tearing through flesh. Animals that hunt or gather food at night often see well in the dark. These adaptations help the organisms survive and reproduce.

Competition among species is reduced because different species obtain resources in unique ways. All the species in a forest do not eat exactly the same diet or want to build their homes or nests in exactly the same locations. Some organisms hunt by day, and others hunt by night. Some meat-eating species may not hunt at all, relying instead on eating animals that have been killed by other predators.

Organisms also look for very different types of shelter. Some species may nest on the ground, in tree branches, or in holes in the trunks of trees. Others may nest underneath exposed tree roots, in caves, or even underground.

Quick Check

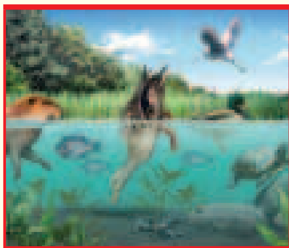
Main Idea and Details What is a niche? Provide examples.

Critical Thinking Different species eat different foods and hunt at different times. How does this help the populations of an ecosystem survive?

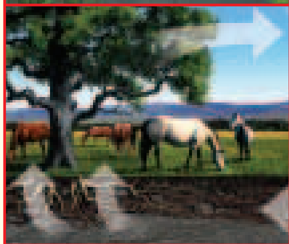
This beaver has its own special role in its ecosystem.

Lesson Review

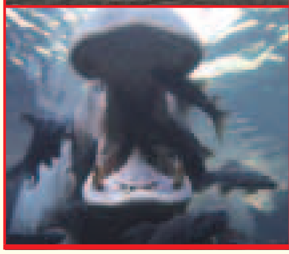
Visual Summary



An **ecosystem** includes all the living things and nonliving things in an area.



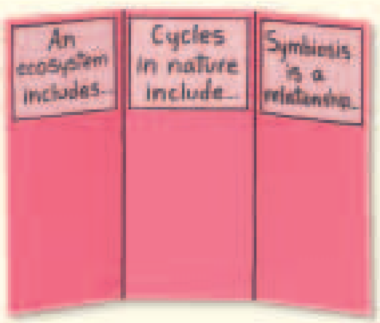
Cycles in nature include the **water cycle**, **nitrogen cycle**, and **oxygen-carbon dioxide cycle**.



Symbiosis is a relationship between two organisms of different species.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the statements shown. Add other details about Earth's ecosystems.



Think, Talk, and Write

1. **Main Idea** Ecosystems include living things and nonliving things that ________.
2. **Vocabulary** An organism's role in an ecosystem is its ________.
3. **Main Idea and Details** Explain how nitrogen cycles through an ecosystem.

Main Idea	Details

4. **Critical Thinking** Why do parasites usually not kill their hosts?
5. **Test Prep** **The relationship between cleaner fish and the larger fish they clean is**
   A parasitic.
   B commensalistic.
   C mutualistic.
   D competitive.
6. **Test Prep** **A pride of lions and a herd of elephants on a grassland in Africa are**
   A part of a population.
   B part of a community.
   C an example of commensalism.
   D an example of mutualism.

Math Link

Calculate Population Growth

A park's deer population, currently 200, doubles every year. How many deer will live in the park after 3 years, excluding all other variables? Make a line graph of the deer population's growth over time.

Social Studies Link

Science and Agriculture

George Washington Carver taught farmers to avoid depleting soil nutrients by including legumes as a part of crop rotation. Research his recommendations, and present your findings to the class.

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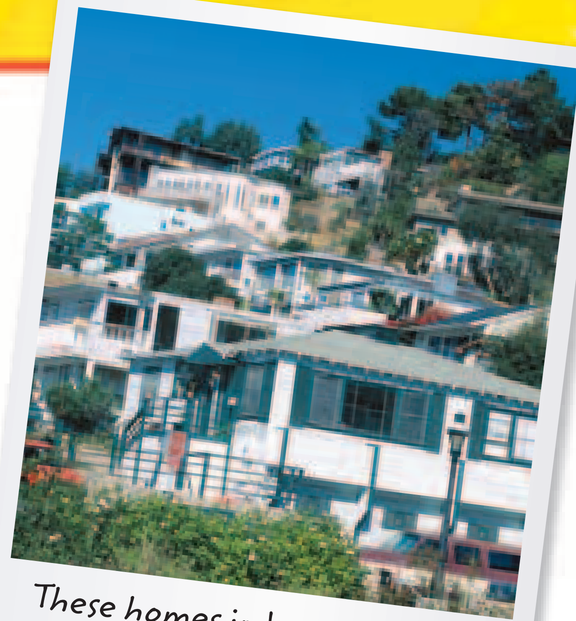
Inquiry Skill: Compare

When scientists **compare**, they look for similarities among objects, materials, or data. An ecosystem provides an opportunity for this type of inquiry. As scientists study a particular area over time, they can make comparisons between the way the ecosystem functions in the present and the way that it functioned in the past.



These homes in Laguna Beach were unaffected by a landslide.

▶ Learn It

An ecosystem may be as small as a puddle or as large as the Sahara. Each of the many types of ecosystems on Earth has its own characteristics. One small change in an ecosystem can affect everything in it. For example, algae in the Arctic thrive at an average depth of about 1 m (3.3 ft). The algae survive on the relatively small amount of light that passes through 5 to 25 cm (2 to 10 in.) of ice. Exposure to too much light, however, can cause the algae to die off. If this occurs, it could destroy the base of the food chain. When scientists study an ecosystem, they examine every variation in order to discover how well parts of an ecosystem will be able to adapt to even the smallest change.

A landslide severely damaged these homes in Laguna Beach.

Charts, or data tables, and Venn diagrams are tools used to **compare**. After you have collected and recorded data, you can see at a glance whether the data, objects, or materials are very similar or not that similar at all. Line graphs and bar graphs can also be used to analyze changing conditions over time.

▶ Try It

Materials **soil, rocks, small twigs, dishpan, watering can, water**

1. Sudden events, such as floods or mudslides, can drastically alter the makeup of an ecosystem. The land and other nonliving things may disappear from the area forever. Such conditions force living things to find new ecosystems in which to live. Scientists monitor how sudden events affect the living and nonliving things in an ecosystem. In this activity you will **compare** a miniature landscape before and after a "flood."

2 Build a hill landscape of soil, rocks, and twig "trees" in a dishpan. Draw a picture of your landscape on a chart like the one on this page. Use the watering can to sprinkle water gently on your hills. Record your observations.

3 Hold the can higher, and continue to let water fall down on the hills. Record your observations. Then pour the rest of the water quickly over the hills. Record your observations. Draw a picture of the way your landscape looks now.

What I Did	My Observations and Drawings
my landscape at the start of the experiment	
sprinkled water gently	
held can higher and sprinkled gently	
poured remaining water quickly	
my landscape at the end of the experiment	

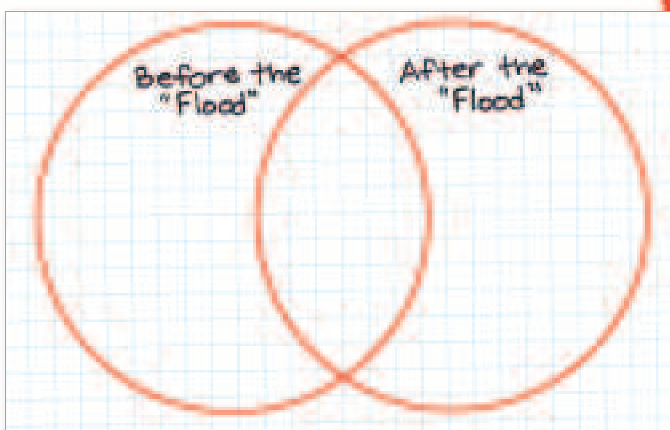
Apply It

1 Now use the information from your data table to make a Venn diagram similar to the one on this page. Draw two overlapping circles. In one circle, list the characteristics of your hill ecosystem before the "flood." In the other circle, list the characteristics of your hill ecosystem after the "flood." Write the characteristics they share in the area where the two circles overlap.

2 How did your hill ecosystem change? How did it stay the same?

3 Choose an ecosystem near your school or home to observe for a month. Note any changes in the ecosystem, and make a chart or Venn diagram to **compare** its characteristics at the beginning and at the end of the month.

Venn diagram



Lesson 2

Food Chains, Webs, and Pyramids

Teklanika River, Alaska

Look and Wonder

Why is this wolf so close to the moose? Even though wolves are much smaller, they hunt and eat larger animals. What does a moose eat?

Explore

Inquiry Activity

How can you model a food chain?

Make a Prediction

What would a connection of 20 organisms—based on what they eat and what eats them—look like? What shape might the path connecting them seem to take? Write your answer in the form "If a food-chain model includes 20 organisms, then it will look . . ."

Test Your Prediction

1. Cut construction paper into 20 rectangles. Write the name of an organism on each rectangle. Include 8 plants, 6 animals that eat plants, 4 animals that eat plant eaters, and 2 animals that eat the animals that eat plant-eaters. Make a hole in each rectangle, and then tie a piece of yarn through each hole.
2. **Make a Model** Cover the top of the bottle with a circle of construction paper to represent the Sun. Punch 8 holes around the rim of the "Sun," and attach the 8 "plants" to these holes with yarn. They should hang off the outer edge of the "Sun." Attach each of the 6 "plant eaters" to a single "food source." Attach each of the "animals that eat plant eaters." Then attach the "animals that eat animals that eat plant eaters."

Draw Conclusions

3. **Observe** How many levels are in your model? What happens to the number of organisms in each level of your model as the distance from the Sun increases? Using your model, follow the path from the Sun to an animal in the level farthest from the Sun. What do the connections between them look like? Does your model look like you predicted it would?
4. **Infer** What could happen to the animal populations represented in your model if a drought destroyed all the plants?

Materials

- scissors
  Be Careful.
- construction paper
- hole punch
- yarn
- top half of empty 2 L bottle

Explore More

What changes might occur in an ecosystem into which new animals move? Make a prediction, and design a way to test it. Then share your ideas with the rest of the class.

Read and Learn

Main Idea

Energy and matter are transferred from one organism to another in food chains and food webs.

Vocabulary

food chain, p. 198
producer, p. 198
consumer, p. 199
decomposer, p. 199
food web, p. 200
predator, p. 201
scavenger, p. 201
energy pyramid, p. 202

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Reading Skill

Sequence

First → Next → Last

Technology

SCIENCE QUEST

Explore energy for life with a farmer.

Cattle are consumers. They obtain energy from grass, which is a producer.

What are food chains?

The energy for almost every living thing on Earth comes originally from the Sun. Energy moves from one organism to another. A **food chain** is a model of the path that the energy in food takes as it moves from one organism to the next in an ecosystem. The path that the energy takes may be short and simple or long and complicated. An organism's size does not always determine its diet or its position in the food chain.

A **producer** is an organism that makes its own food. Producers that perform photosynthesis give off oxygen and produce food that other living things consume to survive. Producers use some of the food they manufacture and store the remainder. Plants may store food in their leaves, stems, or roots. When other organisms eat the plants, they obtain energy from the food that the plants have made and stored.

On land, plants are usually the producers in a food chain. In the ocean, producers are usually phytoplankton. Phytoplankton are mostly single-celled organisms that grow in large numbers near the ocean's surface. Phytoplankton carry out more than half of the photosynthesis that occurs on Earth. Other producers, such as certain types of bacteria living on the ocean floor, use chemicals instead of sunlight as a source of energy with which to make food.

◀ These fungi are decomposers that help recycle substances.

If an organism cannot make its own food, it must consume, or eat, other organisms. These organisms are called **consumers**. A consumer obtains energy either by feeding directly on producers or by eating other consumers.

Consumers are classified by the levels they occupy in the food chain. *Primary consumers* are organisms that eat producers. Primary consumers are the second link in a food chain, after producers. On land, primary consumers include insects, mice, and elephants.

The next link in the food chain consists of *secondary consumers*, which obtain energy by eating primary consumers. Some birds are secondary consumers because they eat insects that eat plants. A snake that eats such a bird is a *tertiary consumer*. Tertiary consumers are at the top of most of the food chains found in an ecosystem. There will almost always be many more producers than consumers in an ecosystem.

When organisms die, their remains contain stored energy. A **decomposer** is an organism that breaks down the remains of dead organisms into simpler substances. Various species of decomposers recycle these substances back into the environment. Worms, bacteria, and fungi are all decomposers that recycle energy and other materials from decaying organisms. As a result, decomposers play a very important role in any ecosystem.

Quick Check

Sequence Why are decomposers so important in an ecosystem?

Critical Thinking Where do humans fit in a food chain?

Forest Food Chain

Read a Diagram

What is a possible food chain in the forest ecosystem above?

Clue: Find producers, three levels of consumers, and decomposers.

What are food webs?

Most animals are part of more than one food chain. A **food web** is a model that shows how food chains overlap in an ecosystem. The organisms that make up a food web fill particular roles. A food web shows the relationships among all the species in an ecosystem.

Herbivores are primary consumers that eat only producers. Large land herbivores have flat-edged teeth in the front of the mouth for cutting plant material. Their flattened back teeth are perfect for grinding plants to a pulp.

Secondary and tertiary consumers are *carnivores*, animals that eat other animals. Some carnivores rip into prey by using their sharp incisors and canine teeth or by using their beaks. Carnivores usually eat more than one kind of animal. For example, coyotes eat small mammals, birds, and snakes. Hawks eat prairie dogs, rabbits, ground squirrels, and other animals.

Consumers that eat both plants and animals are called *omnivores*. Many animals, including humans, are omnivores. Raccoons eat fruits, nuts, birds' eggs, young rabbits, rodents, and sometimes even scraps of garbage. Some ocean-dwelling animals are omnivores as well. For example, some whales are filter feeders. They use toothlike mouth structures called baleen to filter small producers and shrimplike organisms called krill out of huge mouthfuls of water.

Land Food Web

A food web is a series of overlapping food chains. It is a more accurate representation of the feeding relationships in an ecosystem than a food chain is, because most animals eat more than one type of organism.

Read a Diagram

Which of these animals are predators? Which are prey?

Clue: Follow the arrows to see which animals are consumed by others.

Vultures are scavengers. ▲

Events that occur in one part of a food web can often affect other parts. Sometimes different organisms interact in ways that benefit one another. For example, when a bee gathers nectar from a flower, the bee can transfer pollen to other flowers as it gathers more nectar. The bee receives nutrients it needs from the nectar, and exchanging pollen from one flower to another is how many flowering plants reproduce.

Predators and Prey

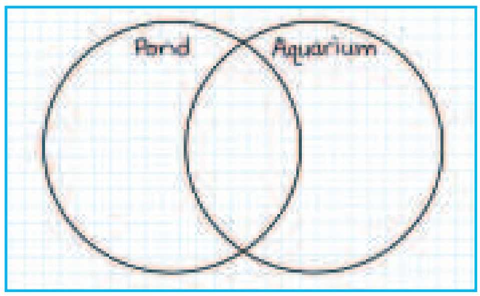
Living things that hunt and kill other living things for food are **predators**. The organisms that they hunt are called *prey*. Most animals, at one time or another, can be both predators and prey. For example, a snake may eat a mouse one day but find itself prey for a hawk the following day.

A **scavenger** is an animal that feeds on the remains of dead animals that it did not hunt or kill. Jackals, vultures, worms, and crows are all scavengers that get part of their nutrients in this manner.

Quick Lab

Water Food Web

1. Obtain two different samples of fresh water from a pond or stream and an aquarium. Do not wade into water to collect samples; ask your teacher or another adult to do this.
2. **Observe** Place a drop of one water sample on a microscope slide. Carefully place a coverslip over it. Examine the slide under low and high power, with your teacher's help if needed. Draw what you see.
3. Repeat step 2 with the other water sample.
4. **Communicate** Make a Venn diagram as shown below. In the correct spots on your diagram, sketch the organisms that you saw.
5. **Infer** Can you tell which observed organisms might be producers? Can you identify any that may be consumers? Label and identify the organisms on a Venn diagram.



Quick Check

Sequence How might the death of one species population affect other species in a food web?

Critical Thinking What advantage might an omnivore have if there were suddenly far fewer species in its environment?

What is an energy pyramid?

Food chains and food webs are models that show how energy in a system is transferred from producers to consumers. As energy is passed from producers to consumers to decomposers, some energy is used for the internal functions of the organisms, and some energy is given off as heat. An **energy pyramid** is a model that shows how energy flows through a food chain.

Producers form the base of the energy pyramid, because they support all the other organisms. Animals that consume producers occupy the next level. Consumers do not absorb all the energy stored in their food. In addition, they use some of this energy when they perform their daily activities and lose energy in the form of heat. Only about 10 percent of the energy from one level of an energy pyramid is available to organisms at the next level.

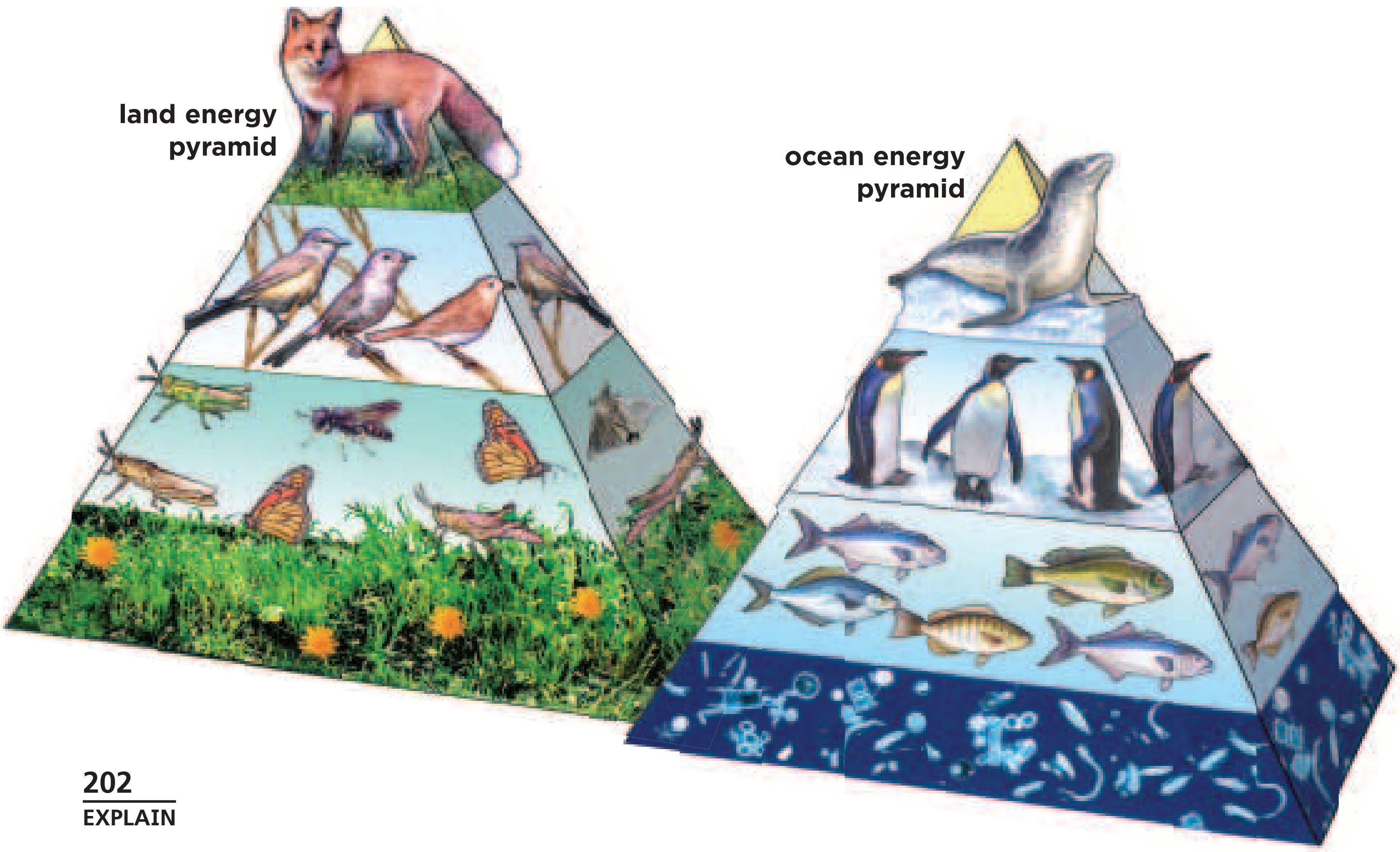
The decrease in energy from one level to the next limits the number of consumers in a food chain. This is why there are usually more producers than consumers.

Changes in an ecosystem can upset the balance of food and energy. A decrease in the food supply may cause an increase in competition. This can affect the population of a species. Knowing how energy flows through food chains helps scientists predict the effects of change on communities.

Quick Check

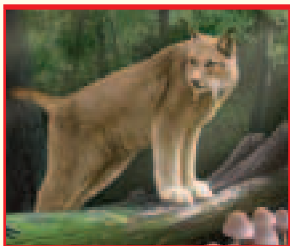
Sequence What do the levels of an energy pyramid show?

Critical Thinking What might happen to the organisms in an ecosystem if food resources in the area decreased?



Lesson Review

Visual Summary



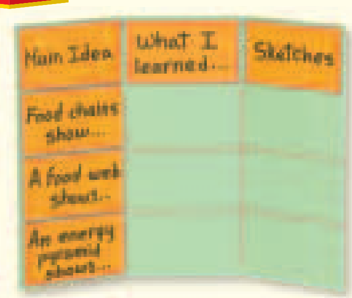
A **food chain** shows the path energy takes as it is transferred from one organism to another in an ecosystem.

A **food web** shows how multiple food chains overlap in an ecosystem.

An **energy pyramid** shows how energy flows from producers through the different levels of consumers.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the statements, showing what you have learned, and include examples.

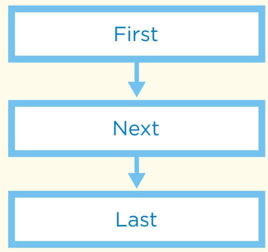


Think, Talk, and Write

1. **Main Idea** A model that shows how food chains overlap is a(n) ________.

2. **Vocabulary** Animals that eat the remains of dead animals are ________.

3. **Sequence** What are the steps in a food chain?



4. **Critical Thinking** Why does a food web tell more about an ecosystem than a food chain does?

5. **Test Prep** **Which of the following is NOT a group into which organisms are classified in an ecosystem?**
   A producers
   B decomposers
   C consumers
   D directors

6. **Test Prep** **Living things that obtain food only by hunting and killing other living things are**
   A herbivores.
   B predators.
   C omnivores.
   D scavengers.

Math Link

Use Percents
About 10 percent of the energy in one level of an energy pyramid reaches the next level. If there are 10,000 units of energy, how much energy will reach the next level? The level after that?

Health Link

Effects of Insecticides
Research the effects of insecticides. How do you think the widespread use of insecticides might affect an ecosystem? Write a paragraph summarizing what you learned from your research.

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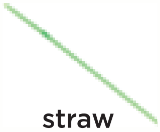
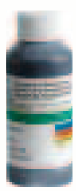
Be a Scientist

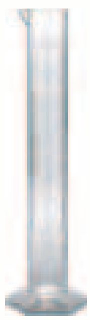
Materials


goggles


straw

cup


bromothymol blue


graduated cylinder


test tube with cap


elodea

Structured Inquiry

What factors affect the carbon cycle?

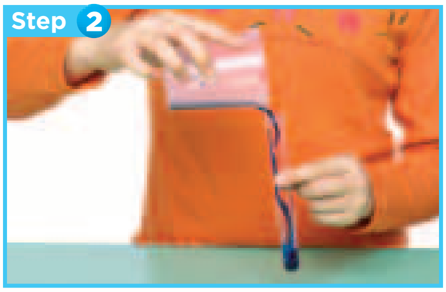
Form a Hypothesis

The carbon cycle is a series of events that recycles carbon through the environment. Carbon exists in many forms and can be found in the air and in plants and animals. Plants take in carbon dioxide from the air and convert it to a usable form. The amount of carbon found in the air is affected by air pollution, especially pollution from the burning of fossil fuels. What role do plants play in the carbon cycle? Write your answer in the form of a hypothesis: "If carbon dioxide is added to a system containing a plant, then . . ."

Test Your Hypothesis

1. Use a straw to blow slowly into a small cup of bromothymol blue. Record your observations.
   ⚠ **Be Careful.** Be sure to breathe out through the straw; do not breathe in. Do not drink the liquid in the cup. Wear safety goggles.

2. **Measure** Pour 10 mL of bromothymol blue into a test tube. Record the color of the liquid.



3. **Experiment** Use the straw to blow gently into the test tube until the liquid turns light green. Place one piece of elodea in the test tube, and put the cap on the tube. Record the color of the liquid.

4. Place the test tube near a window, and check the color of the bromothymol blue every 30 minutes for 2 hours. Record the color of the liquid at each interval.

Draw Conclusions

5. **Interpret Data** What made the bromothymol blue change color in step 1?
6. **Infer** If you had continued blowing into the test tube instead of capping it, what do you think would have happened during the 2-hour experiment?
7. **Infer** What part of the carbon cycle did you represent when you blew into the test tube?

Guided Inquiry

What factors affect the water cycle?

Form a Hypothesis

Does temperature affect the water cycle? Write your answer in the form of a hypothesis: "If the average air temperature changes over a long period of time, then the water cycle will . . ."

Test Your Hypothesis

Design an experiment to investigate how temperature affects the water cycle. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

Did your results support your hypothesis? Why or why not? What do you think would happen to the water cycle in a large land area if volcanic ash blocked the Sun's rays for a few months?

Open Inquiry

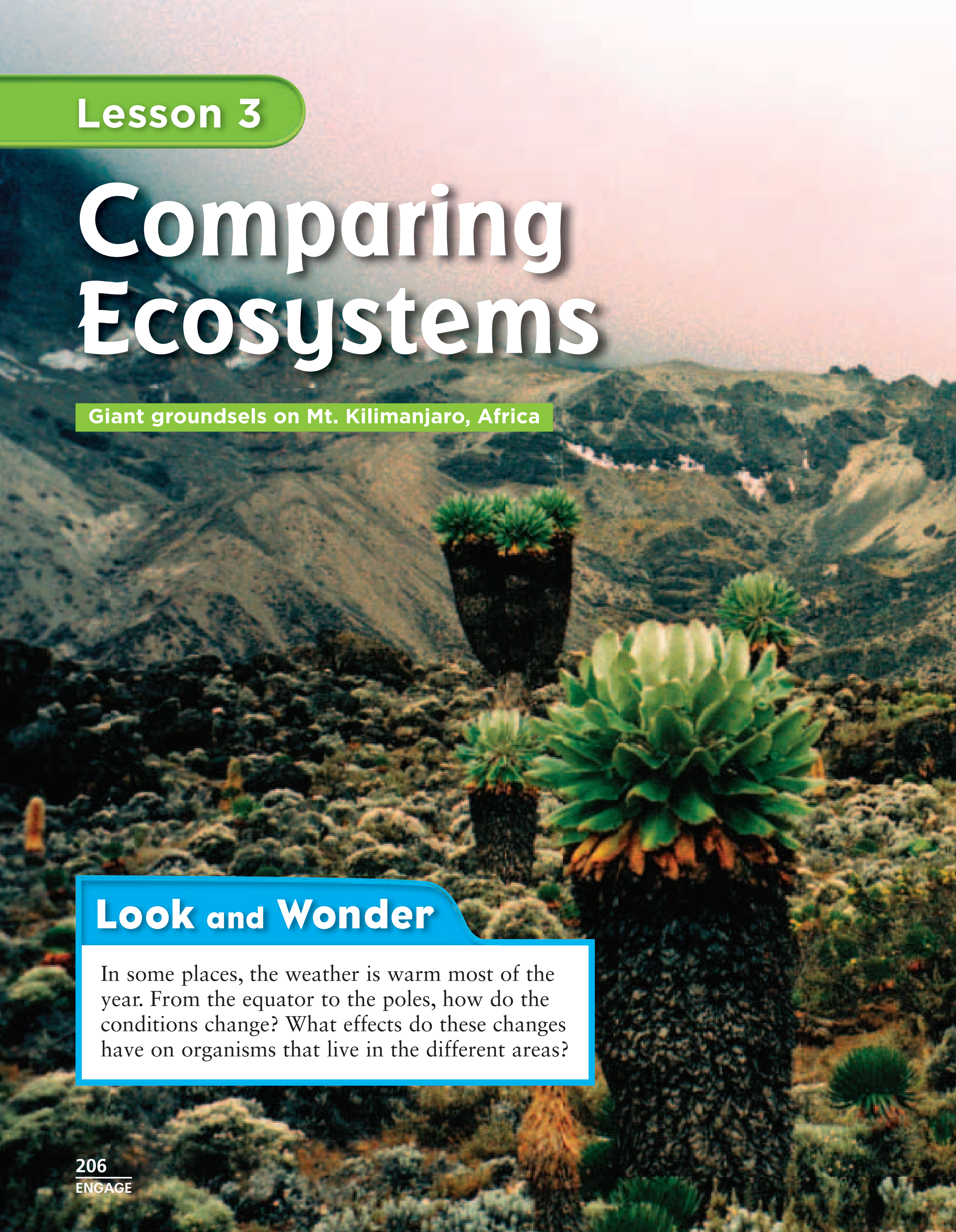
What can you learn about the nitrogen cycle? For example, does pollution affect it? Design an experiment to answer your question, and carry out your experiment. Organize your experiment to test only one variable, or one item being changed. Write down the steps so that another group could complete the experiment by following your instructions.

Remember to follow the steps of the scientific process.

Ask a Question → Form a Hypothesis → Test Your Hypothesis → Draw Conclusions

Lesson 3

Comparing Ecosystems



Giant groundsels on Mt. Kilimanjaro, Africa

Look and Wonder

In some places, the weather is warm most of the year. From the equator to the poles, how do the conditions change? What effects do these changes have on organisms that live in the different areas?

Explore

Inquiry Activity

How do different biomes compare?

Purpose

A biome is a region that has a particular climate. Earth's land biomes include taigas, tundras, rain forests, deciduous forests, deserts, and grasslands. Do all biomes have the same kinds of plants and animals? Research the characteristics of one biome, and draw a mural to represent it.

Procedure

1. Work in groups of four or five. Each group should select one biome to study.
2. Tape the paper to the walls of the classroom.
3. Research the biome your group has selected. Find out about the biome's location, climate, soil, plants, and animals.
4. **Make a Model** Draw a mural that represents your biome. Show at least two plants and two animals that live in the biome. Include a world map that shows the locations of the biome.
5. **Communicate** List on index cards the information you collected, and attach the cards to your mural. Indicate where you obtained the information.

Draw Conclusions

6. **Compare** Compare your group's mural to the other groups' biome murals. What similarities and differences do the plants and animals in the biomes seem to have?

Explore More

Compare various food chains in the biomes. What are the main producers in each? What are the main consumers?

Materials

- masking tape
- long piece of white butcher paper or chart paper
- reference materials
- crayons and colored markers
- index cards

Step 3

Read and Learn

Main Idea

The environment defines where and how organisms can live.

Vocabulary

climate, p. 208

biome, p. 208

estuary, p. 215

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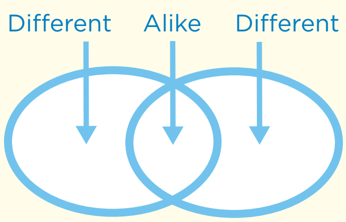
Reading Skill

Compare and Contrast



Technology SCIENCE QUEST

Explore ecosystems with a park ranger.

What are biomes?

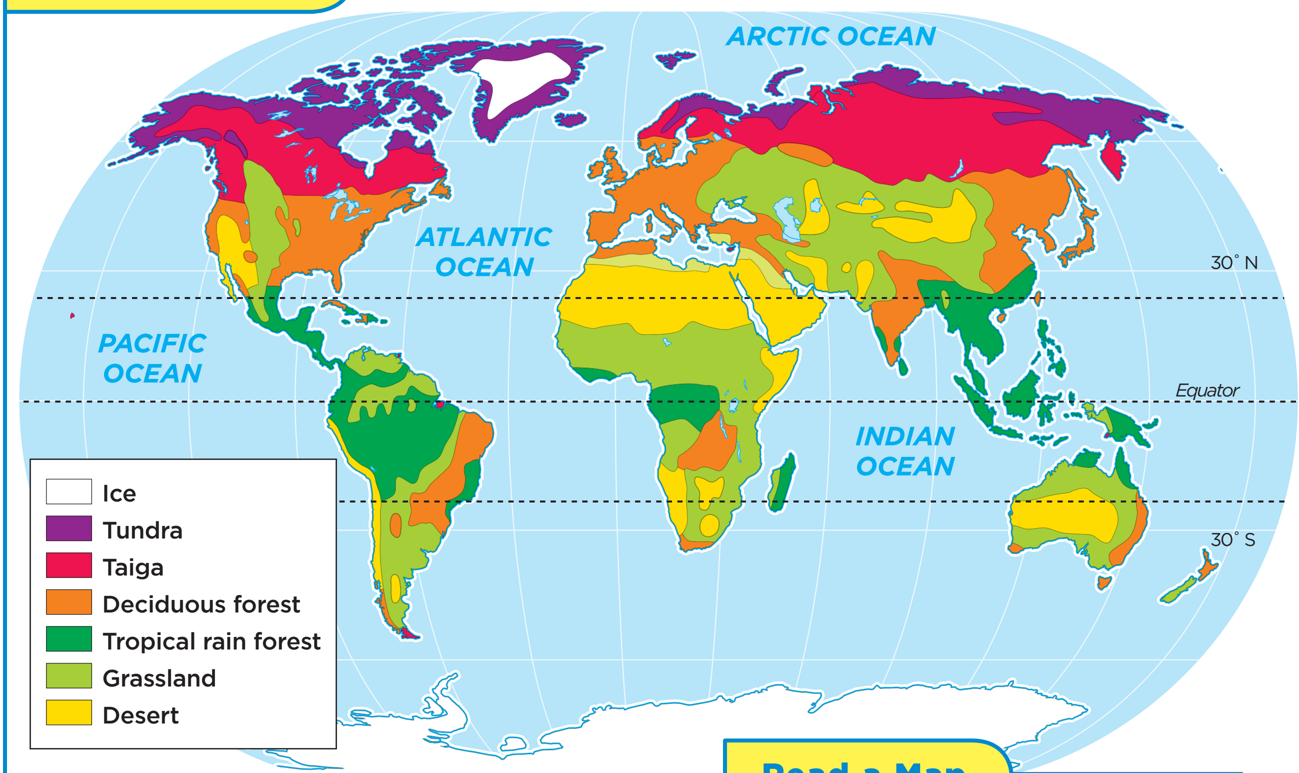
Do you enjoy the change of seasons and the fun of a fresh snowfall? Perhaps you prefer year-round tropical warmth and plenty of sunshine. Your preference describes a particular type of climate (KLIGH•mit). **Climate** is the average weather pattern of a region over time. It is determined mainly by temperature and precipitation. Differences in climate from place to place produce different conditions for living things.

Land on Earth is classified into major climate areas called biomes (BIGH•ohmz). A **biome** is a region that has a particular climate and contains certain types of plants and animals.

Earth's land biomes include taigas (TIGH•guhz), tundras, deserts, grasslands, rain forests, ice, and deciduous forests. A particular type of biome may be found in different parts of the world. For example, tundra biomes exist in North America, Europe, and Asia. Desert biomes exist in North America, South America, Europe, Africa, Asia, Australia, Antarctica, and the Arctic. Most deserts are located at a latitude of about 30°N or 30°S.

These alligators are adapted to the swamps and bayous located in the warmer areas of the United States.

Earth's Biomes



Read a Map

Where are tropical rain forests usually located?

Clue: Around what range of latitudes is this type of biome most often found?

Climate Conditions

One factor that determines a region's climate is the amount of sunlight it receives. Areas closer to the equator receive more direct sunlight than areas closer to the poles. Wind patterns, ocean currents, and barriers such as mountains also affect climate. Places at higher elevations and higher latitudes tend to have cooler climates.

Climate affects living organisms. The organisms in a biome are adapted to live in the region's climate. That is why you will not find a penguin on a beach in California or an orange tree growing in the Arctic.

Each climate area supports different types of plant life. This affects which animals are able to live there. Plants are adapted to grow in particular conditions. These conditions include the amount and intensity of sunlight, the total amount of precipitation, the amount of moisture, and the average temperature. For example, most cactuses are adapted to grow in hot, dry deserts.

Quick Check

Compare and Contrast How might climates change as you traveled north or south from the equator?

Critical Thinking In what kind of biome do you live? Explain.

What are tundras, taigas, and deserts?

Biomes such as tundras, taigas, and deserts have harsh climates. They may have extremely hot or cold temperatures or very little precipitation. These conditions limit the types of plants and animals that can live there.

Tundras

Tundras are found in far northern regions. These biomes have very cold winters and short summers. A tundra is a very cold, dry biome that includes a layer of permanently frozen soil called *permafrost*. Sometimes permafrost is only about 1 meter (3.2 feet) below the surface. The permafrost layer prevents trees and large plants from developing deep roots. However, mosses, grasses, lichens, flowers, and low shrubs with shallow root systems can grow above the permafrost.

Tundras support fewer species than most other biomes, and some areas are covered with ice. However, some species do thrive there, especially during the short summers, when the top layer of permafrost melts and the ground is soggy. Tundra biomes receive only about 25 centimeters (10 inches) of precipitation per year. Tundras cover about 20 percent of Earth's land surface. In the Northern Hemisphere, tundras circle the land just south of the North Pole.

Taigas

Taigas are found south of the northern tundras. *Taiga* is a Russian word meaning "forest." A taiga is a cool forest of cone-bearing evergreen trees.

Taigas in the Northern Hemisphere stretch across parts of Europe, Asia, and North America. Taiga winters are very cold, and the short summers are warm, wetter, and humid. Summer conditions encourage insects to reproduce. The huge insect population is a rich food source that attracts many migrating birds, such as the Siberian thrush. Life on the taiga is limited to the species that can survive the rugged winters. These include low-growing lichens and mosses, trees such as pine, spruce, and hemlock, and animals such as rodents, foxes, wolves, and ravens.


tundra


taiga

Deserts

Deserts receive less than 25 centimeters (10 inches) of precipitation per year. Deserts are found on every one of Earth's continents.

Hot deserts are hot and dry, as their name suggests. Desert air contains little moisture to block the Sun's warming rays. At night, the desert air can be quite cool, because there is no cloud cover and the dry air loses heat easily after dark. When it does rain, water often evaporates before reaching the ground. Occasionally, short periods of heavy rain do occur and may cause flooding.

There are many examples of desert biomes. The Sonoran Desert, which covers parts of Arizona, California, and Mexico, has organisms adapted to live in dry conditions. Plants that conserve water, such as the agave or the saguaro cactus, can survive there. Many species of insects, spiders, reptiles, birds, and burrowing animals also are adapted to life in the desert. They often rest during the heat of the day and become active when the temperature falls at night.

The jerboa, a small rodent, is an example of an animal well adapted to a desert biome such as the African Sahara. The jerboa rests during the day in a cool burrow, then comes out at night to search for food. This behavior protects the animal from the intense daytime heat. Additionally, the jerboa's characteristic long leaps help it avoid predators.

Some deserts have cold seasons, but other deserts are cold year-round. A desert is defined by the amount of precipitation in the area, not by its location or temperature. Cold deserts are found in places such as Greenland, central Asia, and Antarctica. Like tundras and taigas, these deserts have long, cold winters and short summers.

Quick Check

Compare and Contrast How are tundras and taigas similar? How are they different?

Critical Thinking Explain why deserts may seem to have fewer animals during the day than other biomes do.

FACT Not all deserts are hot. There are some deserts in cold regions near the South Pole.

What are grasslands and forests?

Before the arrival of immigrant settlers, much of North America was grassland or forest. Grasslands are biomes in which various species of grasses are the main form of plant life. In North America, grasslands are sometimes called prairies. In the late 1800s, thousands of settlers moved into the area of North America known as the Great Plains. Arriving in covered wagons called prairie schooners (SKEW•nuhrz), they found large areas full of tall grasses as well as bison and other animals. Before long, these tallgrass prairies were plowed under for farmland. Today, less than 1 percent of the original tallgrass prairies remain.

Rainfall in grasslands is irregular and usually not plentiful. Temperatures are cool in winter and warm in summer. Some of the world's most fertile soil is found in grasslands. For this reason grasslands are often used for farming. The roots of grassland plants hold soil in place. If the plants are removed, the soil can be blown away by winds.

The plants and animals found in grasslands vary from place to place. In North America, herbivores such as bison, gophers, ground squirrels, and prairie dogs live in the grasslands. Carnivores there include coyotes, badgers, and black-footed ferrets. The grasslands of central Russia, known as steppes, have different animals, such as Siberian chipmunks and wild boars. The grasslands of Argentina, known as the pampas, are home to other kinds of animals, such as pampas deer.

Deciduous Forests

For only a few months each year, the deciduous (di•SIJ•uh•wuhs) forests in some parts of North America are bright with color. This is the time during which the leaves of the forests' trees turn from green to the characteristic colors of autumn—red, orange, yellow, and brown—before falling to the ground. The term *deciduous* means "falling off."

grassland

deciduous forest

tropical rain forest

In deciduous forests, many trees lose their leaves when winter approaches. With fewer leaves, less transpiration occurs. For this reason, losing leaves enables trees to conserve water. This is especially important when rainfall is scarce and the ground is frozen. Deciduous trees include ash, oak, beech, hickory, and maple trees.

Deciduous forests are found in eastern North America, northeastern Asia, and western and central Europe. In these forests mosses, mushrooms, and ferns grow on the forest floor.

Rain Forests

Tropical rain forests are located relatively close to the equator. The climate within tropical rain forests is hot and humid. Tropical rain forests have abundant rainfall, often more than 2 meters (6.5 feet) per year. This type of climate supports an enormous variety of species. Tropical rain forests are home to more species than are found in all other land biomes combined.

Temperate rain forests are found in some Pacific Northwest areas, such as Oregon. *Temperate* means "mild." Temperate rain forests have lower temperatures than tropical rain forests. However, both have abundant rainfall. Temperate rain forests are also home to many different species.

Although the species found in rain forest environments differ, some have similar roles. For example, the squirrel monkey lives in large troops in the tropical rain forests of South America. The talapoin, another monkey, lives in large troops in the tropical rain forests of central Africa. Both monkeys eat rain-forest fruits, seeds, insects, and eggs.

Quick Check

Compare and Contrast How are tropical and temperate rain forests similar? How are they different?

Critical Thinking What do grassland biomes have in common with deserts?

What are freshwater ecosystems?

Freshwater ecosystems are a type of biome that exist within and around bodies of water that contain little salt. These bodies of water include ponds, lakes, streams, rivers, and wetlands.

Ponds and Lakes

In most ponds and lakes, the water does not appear to move. There may be a covering of green algae on the water's surface. Plants there may include cattails, reeds, and water lilies. Insects glide over the water's surface, and they may become food for fish swimming below. Turtles, crayfish, and frogs may live there as well. Birds, snakes, or raccoons may look for prey along the shore. At first it may seem as if the entire freshwater ecosystem can be easily observed at the surface.

However, it would take much closer observation to see the plankton (PLANGK•tuhn) upon which insects and small fish feed. *Plankton* are tiny organisms that live in water. Some plankton species make their own food through photosynthesis, and others must ingest food. Plantlike plankton and algae form the base of the food chain in water ecosystems.

Streams and Rivers

Streams and rivers have moving water. Organisms there have developed adaptations to keep from being swept away. Reeds have roots that anchor them to the bottom. Fish, such as trout, have streamlined bodies to help them swim in the currents. Other animals have hooks and claws that help them cling to rocks and other objects.

▼ These otters live in a freshwater ecosystem.

great egrets in a wetland

Wetlands

Wetlands are areas in which water is near the surface of the soil much of the time. Wetlands include marshes, swamps, and bogs. These environments are rich in plant life, so they provide a home for many living things. They also are important breeding grounds for birds and other animals. Wetlands serve as natural water filters and sponges. They can help remove various pollutants released by nature, by industry, or by agriculture. Wetlands also provide flood protection and erosion control for the surrounding areas.

Estuaries

Estuaries (ES•chew•er•eez) are water ecosystems that are located where rivers flow into oceans. The water in estuaries contains less salt than ocean water, but it is saltier than water in rivers. The plants and animals that live in estuaries have adaptations that help them survive the variations in salt content, or *salinity*. Estuaries are very important natural resources. Many kinds of birds and water-dwelling animals breed in estuaries. More than three fourths of all the fish species caught in the United States each year spend part of their lives in estuaries.

Quick Lab

Wetlands as Water Filters

1. **Make a Model** Place two small, potted houseplants in two clear containers. Each plant and pot represents a wetland.
2. Slowly pour clean water into one of the pots. Observe the liquid that comes out of the bottom of the pot.
3. **Experiment** Add some colored, powdered drink mix to a cup of water, and stir. This represents polluted water. Slowly pour the mixture into the second pot. Observe what happens, and note the color of the water that drains from the pot.

4. **Draw Conclusions** Based on your observations, what can you conclude about the role of wetlands?

Quick Check

Compare and Contrast How are estuaries and wetlands similar? How are they different?

Critical Thinking What role do plankton play in freshwater ecosystems?

What lives in the ocean?

The ocean covers more than 70 percent of Earth's surface. Ocean water plays an important role in the water cycle and contains nutrients that support a variety of life-forms. Ocean food chains begin with plankton, which live near the surface of the water. *Nekton* (NEK•tuhn) are animals that swim through the water. *Benthos* (BEN•thahs) are organisms that live on or near the ocean floor.

The ocean is divided into regions, and each region affects living things in different ways. Factors include tides, temperature, salinity, water pressure, and the amount of sunlight penetrating the water. Near the surface, sunlight warms the water and provides energy for different photosynthetic species.

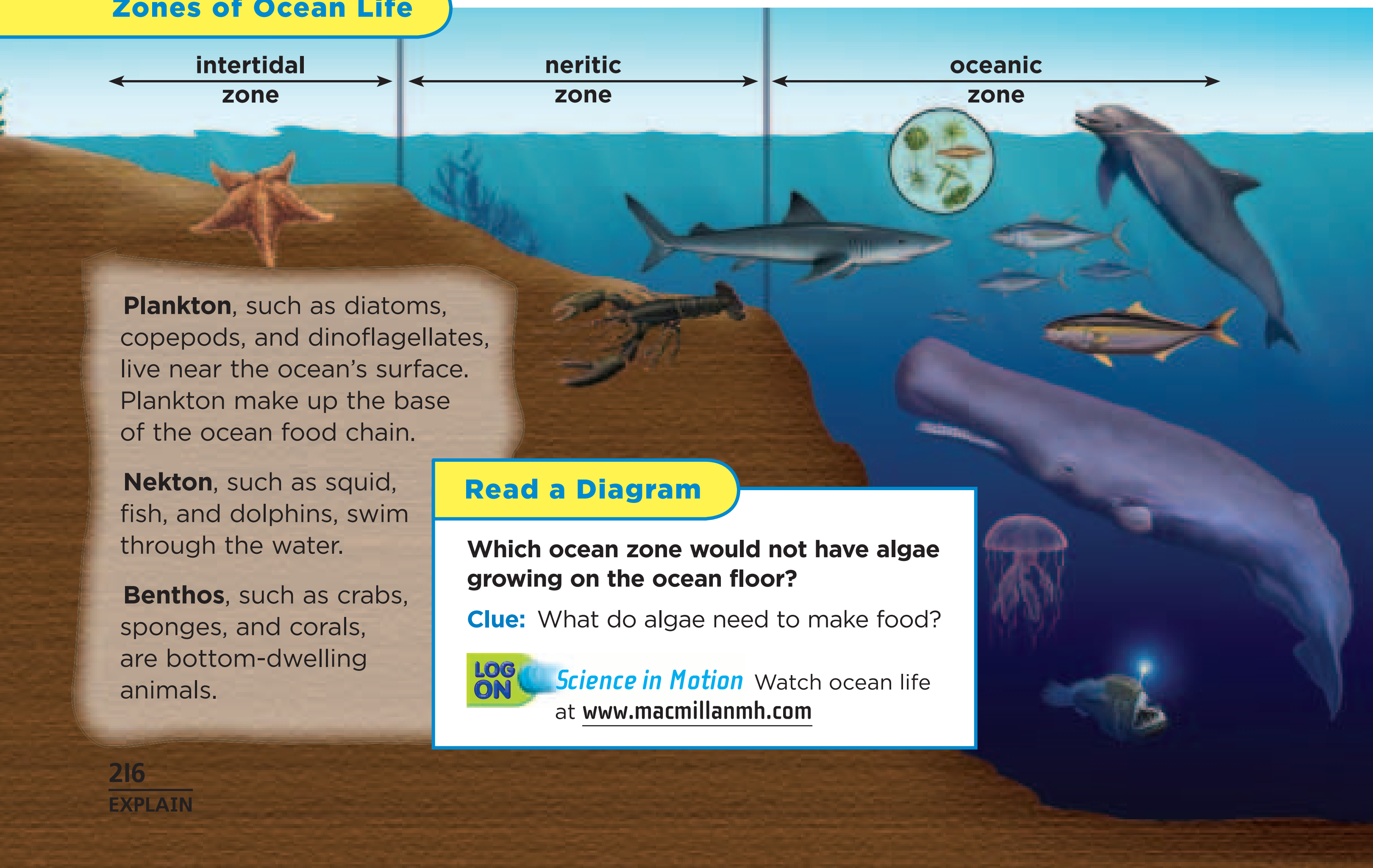
Almost no sunlight reaches depths greater than 200 meters (656 feet). Depths beyond this point are increasingly dark and cold, and photosynthesis does not occur. Most deep-ocean organisms feed on each other and on materials that sink down from the ocean's surface. Some other deep-ocean organisms, such as certain kinds of bacteria, feed on materials from hydrothermal vents, deep cracks in the ocean floor from which hot chemicals flow.

Quick Check

Compare and Contrast How do ocean ecosystems compare to and contrast with land biomes?

Critical Thinking How does depth affect ocean water's temperature?

Zones of Ocean Life



Plankton, such as diatoms, copepods, and dinoflagellates, live near the ocean's surface. Plankton make up the base of the ocean food chain.

Nekton, such as squid, fish, and dolphins, swim through the water.

Benthos, such as crabs, sponges, and corals, are bottom-dwelling animals.

Read a Diagram

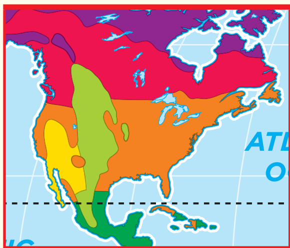
Which ocean zone would not have algae growing on the ocean floor?

Clue: What do algae need to make food?

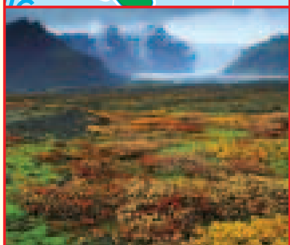
LOG ON *Science in Motion* Watch ocean life at www.macmillanmh.com

Lesson Review

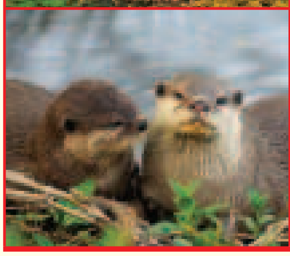
Visual Summary



Each **biome** has a certain **climate** and particular types of organisms.



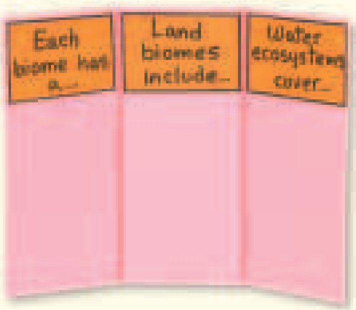
Land biomes include tundras, taigas, deserts, grasslands, rain forests, and deciduous forests.



Water ecosystems cover the majority of Earth's surface.

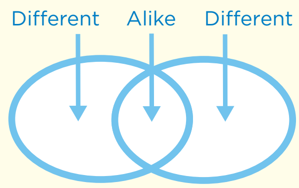
Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the statements and add details about land biomes and water ecosystems.



Think, Talk, and Write

1. **Main Idea** What factors determine which organisms live in a biome?
2. **Vocabulary** A land region with a particular climate that contains certain types of organisms is a(n) _________.
3. **Compare and Contrast** How are freshwater and ocean ecosystems similar? How are they different?



4. **Critical Thinking** Explain why parts of Antarctica can be classified as deserts.
5. **Test Prep** **The biome dominated by trees that shed their leaves in autumn is the**
   A tropical rain forest.
   B grassland.
   C deciduous forest.
   D taiga.
6. **Test Prep** **Temperature and precipitation are two factors that determine an area's**
   A climate.
   B longitude.
   C elevation.
   D erosion.

Writing Link

Persuasive Writing

Prepare a travel brochure encouraging people to visit one of the biomes you have studied. Include important facts, such as the biome's location, climate, soil, plants, and animals.

Social Studies

Compare Cultures

Plants and animals adapt to their biomes, and people adapt as well. Research the food, shelter, and clothing of people in two different biomes. Write a report comparing the cultures of the two groups.

A TRIP TO A "NEW" RAIN FOREST

In December 2005, a scientific team found a "lost world" in the remote, mist-shrouded Foja Mountains. The mountains are on the island of New Guinea. Scientists found many new species of frogs, butterflies, and plants. The scientists also spotted rare species that they thought might be extinct.

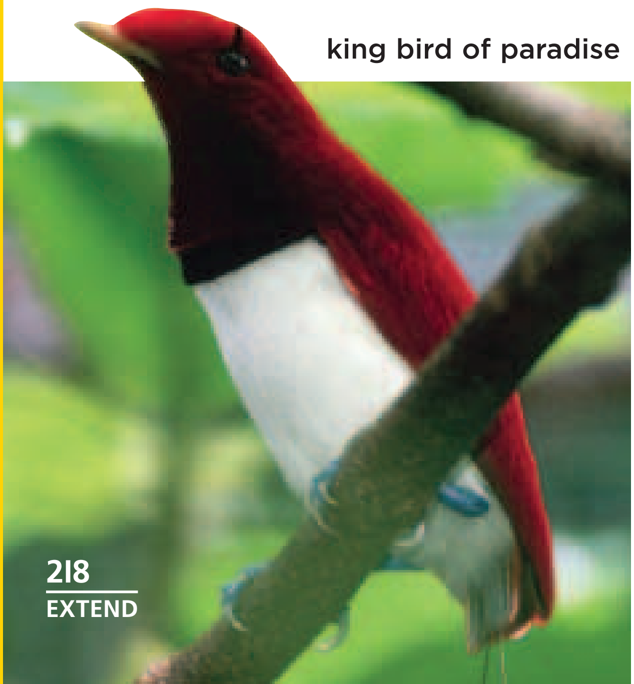
My parents are nature photographers—and so I was lucky enough to go with them. It was a thrill I will never forget. Our stay was a biologist's dream. One morning, I saw a flash of light fly into a bower of sticks covered with purple berries. Mom said it was a male golden-fronted bowerbird. It uses the berries to attract a mate. The most remarkable bird we saw was a beautiful bird of paradise. As we watched, the bird did a mating dance for a female bird perched nearby!

Then one day, my dad pointed to a branch high in a tree. "That's a golden-mantled tree kangaroo. People thought this kangaroo was almost extinct, but here it is," he said. My treasure from my trip to the "lost world" is a picture of me with the tree kangaroo cuddled in my arms, its long, ringed tail reaching down. That trip will always be a highlight of my life.

Personal Narrative

A good personal narrative

- tells a story from personal experience
- expresses the writer's feelings in the first-person point of view (*I*)
- has an interesting beginning, middle, and end
- shares events in a sequence that makes sense
- uses time-order words to connect ideas and show the sequence of events


king bird of paradise

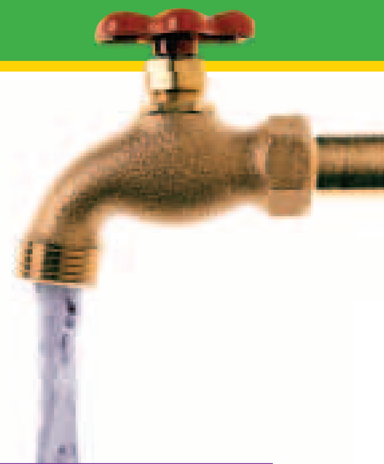
Write About It

Personal Narrative Write a personal narrative about a trip to a distinct environment, or ecosystem. It can be a desert, a rain forest, an ice-covered land, or even the beach. Use the first-person point of view (*I*) to tell what you observed and what you did.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Math in Science

How Much Water Do People Use Each Day?



Water is a widely used resource. The average use per person varies among communities for many reasons, such as climate differences, household sizes, or the amount of industry or farmland. For example, the use of public water per person is about 50 percent higher in western states than eastern ones, mostly due to a greater need for outdoor irrigation.

On average, household use of water makes up less than 1 percent of total water use nationwide. An average U. S. household uses about 285 liters of water per person each day. The table on the right shows typical daily household water use. Use this data to find how many liters of water are used daily per person for bathing and showering. In your view, is this a reasonable amount of water for this purpose?

Average Daily Water Use per Person	
bath or shower	18.6%
faucet	15.7%
clothes washer	21.7%
dishwasher	1.4%
toilet	26.7%
leaks	13.7%
other	2.2%

Solve It

1. About how much water does one person use each day for bathing?
2. What percent of a person's daily water use goes toward washing clothes and dishes? (Hint: Adding or subtracting percents is the same as adding or subtracting decimals. Remember to align the decimal points vertically.)
3. Compare the new low-flow toilets that use about 6 liters of water per flush with standard toilets that use 23 liters. How much water can consumers save over 25 flushes with a low-flow toilet?

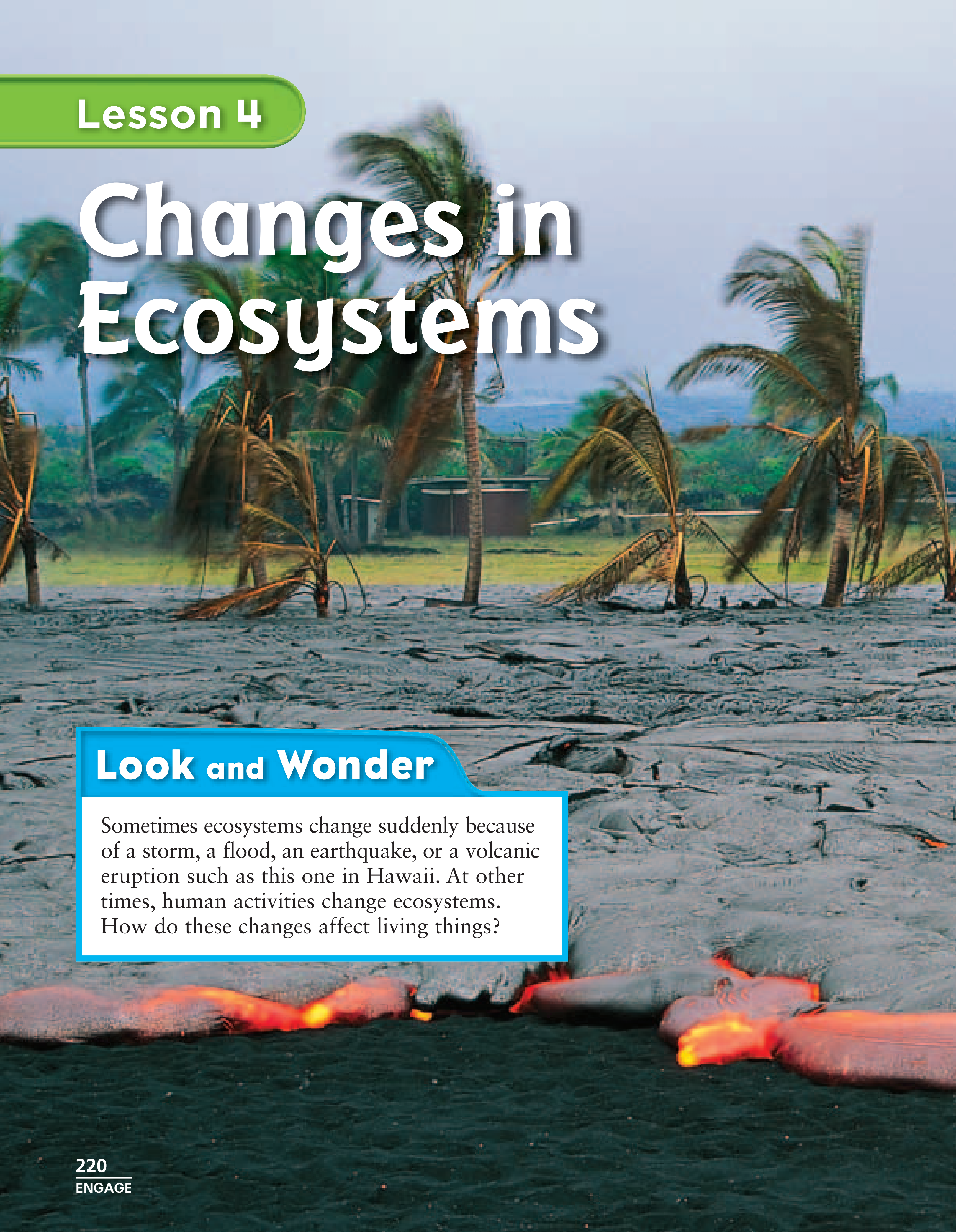
Calculate Percent

To find the percent of a whole number,

- **change the percent to a decimal**

$$18.6\% = \frac{18.6}{100} = 0.186$$

- **multiply the decimal by the whole number, keeping the same number of digits behind the decimal point**



Lesson 4

Changes in Ecosystems

Look and Wonder

Sometimes ecosystems change suddenly because of a storm, a flood, an earthquake, or a volcanic eruption such as this one in Hawaii. At other times, human activities change ecosystems. How do these changes affect living things?

Explore

Inquiry Activity

How do volcanic eruptions affect habitats?

Make a Prediction

If a volcano erupts, what do you think will happen to the habitats around it? Write your answer in the form of a prediction: "If a volcano erupts, then the surrounding area will . . ."

Test Your Prediction

1. **Observe** Study the photographs of Mount St. Helens before and after the volcanic eruption of 1980. What changes to the mountain and its vegetation do you see?
2. **Compare** How did the upper and lower slopes of Mount St. Helens change?

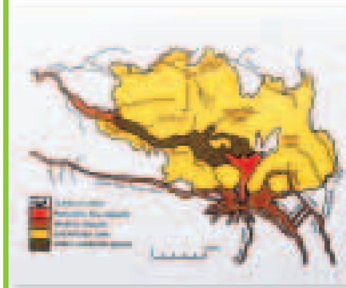
Draw Conclusions

3. **Infer** A topographic map shows the elevations of landforms in an area. Do you think it would have been necessary to redraw a topographic map of this area after the volcano erupted? Why or why not?
4. **Interpret Data** How would you explain what you observed? Did your observations support your prediction? How does an erupting volcano affect the area that surrounds it?

Explore More

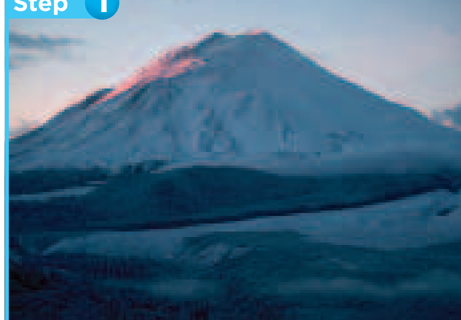
Choose another natural disaster to study, such as the 2004 tsunami in Southeast Asia or Hurricane Katrina in 2005. Find photographs taken of the area before and after the disaster. Describe any changes you see in the landforms and the local vegetation. Analyze your results, and present them to the class.

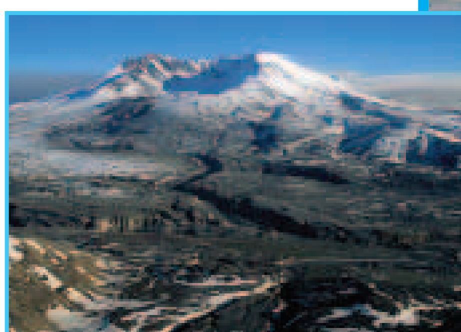
Materials



- photograph of Mount St. Helens before the 1980 eruption (shown)
- photograph of Mount St. Helens after the 1980 eruption (shown)
- map showing extent of damage

Step 1





Read and Learn

Main Idea

Natural factors and human activities cause ecosystems to change over time.

Vocabulary

limiting factor, p. 222
threatened, p. 224
endangered, p. 224
extinct, p. 224
biodiversity, p. 225
succession, p. 226
pioneer community, p. 227
climax community, p. 227

LOG ON e-Glossary
at www.macmillanmh.com

Reading Skill

Cause and Effect

Cause → Effect
→
→
→
→

Technology

SCIENCE QUEST

Explore ecosystems with a park ranger.

What changes affect the environment?

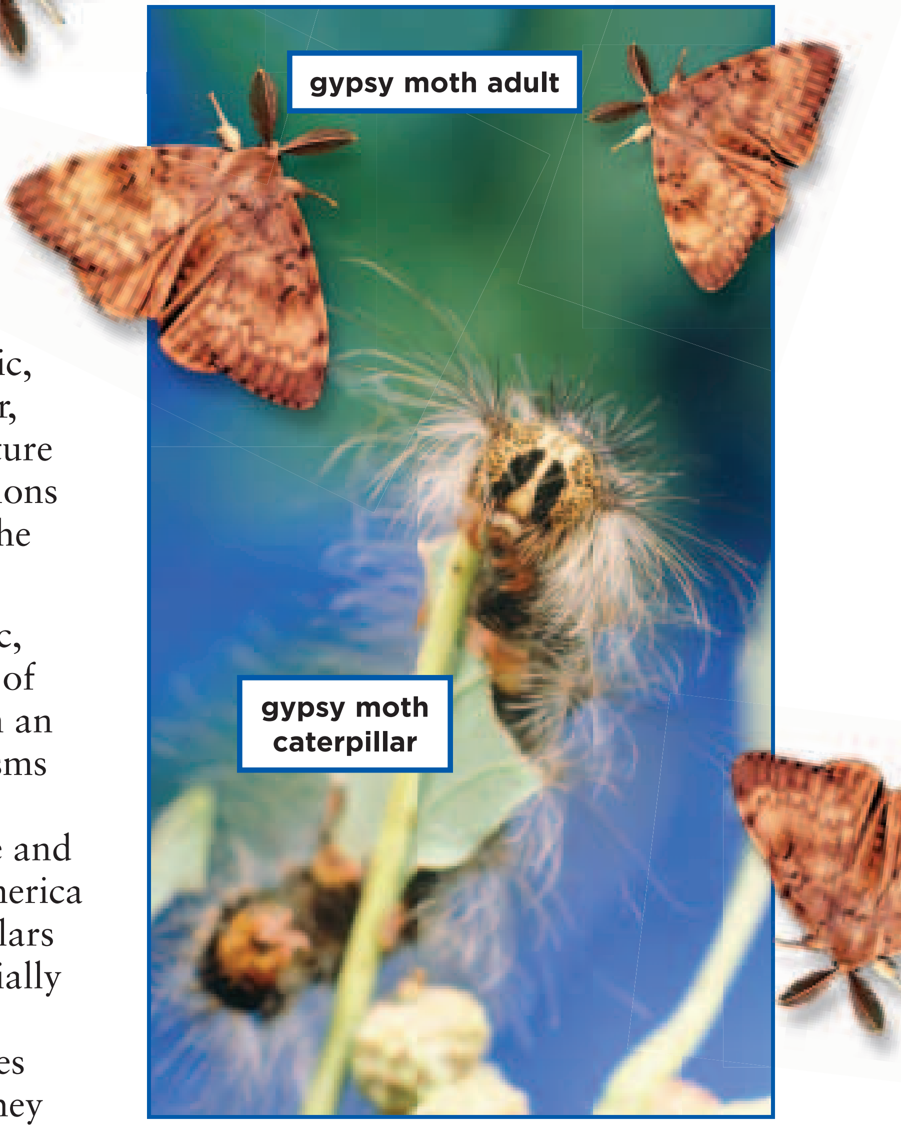
Natural disasters such as wildfires, earthquakes, floods, hurricanes, and volcanoes can change ecosystems and affect the organisms that live there. For example, changes may suddenly damage an organism's habitat or destroy a food source.

Other changes in the environment occur more gradually. For example, deer mice live in North American forests and grasslands. They reproduce rapidly, but owls, weasels, badgers, and other animals hunt them. This keeps the deer-mouse population from growing too large. What might happen if the deer mice migrated to a new ecosystem with no predators? How might deer mice change that ecosystem? Without predators, the population of deer mice would increase quickly, because more individuals would survive and produce offspring.

A condition that controls the size or growth of a population is called a **limiting factor**. Predators often limit the sizes of animal populations. Diseases, as well as competition for food and nutrients, also limit population growth.

Although some farmers and ranchers think of them as pests, prairie dogs have become endangered by loss of habitat.

When introduced into a new area, gypsy moth caterpillars can damage native plants. ▶



Types of Limiting Factors

Some limiting factors are abiotic, or nonliving. Sunlight, wind, water, chemicals, nutrients, and temperature are abiotic limiting factors. Variations in any of these factors can affect the populations in a community.

Other limiting factors are biotic, or living. For example, the arrival of a nonnative, or invasive, species in an ecosystem can affect other organisms that live there. The gypsy moth, a species originally native to Europe and Asia, was introduced to North America in the 1860s. Gypsy moth caterpillars feed on plant leaves and are especially damaging to oak and aspen trees. Nonnative plant and animal species can quickly affect ecosystems as they compete for resources.

Humans can also have a significant impact on ecosystems. People cut trees for lumber. They clear land to grow crops and to build homes and roads. They also cause pollution by burning fossil fuels and by using chemicals as fertilizers and pesticides. Pollution and the clearing of land can damage or destroy habitats. These practices can also upset the balance between predators and prey, causing changes in population levels. The loss of trees also affects ecosystems. During photosynthesis, trees absorb carbon dioxide and produce oxygen.

Fortunately, some people are aware of the impact human activities can have on the environment. They weigh the benefits of human activities against possible environmental risks. Many laws that protect the environment from damage have been enacted as a result.

Quick Check

Cause and Effect How do limiting factors affect an ecosystem?

Critical Thinking What are some ways in which humans affect the environment?

What happens after the environment changes?

Changes to ecosystems can have tremendous effects on the organisms that live there. Sometimes organisms can adjust to these changes. They may find other food sources or shelter. For example, when habitats are lost due to the building of houses, deer and other animals often adapt by eating discarded food or the plants in people's gardens.

If organisms cannot adapt to the changes in their ecosystem, they may move to another location. If they do not, the species may become threatened. A species is **threatened** if its numbers have declined to a level at which the species may become endangered if steps are not taken to protect it. A species is **endangered** when its numbers have been so reduced that the species is in danger of extinction. A species is **extinct** when it no longer exists in the wild or in captivity.

People have taken steps to save some species. In the 1500s, there were an estimated 50 million bison in America's grasslands. As new settlers arrived on the prairies, they plowed the grasslands and hunted the bison. By the late 1880s, there were less than 1,000 bison in the United States. In time, strict laws were put in place to protect them. Today, state and national parks provide a safe place for bison to live. The population is growing, and bison are no longer endangered.

The main reason that organisms become threatened or endangered is loss of habitat. However, there are other causes as well, including hunting, diseases, harsh weather, competition from other species, and natural disasters. It is estimated that perhaps one dozen plant or animal species become extinct every hour of every day.

These raccoons have found a solution to their need for new food sources!


coral reef

Biodiversity

Why should people be concerned about threatened or endangered species? All living things are part of an interdependent system. The loss of any species affects **biodiversity**, or the wide variety of life on Earth.

Coral reefs are among the most biologically diverse ecosystems in the world. Reef organisms such as sponges and tunicates (TEW•ni•kuhts) may be useful to people in many ways. Scientists are still learning many things about reef ecosystems. Unfortunately, most coral reefs are classified as threatened.

Plants and animals are of great value to humans. Many medicines and other products originated from various plant and animal species. Medicines such as antibiotics and drugs that treat heart disease and cancer are based on chemical substances originally discovered in plants. Whenever a plant becomes extinct, it takes with it the possibility of medicines that will never be discovered.

Quick Lab

Testing Soil pH

1. **Experiment** Put three different soil samples into separate cups. Test the pH level of each soil sample, using the test kit provided by your teacher. The pH scale measures how acidic or basic a substance is. Soil pH can be a limiting factor.
2. **Interpret Data** Record the pH of each sample. A substance with a pH less than 7 is acidic. A substance with a pH greater than 7 is basic. A substance with a pH of 7 is neutral, neither acidic nor basic. Look at the colors and numbers as directed in your test kit. Where do your samples fall on the pH scale?
3. **Predict** What might the results be if you used soil from a field of ripe lemon trees or an orange grove? Design an experiment to test your prediction. If possible, perform your test and share the results.

Quick Check

Cause and Effect How do organisms respond to changes in their habitats?

Critical Thinking What is the difference between an endangered species and a threatened species?

What is succession?

Picture what neighborhoods might look like if yards, gardens, and parks were not mowed and weeded. The grass would grow tall, new plants would take root, and new animals would probably move into the area.

The gradual replacement of one community by another is called **succession**. This process can occur as a result of the life functions of plants and animals. For example, trees grow taller and spread their branches, shading locations that were once sunny. Plants that require sunlight can no longer thrive in that area. When succession occurs where a community previously existed, it is called secondary succession.

Suppose a farmer decided to stop farming the fields. Before this decision, the farmer had controlled the ecosystem by plowing the fields, planting crops, eliminating weeds, and raising animals. Once these farming activities ended, natural processes would take over.

In the first year, a community of crabgrass, insects, and mice might invade the farmer's fields. Tall grasses and weeds such as asters, ragweed, and goldenrod could then grow. These plants would block sunlight from reaching the crabgrass, which would then die out. Rabbits and other animals would move in. The seeds of trees such as oaks and hickories would germinate and sprout. Gradually, plowed fields left untouched would become forests.

Succession and Species

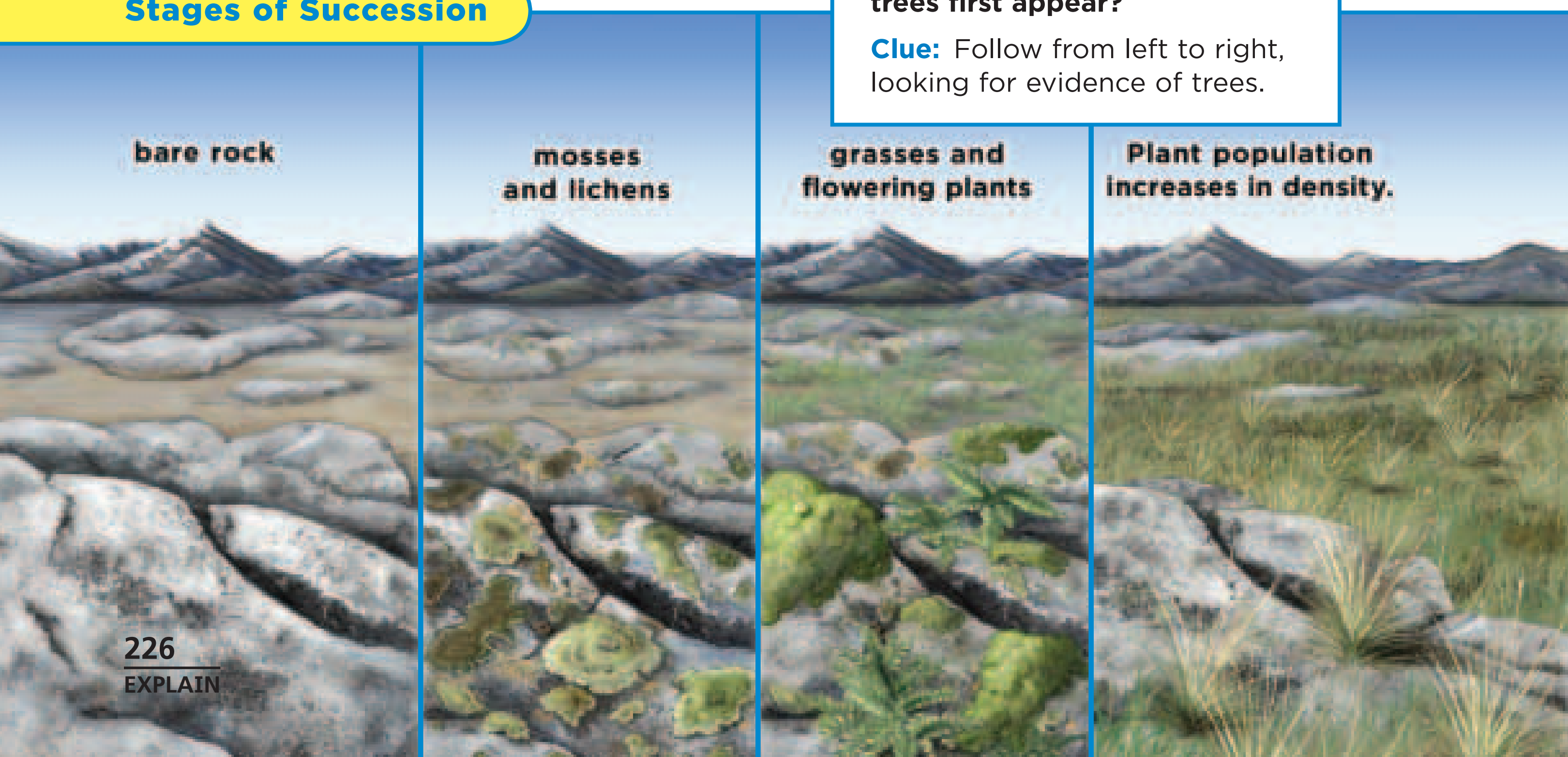
Primary succession occurs in an area where there are no existing communities. Sometimes new land is formed. The island of Surtsey, near Iceland, was formed by a volcanic eruption in 1963. Barren landscapes such as this can provide the foundation for the growth of new communities.

Read a Diagram

At what stage of succession do trees first appear?

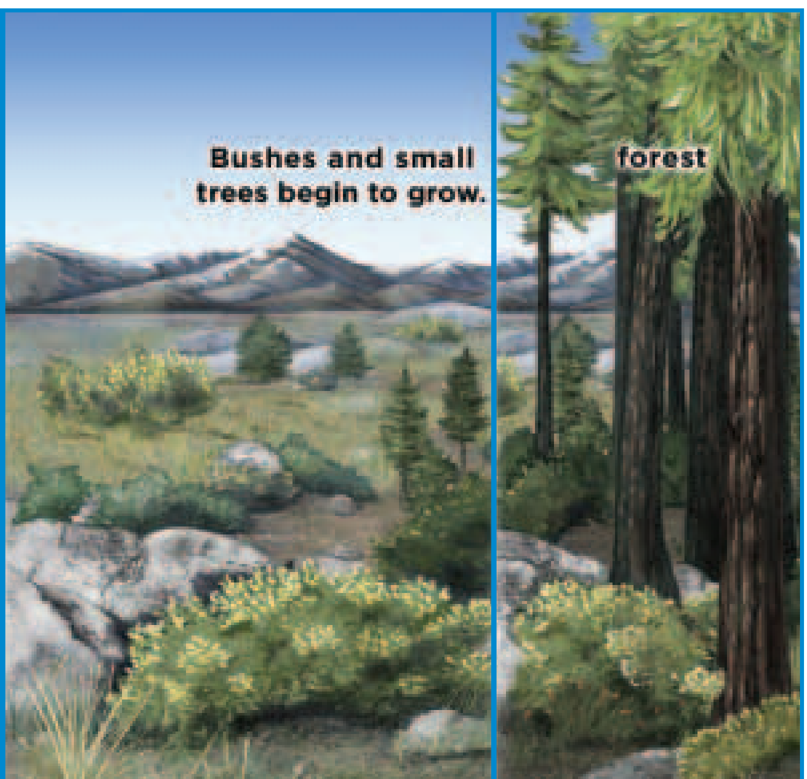
Clue: Follow from left to right, looking for evidence of trees.

Stages of Succession



The first species to establish themselves in a lifeless area are called pioneer species. On land these species include mosses and lichens, as well as grasses and other small, aggressive, self-pollinating plants with strong root systems. Soon, after these organisms are established, they begin to attract insects. The insects then attract birds. Just as the first people who settle in an area build towns, pioneer species establish a new community called a **pioneer community**.

Over time, a pioneer community becomes more established and takes on particular characteristics. The area may become a deciduous forest, a tide pool, or some other type of environment. When the community has stabilized and succession has slowed down or almost stopped, it is then called a **climax community**. It can take years, even centuries, to reach this point, and at any time the process may stop. Trees may be cut, storms or floods may wash away coastlines, or other environmental changes may occur. Then the process might start anew.



▲ Grasses are typical pioneer species on barren land. Grasses can even grow in small cracks of rock formed by a volcano in Hawaii.

The process of succession can also be observed in pond ecosystems. As a pond slowly fills with sediment and fallen leaves, grasses become established. Eventually, the pond becomes a marsh. As the marsh plants die and the pond continues to fill in, the area can eventually become dry land.

Secondary succession can also occur after a natural disaster such as a forest fire. Although it may seem as if a fire has wiped out a community, naturally occurring forest fires can actually help an ecosystem. Forest fires clear out old growth that has prevented new plants from becoming established. Some forest plants depend on the heat of a forest fire to help release their seeds.

Quick Check

Cause and Effect How does the formation of new land affect succession?

Critical Thinking What role does sunlight play in succession?

What is evidence of change over time?

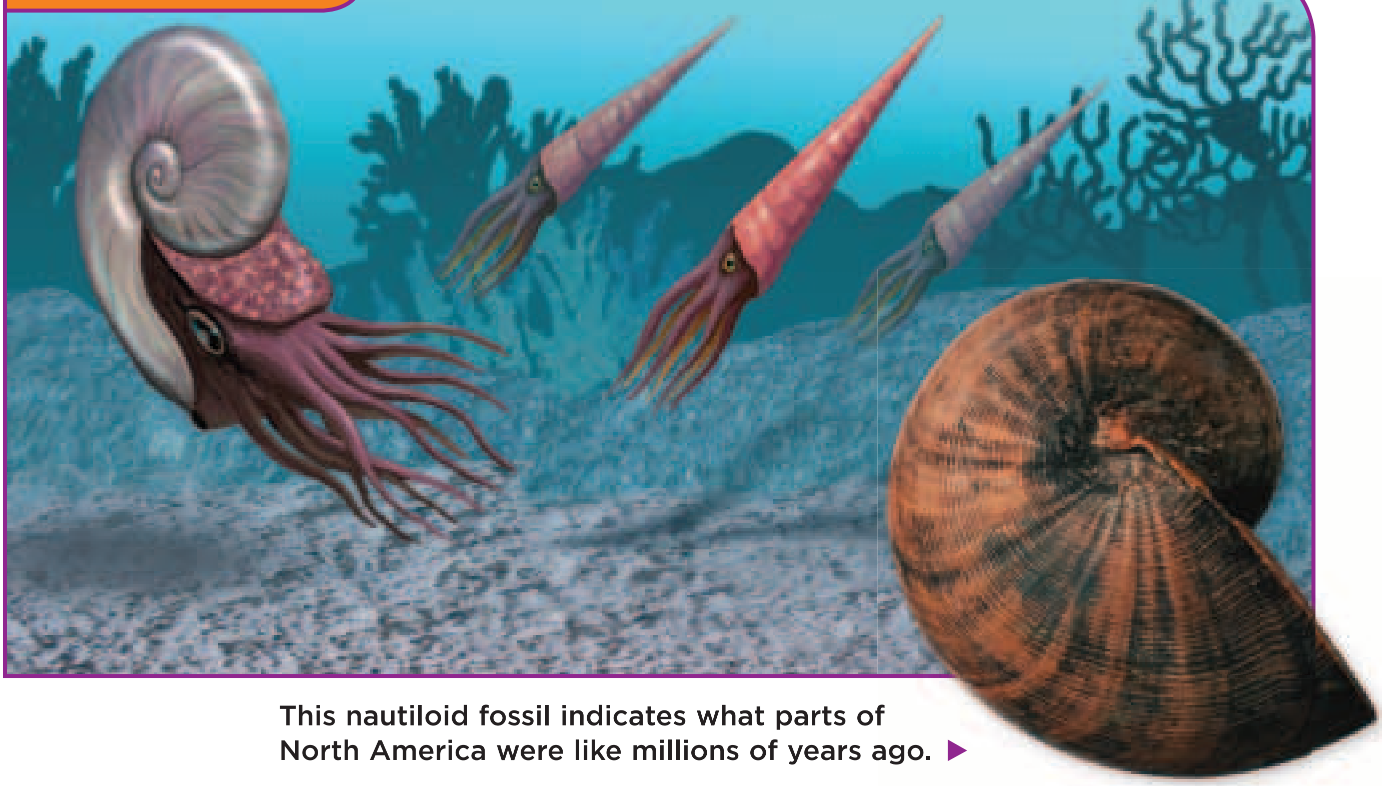
Dramatic changes have occurred on Earth over time. Continents have drifted, climates have changed, and seas have dried up. The history of these changes can be found in the millions of fossils collected by scientists.

Scientists have found fossils of marine organisms, such as trilobites and brachiopods, and even sharks' teeth in rock in Kentucky, Illinois, and Missouri. These fossils indicate that the land in these states was once covered with warm, shallow seas. Scientists now know that shallow seas covered most of North America at one time.

The eras of Earth's history were marked by significant changes in geography and climate, which brought different kinds of organisms that were adapted to live in those conditions. When environments change, organisms must adapt, move on, or die out. Fossil evidence indicates to scientists that species do change over time.

An example that supports the idea of change over time is the history of the horse. Ancestors of modern horses walked on several spread-out toes, which probably helped the animals move through swamps and mud. As the land dried, horses changed as well. In time, horses developed a single, flat hoof on each of their feet. Horses could run faster and could better escape from predators. The hooves of horses absorb the shocks of running on hard ground. Today, horses are large, single-toed, hoofed animals. The modern horse is the result of many physical changes that occurred over time.

Fossil Evidence



This nautiloid fossil indicates what parts of North America were like millions of years ago. ▶

Comparing Changes

Scientists compare features of modern organisms to look for similarities that may suggest that the organisms had a common ancestor. The diagram on this page shows how the limbs of several animals are similar in shape and arrangement. However, each structure is adapted for each organism's environment. Similar features in different organisms are known as *comparative structures*. When body parts are similar but meet different needs, they are called *homologous structures*.

The embryos—unborn or unhatched developing organisms—of different species can show similar changes over time. Vertebrate embryos are similar during their early stages of development. As embryos develop, similarities decrease as structures grow into arms, wings, or flippers that serve different, specific functions.

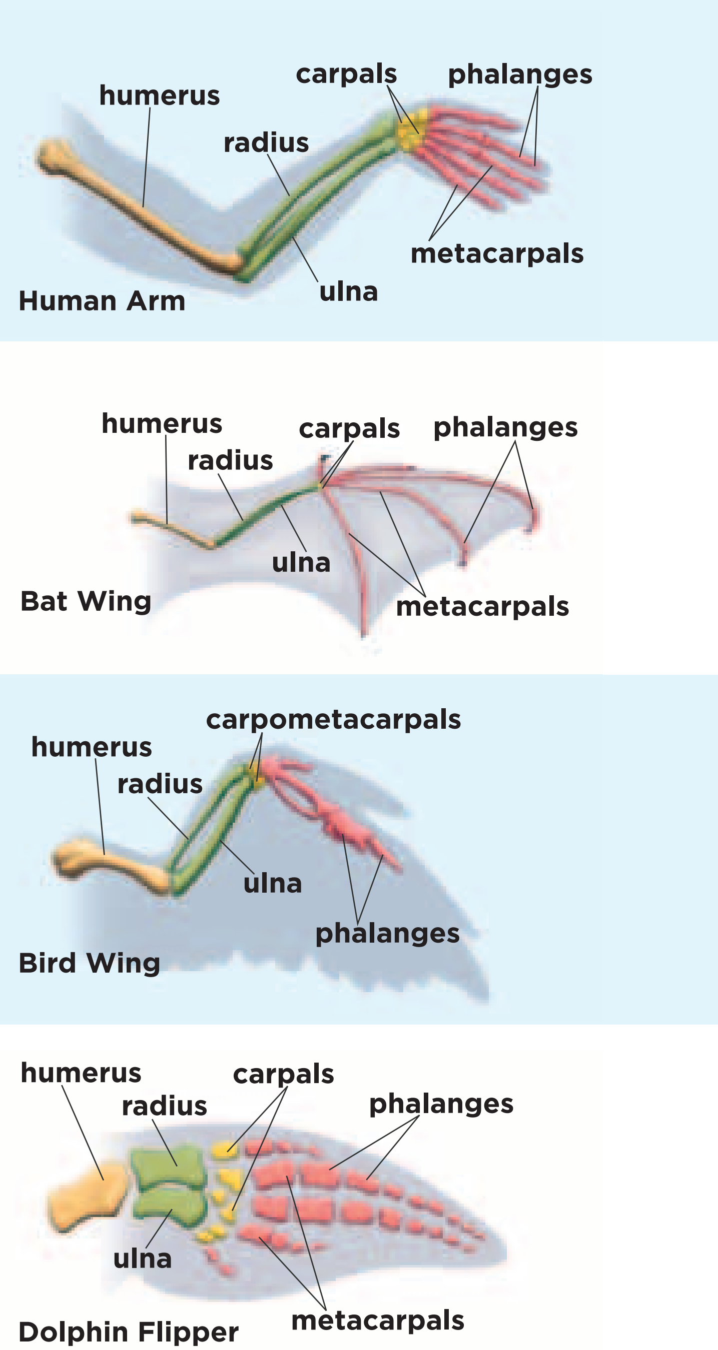
Because DNA is passed from one generation to the next, similarities do exist in the DNA of related species. By comparing the DNA of different species, scientists can determine the degree to which species are related to one another.

Quick Check

Cause and Effect How do environmental changes cause species to change?

Critical Thinking What can fossils tell scientists about how ecosystems have changed over time?

Homologous Structures



Read a Diagram

How are the bat, bird, and dolphin limbs similar to the human limb?

Clue: Match the parts of the limb from one species to another.

FACT A species does not adapt genetically within a single lifetime.

How do environments change over time?

Changes to ecosystems, whether caused by nature or by people, can have far-reaching effects. One example occurred in the United States in the 1930s. In the grasslands of the Great Plains states, farmers plowed the land and planted wheat. The plowing removed the root systems of the native grasses that held the soil in place. In 1931, the region was hit with a drought that lasted for almost a decade. The wheat died, and without plants to hold the soil in place, winds blew the nutrient-rich topsoil away.

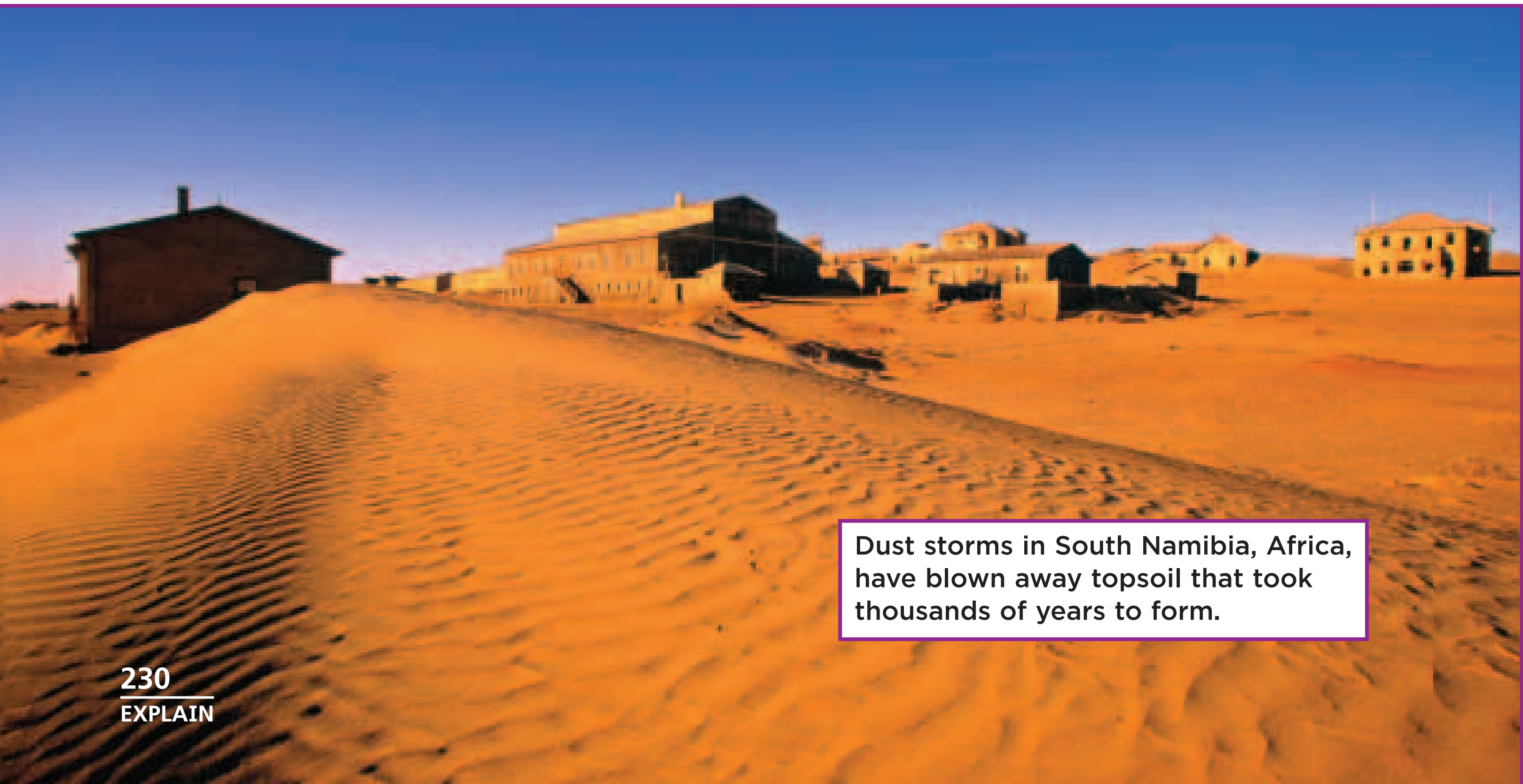
For many years, people viewed wetlands as wastelands. Since their value was not recognized, wetlands were often filled in and then used as areas for building and development. Today, wetland ecosystems are recognized for their value as habitats for a large variety of living things. Wetlands are valued as natural filters that help clean and purify the water. Wetlands also help prevent flooding by absorbing great quantities of water. For these reasons, many people now act to conserve wetland environments.

Desert environments can also change over time. The transformation of land into desert is known as *desertification*. This transformation may be caused by human activities such as plowing, cutting trees, or grazing livestock, all of which can disturb or remove plants that hold soil in place. Drought can increase the effects of these practices. As a result, an area may turn into a desert, or an existing desert may expand further.

Quick Check

Cause and Effect How did farmers worsen the drought of the 1930s?

Critical Thinking How might desertification affect people living on the edge of a desert?



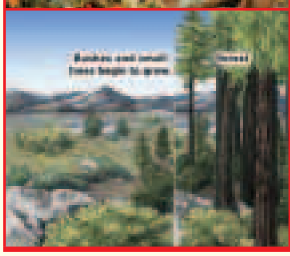
Dust storms in South Namibia, Africa, have blown away topsoil that took thousands of years to form.

Lesson Review

Visual Summary

Limiting factors control the sizes and growth of populations.

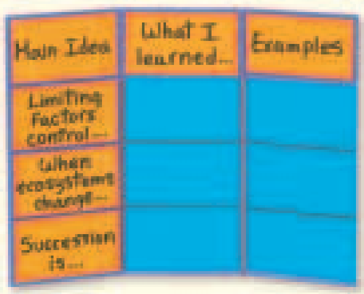
When ecosystems change, organisms may adapt or move on, or they may become **threatened**, **endangered**, or **extinct**.



Succession is the gradual replacement of one community by another.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the statements showing what you learned, and include examples.



Think, Talk, and Write

1. **Main Idea** Ecosystems change over time because of natural factors and ________.
2. **Vocabulary** A species whose numbers are so reduced that it is in danger of extinction is considered ________.
3. **Cause and Effect** How does the loss of a species affect biodiversity?

Cause	→	Effect
	→	
	→	
	→	
	→	

4. **Critical Thinking** What might happen if natural predators, such as coyotes, were driven from their habitats?
5. **Test Prep** **A plant that appears soon after a natural disaster in an area is a**
   - **A** climax species.
   - **B** limiting factor.
   - **C** community species.
   - **D** pioneer species.
6. **Test Prep** **The transformation of land into desert is**
   - **A** desertification.
   - **B** biodiversity.
   - **C** fossil evidence.
   - **D** succession.

Writing Link

Explanatory Writing

Prepare a brochure about the importance of land management. Explain how land use affects ecosystems. Include pictures, graphs, short paragraphs, and bulleted statements.

Math Link

Graph Population Growth

Research population growth in the United States over the past five years, and make a line graph of your data. Plot the years on the *x*-axis and the numbers of people on the *y*-axis.

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Meet Eleanor Sterling

Like sprawling cities in the sea, coral reefs are home to thousands of species of marine organisms, from sea turtles and giant clams to tiny coral polyps. When reefs are damaged, the organisms that live there are in danger, too. Protecting coral reefs is quite complicated, but that is exactly what Eleanor Sterling and her colleagues are working to do.

Eleanor is a conservation biologist. That is a scientist who studies endangered environments and organisms and works to ensure their conservation.

Eleanor is a scientist at the American Museum of Natural History. She travels to different ecosystems around the world to study and conserve the diversity of life. She and her colleagues recently visited a group of islands in the middle of the Pacific Ocean to study coral reefs.

One of the islands Eleanor studies is called the Palmyra Atoll. It is unusual because it is one of the most isolated places in the world, and only scientists are allowed to visit it. The reefs at Palmyra are healthy. Unfortunately, though, many reefs around the world are now threatened by fishing practices, unusually warm water temperatures, deforestation, soil erosion, and tourism.

Eleanor studies the sea-turtle population and its habitat in Palmyra.

In Palmyra, Eleanor and her colleagues dive underwater and kayak around the islands to document the wildlife living in the reef. They are especially interested in sea turtles. Nobody knows exactly how many sea turtles live in Palmyra. The scientists are trying to find out the size of the population, what parts of the reefs they use, and what they need to survive. The scientists use all this information to find ways to protect this unique habitat. From this work, scientists learn valuable lessons that can then be used to protect marine ecosystems all over the world.

Write About It

Cause and Effect

1. What factors cause damage to coral reefs?
2. How does damage to coral reefs affect the organisms that live in them?

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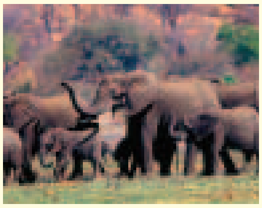
Cause and Effect

- Think about factors that cause changes to occur.
- Consider the effects of each type of change.

American Museum of Natural History

CHAPTER 4 Review

Visual Summary



Lesson 1 Ecosystems include living and nonliving things that interact.

Lesson 2 Energy and matter are transferred from one organism to another in food chains and food webs.

Lesson 3 The environment defines where and how organisms can live.

Lesson 4 Natural factors and human activities cause ecosystems to change over time.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.

Vocabulary

Fill each blank with the best term from the list.

climate, p. 208	**predator**, p. 201
community, p. 187	**producer**, p. 198
estuary, p. 215	**symbiosis**, p. 190
extinct, p. 224	**threatened**, p. 224

1. A relationship between two organisms that lasts over time is called ________.

2. The average pattern of a region's weather over time is its ________.

3. An ecosystem that forms where a river enters an ocean is a(n) ________.

4. When its numbers decline and it may soon become endangered, a species is ________.

5. An organism that makes its own food is a(n) ________.

6. A living thing that hunts and kills other living things for food is a(n) ________.

7. When a species no longer exists in the wild or in captivity, it is ________.

8. All the populations in an ecosystem make up a(n) ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. **Sequence** What is the first step that begins each food chain?

10. **Personal Narrative** Write a personal narrative about the way you interact with other organisms in your ecosystem.

11. **Make a Model** Suppose you were making a model ecosystem in a bottle. What abiotic features might you include in your model?

12. **Critical Thinking** Gray wolves were reintroduced into Yellowstone National Park in the 1990s. There had been few wolves in the area for more than 20 years. How do you think the new wolves changed the park's ecosystem?

13. **Interpret Data** Which biome is shown in the photograph below? What has replaced most of this biome in the United States?

14. How do organisms exchange energy and nutrients in an ecosystem?

Performance Assessment

There's No Place Like My Biome

Your goal is to use research and observations to learn more about your biome.

What to Do

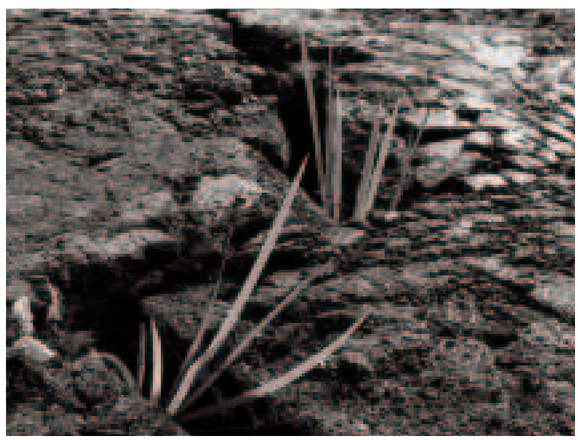
1. Describe the climate in your area.
2. Identify and classify at least five kinds of plants that grow in your area.
3. Observe or research local animal life. Identify and classify at least five kinds of animals that live in your area.

Analyze Your Results

- In which of the major biomes do you live? Explain how you reached this conclusion.

Test Prep

1. Look at the picture below.



The term that BEST describes the species shown in this picture is

A climax community.

B coniferous plant.

C succession species.

D pioneer species.

Tree-Care Technician

If you enjoy working outdoors and meeting new challenges, you may want to consider a career as a tree-care technician. Tree-care technicians promote the health of trees in neighborhoods, parks, and forests. This requires a great deal of physical activity and the ability to handle heavy equipment. Duties may include climbing trees to access work areas, inspecting trees for disease or pest problems, and operating shredding and chipping machines. Tree-care technicians help with storm recovery by removing trees that have fallen on roads, houses, or electrical wires. Tree-care technicians often receive on-the-job training. Education in forestry, biology, arboriculture, and pest management is also helpful.

▲ Tree-care technicians help keep the trees on our planet healthy.

▼ Wildlife biologists work to protect endangered species.

Wildlife Biologist

As human populations grow and make more demands on Earth's land and resources, there is an increasing need for people who care about wildlife. Earth's environment depends on stable ecosystems. However, as more animal habitats are altered to meet human needs, more species of wildlife are becoming endangered or even extinct. Wildlife biologists work to protect and recover endangered species and their habitats. They generally have at least a bachelor's degree and a background in biology, ecology, and math. They are also familiar with the social, economic, and political factors that affect wildlife management. In addition, wildlife biologists need good communication skills to interact with members of the public who visit forests and other natural areas.

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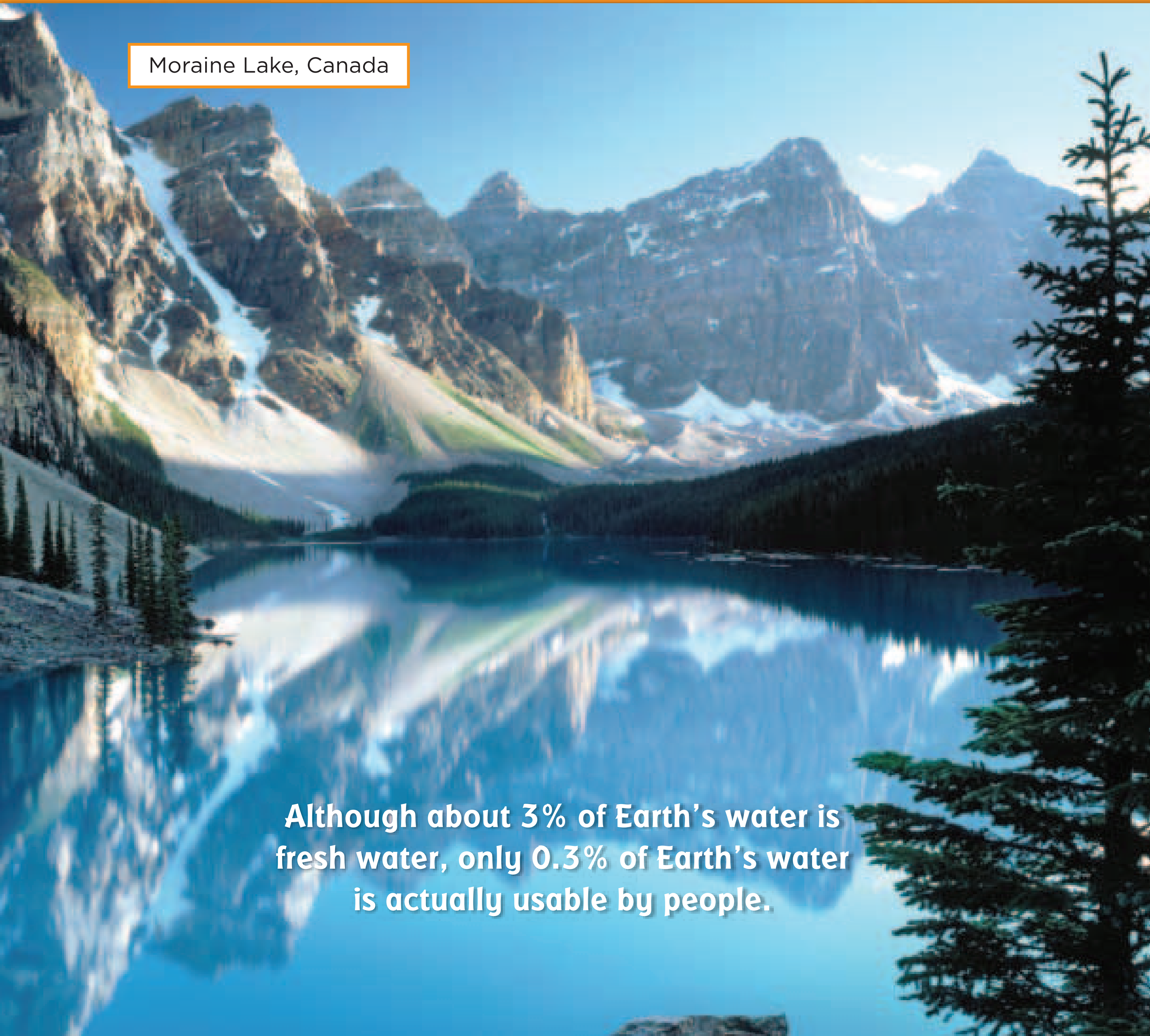
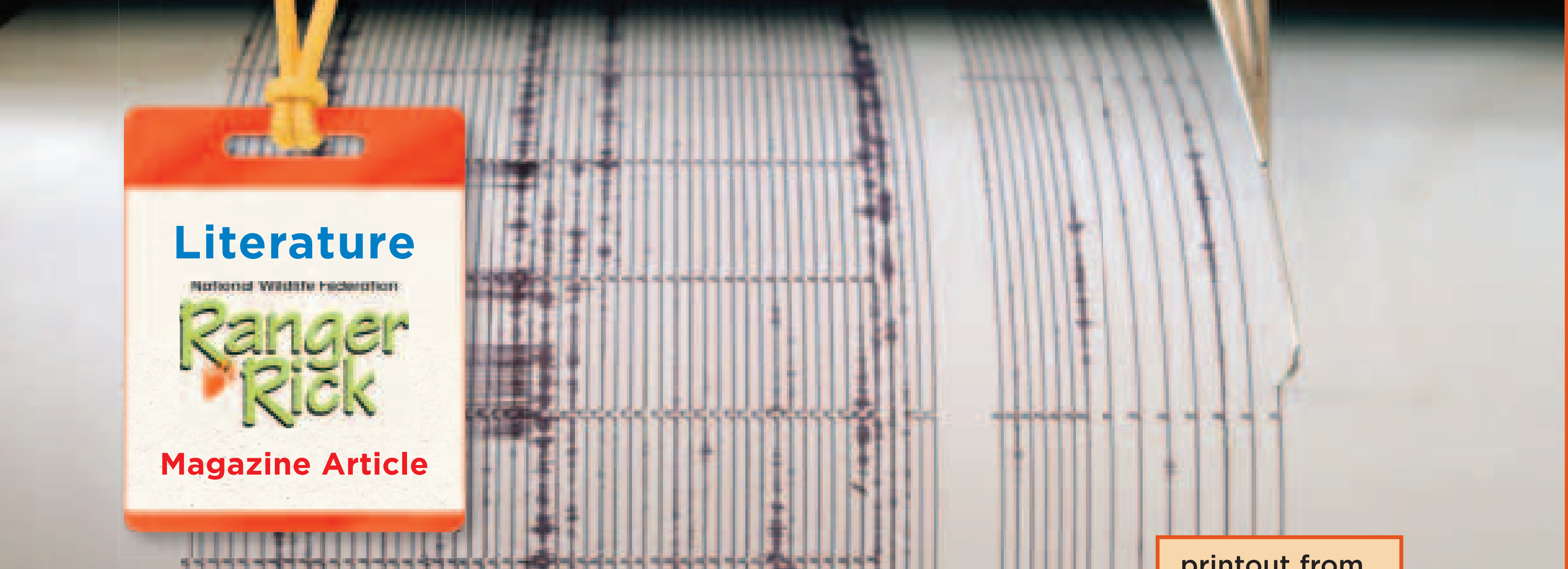
UNIT C

Earth and Its Resources



Moraine Lake, Canada

Although about 3% of Earth's water is fresh water, only 0.3% of Earth's water is actually usable by people.



Literature

National Wildlife Federation Ranger Rick

Magazine Article

printout from a seismograph

Understanding EARTHQUAKES

In an earthquake, the solid ground beneath our feet shakes, cracks, and rolls in waves like those in the sea. Long before science could explain this terrifying event, people felt a need to understand what caused earthquakes.

Earthquakes: Past Perspective

Ancient cultures around the world explained earthquakes through myths and stories. Native Americans in California tell a story of giant turtles that carried the land on their backs. One day when the turtles argued and swam in opposite directions, the land shook and cracked. The story says that now and then the turtles argue again, and each time California quakes. In a tale from India, the land is held up by mighty elephants. When one of the elephants gets tired, it lowers its head and shakes it, causing an earthquake. A Japanese myth explains earthquakes as the wriggling of a giant catfish that lives in the mud under Earth.

People long ago also tried to measure earthquakes. The first known earthquake-detecting device, built in China in A.D. 132 by Chang Heng, was a bronze jar with a heavy pendulum inside. During an earthquake,

Chang Heng's dragon jar

the pendulum remained still, while the jar moved. This triggered one of the dragons around the edge of the jar to open its jaws and drop a ball into the open mouth of a toad below.

Earthquakes: Present View

Today, we know that earthquakes are caused by the motion of Earth's tectonic plates. Seismologists, people who study earthquakes, use sensitive instruments called seismographs to detect the location and size of an earthquake. Inside the seismograph, a mass on a spring records motion in Earth's crust. It draws a flat line when the land is still. During an earthquake, a seismograph records a line of jagged spikes that indicate the strength of the tremors. Seismographs are installed at monitoring stations all over the world. When an earthquake occurs, scientists combine the information from different stations to determine where and when the quake took place and how strong it was. Then they report this news to people throughout the world. In this country, the U.S. Geological Survey is responsible for recording and reporting earthquakes.

Write About It

Response to Literature This article describes the study of earthquakes over the centuries. It explains how human knowledge about earthquakes has changed. Research a major earthquake that occurred in the past. Then write an essay describing the earthquake and its effects on people's lives.

LOG ON e-Journal Write about it online at www.macmillanmh.com

from *Ranger Rick*

San Andreas Fault, California

CHAPTER 5

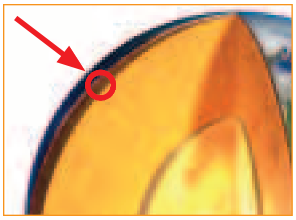
Changes over Time

The Big Idea

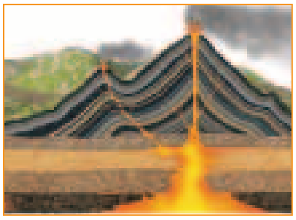
What forces have shaped Earth's landscape?

Racetrack Playa at Death Valley, California.

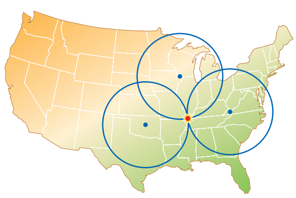
Key Vocabulary



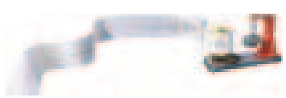
lithosphere
The crust and the rigid part of Earth's mantle. (p. 250)



magma
Hot, fluid rock below Earth's surface. (p. 257)



epicenter
The location on the surface of Earth above the focus of an earthquake. (p. 271)



seismograph
An instrument that detects, measures, and records the energy of earthquake vibrations at a given location. (p. 272)

vent
A central opening through which magma erupts when it reaches the surface. (p. 276)

fossil
Any trace, imprint, or remains of a living thing preserved in Earth's crust. (p. 300)

More Vocabulary

hydrosphere, p. 244

latitude, p. 248

longitude, p. 248

crust, p. 250

mantle, p. 250

core, p. 250

continental drift, p. 256

plate tectonics, p. 257

fault, p. 268

focus, p. 270

seismic wave, p. 271

magnitude, p. 274

weathering, p. 284

erosion, p. 286

deposition, p. 286

mass wasting, p. 287

moraine, p. 289

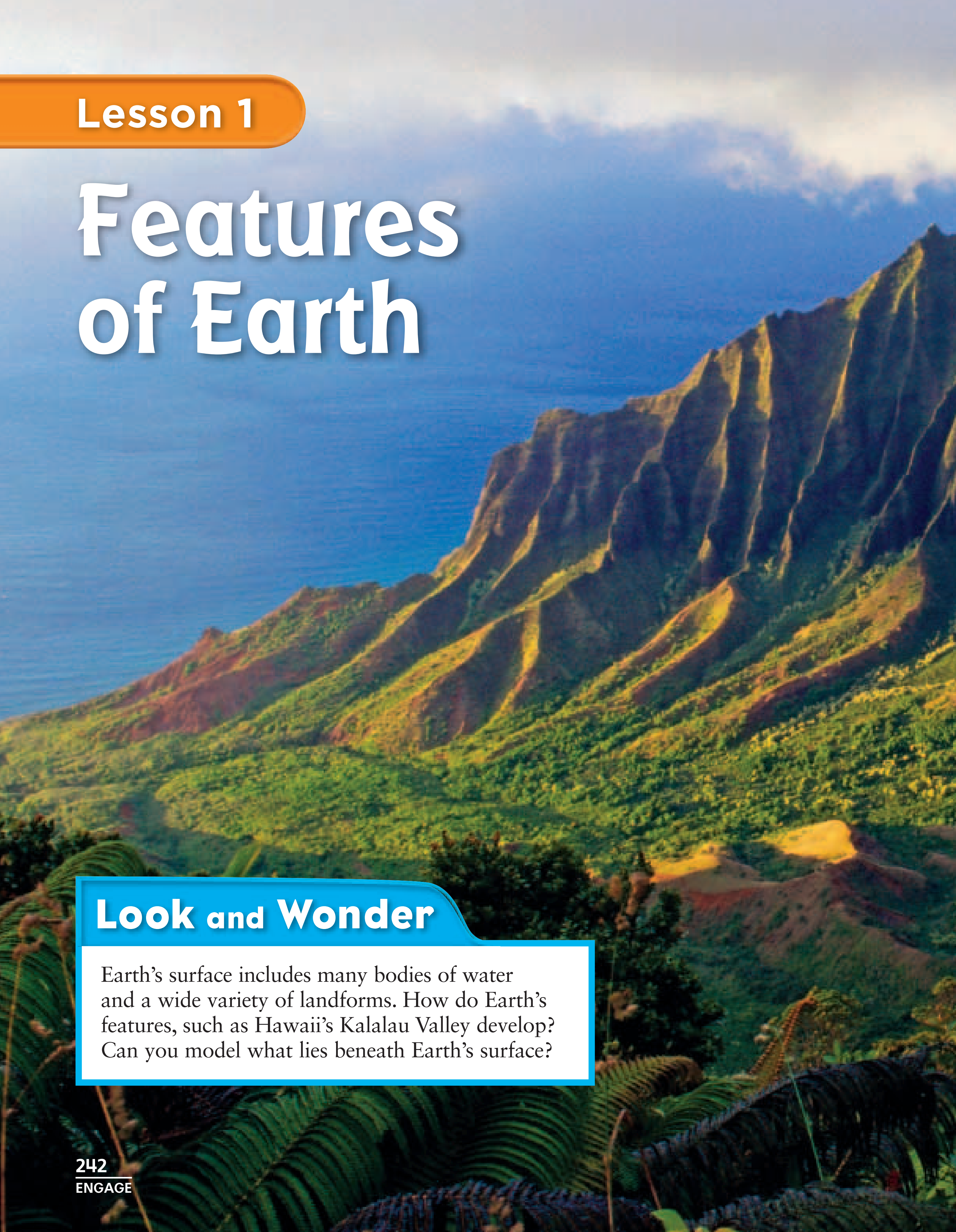
relative age, p. 298

half-life, p. 302

absolute age, p. 302

Lesson 1

Features of Earth



Look and Wonder

Earth's surface includes many bodies of water and a wide variety of landforms. How do Earth's features, such as Hawaii's Kalalau Valley develop? Can you model what lies beneath Earth's surface?

Explore

Inquiry Activity

How can you make a model of Earth's interior?

Purpose

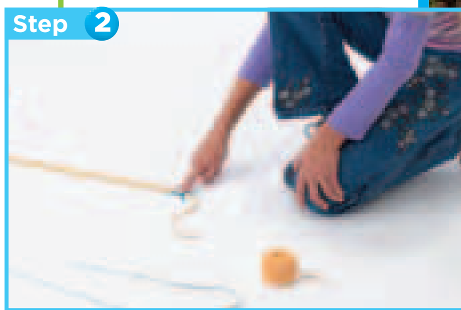
Scientists study earthquake waves that travel through Earth. These waves provide information about the different layers of Earth's interior. Make a model to compare the thicknesses of Earth's layers.

Materials

- chalk
- string
- measuring tape or meterstick
- scissors

Procedure

1. **Make a Model** Draw a small *x* on the ground with chalk. This will be your center point for making three circles.
2. **Measure** Tie one end of a piece of string to the piece of chalk. Then measure and cut the string to be 185 cm long. ⚠ **Be Careful.** Hold one end of the string at the center of the *x*, and have a partner draw a circle around the *x*, keeping the string straight and taut all the way around.
3. Repeat the process two more times, cutting your string first to 182 cm and then to 100 cm.



Draw Conclusions

4. **Use Numbers** The scale for your model is 1 cm = 35 km. How many real kilometers are represented by each layer in your model?
5. Are the layers in your model the same thickness? According to your model, what is the distance from the surface of Earth to its center?

Explore More

Can a scale model of Earth be designed to fit on a sheet of notebook paper? Measure the paper, and then calculate the scale that would work best for this new size. Try out your model. Is this model as helpful? Explain why or why not.

Read and Learn

Main Idea

Earth's surface includes features such as bodies of water and landforms.

Vocabulary

hydrosphere, p. 244
latitude, p. 248
longitude, p. 248
elevation, p. 249
crust, p. 250
mantle, p. 250
lithosphere, p. 250
core, p. 250

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Reading Skill

Summarize

[ ] [ ] [ ] → Summary

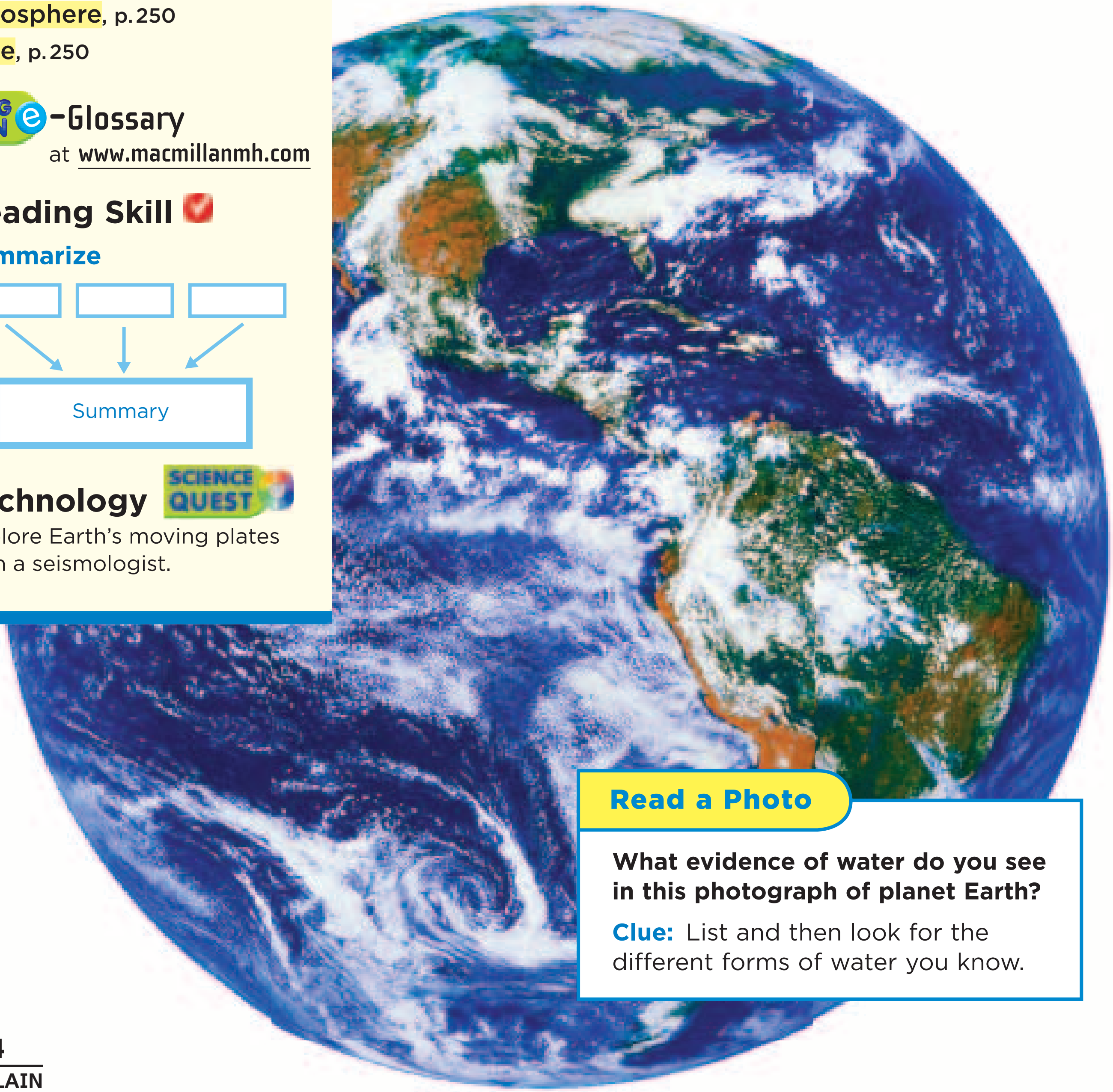
Technology SCIENCE QUEST

Explore Earth's moving plates with a seismologist.

Where is water on Earth?

Have you ever wondered which parts of Earth contain water? The **hydrosphere** (HIGH•druh•sfeer) is the part of Earth that contains water. Water covers about 75 percent of Earth's surface. It exists in many forms and in many places in the hydrosphere. Water can be found as a solid, in the form of ice or snow; as a liquid, in oceans, lakes, and rivers; and in the atmosphere, as water vapor or water droplets.

The Hydrosphere: Earth's Water



Read a Photo

What evidence of water do you see in this photograph of planet Earth?

Clue: List and then look for the different forms of water you know.

Earth's water exists in two basic forms: salt water and fresh water. More than 95 percent of the water on Earth is salt water, or water that has salts dissolved in it. Ocean water contains salts such as sodium chloride and magnesium chloride. Scientists use the term *salinity* to describe how much salt is dissolved in water.

Fresh water contains little or no salt. It comes from sources such as rivers, lakes, and also from rainfall. Most of Earth's fresh water exists as ice.

Glaciers are large sheets of ice that slowly move. Valley glaciers form at high elevations, in areas such as mountains. Continental glaciers cover large parts of the polar regions.

Quick Check

Summarize Where is water found in Earth's hydrosphere?

Critical Thinking Why is water on Earth's surface found sometimes as a solid and sometimes as a liquid?

What are Earth's landforms?

Suppose you took a trip around the world. You would notice that the appearance of the land varied. In some areas, the land would be flat. In other areas, there would be hills and mountains. Some places would have rivers, lakes, or deserts. All of these features are called landforms.

Types of Landforms

Mountain ranges such as Annapurna in Nepal are areas that rise high above the surrounding land. They form when rock layers fold or are pushed up by forces inside Earth. They may also form when volcanoes erupt.

Plains are large, flat areas of land. They include coastal plains, which are found near the oceans, and interior plains, which are found in the middle of continents. The plains shown here are located in Argentina.

Plateaus are flat, raised areas of land. A plateau forms when forces inside Earth lift up a horizontal layer of rock. Arizona's Merrick Butte, shown here, was once part of a larger plateau that has been slowly worn away.

U.S. Landforms

Major U.S. Landforms

The United States has many significant landforms. Some of these landforms can be described in terms of their height above or below sea level.

Low regions of the United States include plains and basins. Plains are large, flat areas of land. Basins are regions into which rivers in the surrounding area flow.

High regions include plateaus and mountains. Plateaus are large areas of flat, raised land high above sea level. Plateaus may be worn away to form smaller structures such as buttes and mesas. Mountains are masses of rock that rise more than 610 meters (2,000 feet) above the surrounding land. Groups of mountains in long, narrow belts are called mountain ranges.

The map on this page is a *relief map*, which shows regions of different heights as different colors. As you look for landforms on the map, you will notice where mountains are located. This map also has a line that represents the Continental Divide. The Continental Divide is a ridge running from Mexico to Canada. West of this ridge, rivers flow toward the Pacific Ocean. East of this ridge, rivers flow toward the Atlantic Ocean or the Gulf of Mexico.

Quick Check

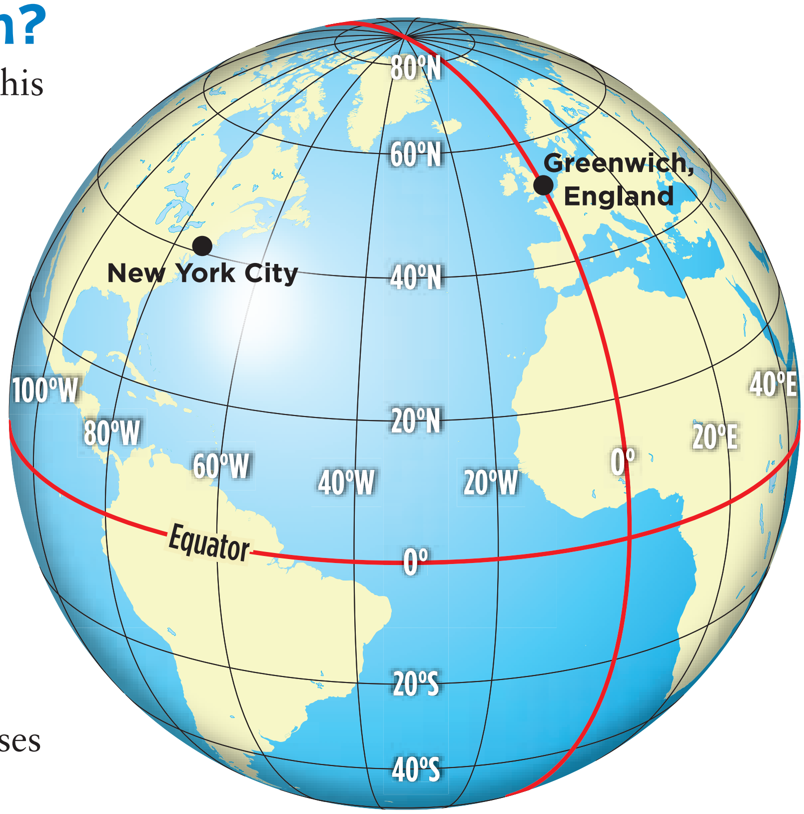
Summarize Write a short summary of the major landforms found in the United States.

Critical Thinking How could people know whether they were on a plain or on a plateau without being told?

How do we map Earth?

Look at the globe pictured on this page. With your finger, trace the horizontal line halfway between the North and South poles. This line is the equator. Now trace the horizontal lines above and below the equator. These are lines of latitude. **Latitude** shows location north or south of the equator.

Now trace the vertical lines around the globe. They meet only at the poles. These are lines of longitude. **Longitude** shows location east or west of the prime meridian, the vertical line that passes through Greenwich, England.



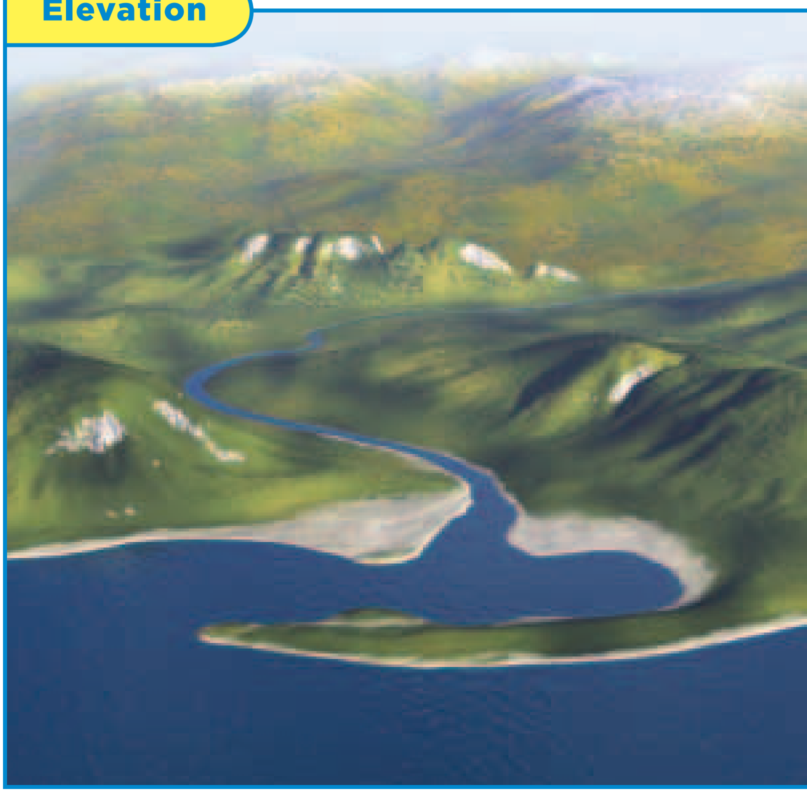
▲ Latitude and longitude enable you to precisely locate any place on the planet.

Finding Places on Earth

To use latitude and longitude to locate a city, follow these steps. Find the latitude line nearest the city's latitude. If the city is between two latitude lines, estimate the distance between them. Latitude above the equator is north (N). Latitude below the equator is south (S).

Then find the longitude line that is closest to the longitude of the city. Longitude to the right of the prime meridian is east (E). Longitude to the left of the prime meridian is west (W). The point where the city's latitude and longitude lines cross is its location. For example, the location of New York City is 41°N, 74°W.

Elevation



Elevation

Sometimes you need information that a typical globe cannot provide. For example, most globes do not show how high a mountain is. A topographic map shows **elevation**, the height above or below sea level. You can find elevation by using contour lines. *Contour lines* connect places on a map that have the same elevation.

Geographers and scientists use the word *elevation* in reference to places on Earth. They use the term *altitude* for elevation in the air, as for clouds or airplanes, or for locations in space.

Read a Diagram

If you were hiking in the mountains, would you use the drawing or the topographic map?

Clue: Which image shows a greater amount of detail about elevation?

Quick Lab

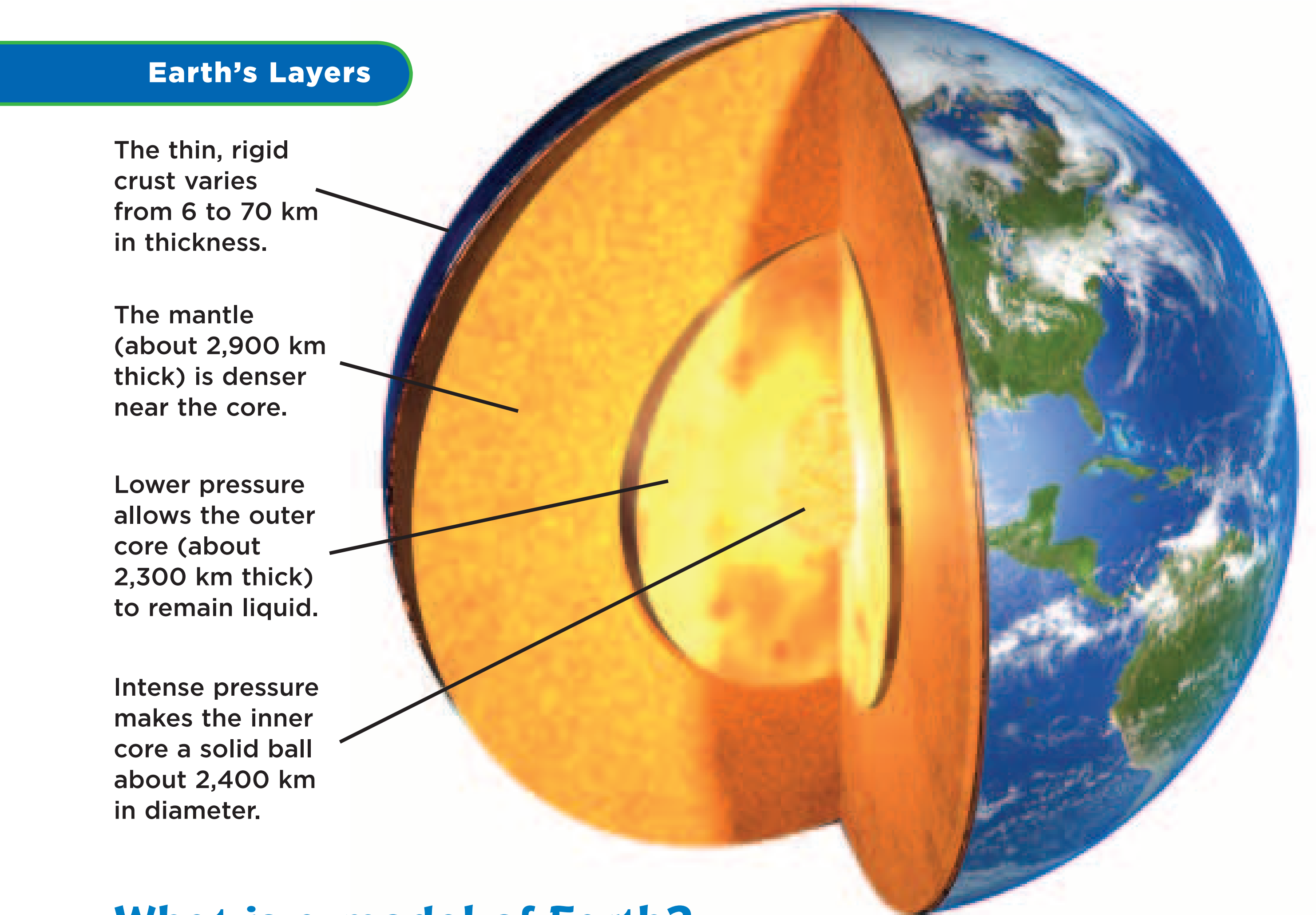
Map-Challenge Game

1. Play the game in pairs. Obtain two identical maps, one for each player, that show latitude and longitude.
2. Using his or her map, player A should choose a city and tell player B only its latitude and longitude.
3. Player B should look at his or her own map, find the location, and call out the name of the city.
4. Switch roles, and continue taking turns until each player has correctly identified five cities.
5. **Infer** How might scientists use latitude and longitude to report data?

Quick Check

Summarize Summarize how you would find the location of a city on a globe.

Critical Thinking Which kind of map would you prefer to bring on a camping trip: a globe or a topographic map? Why?



What is a model of Earth?

As you know, the hydrosphere is the part of Earth that contains water. The atmosphere is the layer of gases that surrounds Earth. What else makes up Earth? Scientists have gathered evidence from earthquakes and volcanoes to form a model of Earth's interior. The evidence strongly suggests that Earth is made of layers.

Earth's solid, rocky surface is the **crust**. The crust includes the continents and the ocean floor. The layer beneath the crust is the **mantle**. The upper part of the mantle nearest the crust is solid and rigid, or stiff. Together, the crust and the rigid part of the mantle make up what is called the **lithosphere** (LITH•uh•sfeer). The part of the mantle just below the lithosphere is very hot, and scientists think it flows like plastic putty.

Beneath the mantle is the **core**, the central part of Earth. The core is made up of two parts. The *outer core* is the molten, or fluid, part of the core. The *inner core* is solid. Earth's core is very dense, and it is under high pressure.

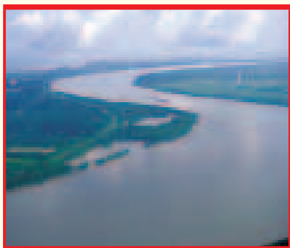
Quick Check

Summarize Write a brief summary of the different layers that make up Earth's interior.

Critical Thinking What conditions might make travel to the center of Earth very difficult?

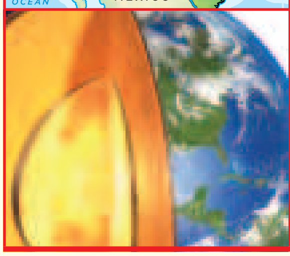
Lesson Review

Visual Summary



Earth's **hydrosphere** contains fresh water and salt water.

A relief map shows **landforms**. Maps can also show latitude, longitude, and elevation.



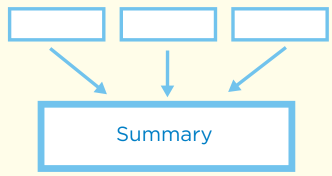
Earth is made up of layers, including the **crust**, **mantle**, and **core**.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, summarize the feature of Earth.

Think, Talk, and Write

1. **Main Idea** What types of landforms are found on Earth's surface?
2. **Vocabulary** The crust and the rigid part of Earth's mantle together make up the ________.
3. **Summarize** What information do latitude and longitude provide?



4. **Critical Thinking** Given that 75 percent of Earth's surface is covered with water, why is water considered a scarce resource?
5. **Test Prep** **Glaciers are part of Earth's**
   - **A** atmosphere.
   - **B** hydrosphere.
   - **C** mantle.
   - **D** outer core.
6. **Test Prep** **Contour lines on a map connect places that have the same**
   - **A** latitude.
   - **B** longitude.
   - **C** elevation.
   - **D** salinity.

Writing Link

Expository Writing

Write a report describing the sources of fresh water in your area. Do research to find out about local bodies of water. Which ones contain fresh water? Where are they located?

Math Link

Use a Contour Map

On a contour map, point A is located 220 m above sea level. Point B is located 40 m below sea level. What is the difference in elevation between the two points?

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Focus on Skills

Inquiry Skill: Communicate

When you **communicate**, you share information with others. Sometimes, the information may be spoken. At other times, it may be written. Another useful way of communicating information is by making a map. One type of map that is very useful to geologists in particular is a topographic map.

▶ Learn It

A topographic map uses contour lines to **communicate**. Contour lines connect points of equal elevation. By looking at contour lines, you can learn a great deal about how a region looks.

▶ Try It

Materials **permanent marker, ruler, plastic container, modeling clay, water, pencil**

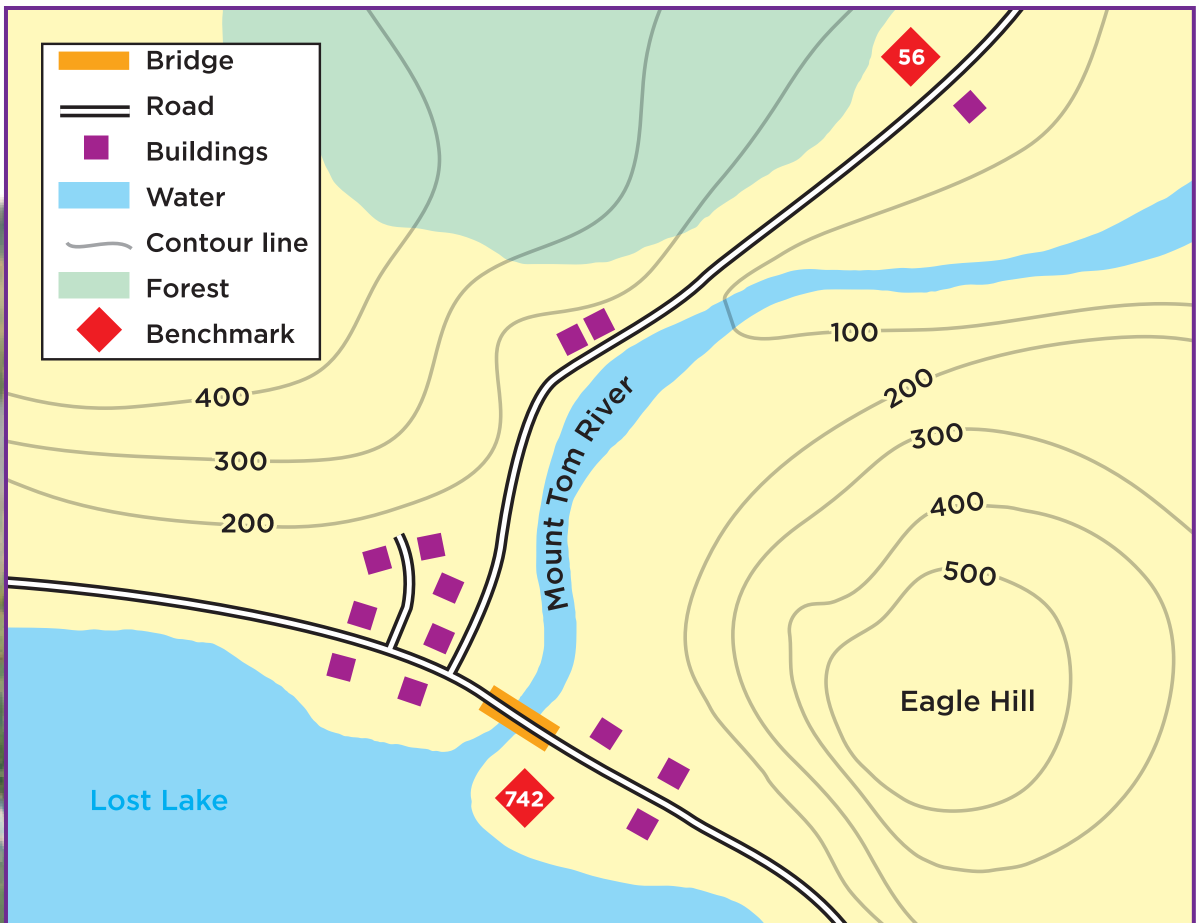
1. With the permanent marker and ruler, mark horizontal lines on the side of the plastic container at 1 cm intervals, from bottom to top.
2. Make a clay hill that is steep on one side and gently sloping on the other.
3. Place your hill in the center of the plastic container.
4. Pour water into the container until the water reaches the first mark.
5. Use a pencil to scratch a contour line along the entire shoreline of your hill.
6. Repeat steps 4 and 5 at successive elevation levels until you have covered your hill with water.
7. Carefully pour the water out of your container.

Surveyors collect the data that are displayed on topographic maps.

▶ Apply It

Make a short presentation to **communicate** what you learned about topographic maps from performing this activity. Use the questions below as a guide.

1. Look at your hill from above. Observe the traced lines on the clay. What information do these lines provide?
2. What is the highest elevation of your hill?
3. What is the contour interval, or the difference in elevation between adjacent contour lines?
4. How does the spacing between contour lines on the gently sloping side of your hill compare to the spacing between contour lines on the steep side of your hill?
5. What can you conclude about the relationship between contour lines and the steepness of a hill?



Lesson 2

Earth's Moving Continents

Look and Wonder

When you put together a jigsaw puzzle, what do you do? First, you look for edges that match. Could Earth's continents be like giant puzzle pieces that have moved apart? What evidence supports this?

Explore

Inquiry Activity

Are the continents moving?

Make a Prediction

Were the separate continents we know today one huge landmass in the past? Do the outlines of the continents fit together? Write your answer in the form of a prediction: "If the continents were once connected, then . . ."

Test Your Prediction

1. Place tracing paper over a map of the world. Trace the outlines of North America, South America, Europe and Asia (including India), Africa, Australia, and Antarctica.
2. Cut out the continents along their coastlines, and label them. **Be Careful.**
3. **Experiment** Using your cutouts like pieces of a jigsaw puzzle, find ways the continents might have fit together in the past. Draw several sketches that show how they could fit together.

Draw Conclusions

4. **Interpret Data** Which continents have coastlines that fit together most closely?
5. **Infer** Which of your sketches shows the greatest number of continents fitting together? Which continents did you have trouble connecting? How can you explain this?

Explore More

What if the continents in your finished puzzle moved apart to the positions they are in today? If they kept moving, how might they be arranged in the distant future? Make a prediction and map it. Then present your results to the class.

Materials

- tracing paper
- map of the world
- pencil
- scissors

Read and Learn

Main Idea

Earth's crust is made of moving plates that slowly but constantly change its surface.

Vocabulary

continental drift, p. 256
plate tectonics, p. 257
magma, p. 257
seafloor spreading, p. 258

Reading Skill

Draw Conclusions

Text Clues	Conclusions

Technology SCIENCE QUEST

Explore Earth's moving plates with a seismologist.

Are the continents moving?

In 1915 Alfred Wegener, a German scientist, published a book proposing that the continents had been connected as a single body of land earlier in Earth's history. Wegener gave evidence for his idea. He showed that some of the continents fit together like pieces of a jigsaw puzzle. He noted places in which different continents had fossils of the same plants and animals and matching rocks, glaciers, or mountain ranges. He also noted that Antarctica had fossils of species that were most likely tropical. This suggested that Antarctica had been located near the equator at one time.

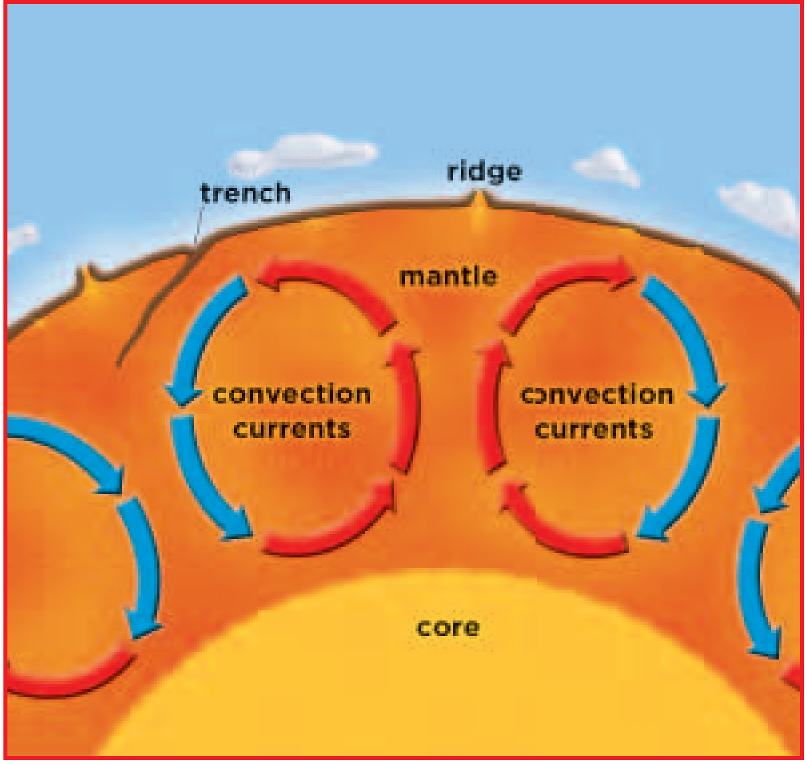
Wegener concluded that all the continents had once been part of a single "supercontinent." He called this landmass *Pangaea* (pan•JEE•uh). He suggested that Pangaea later split apart and that the continents then "drifted" to their present positions. Wegener's concept became known as **continental drift**.

Fossil Evidence of Continental Drift

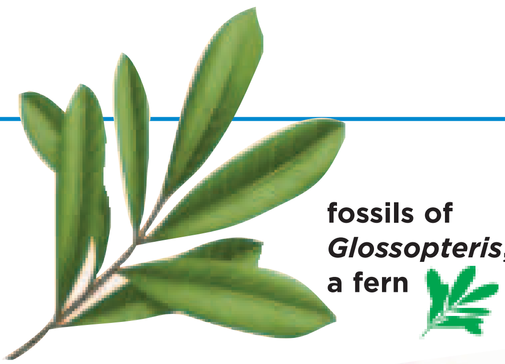
fossils of *Cynognathus*

The map shows where fossils of ancient organisms have been found in the southern continents.

fossils of *Lystrosaurus*, a land reptile



▲ Heat is transferred in Earth's interior by convection currents, movements that form as warmer material rises and then cools and sinks.



fossils of *Glossopteris*, a fern

fossils of *Mesosaurus*, a freshwater reptile

Read a Map

How does this map support the idea of continental drift?

Clue: Locate on the map where each fossil type was found.

Plate Tectonics

In Wegener's time, many people rejected the idea of continental drift. People wondered how continents could move through solid rock. However, new evidence supporting Wegener's proposal came to light in the 1950s, when scientists mapping the floor of the Atlantic Ocean made an amazing discovery. They found that in the middle of the Atlantic, there was an underwater mountain chain. By the 1960s, similar structures had been discovered in other oceans. On both sides of these mountain chains, the ocean floor was moving.

Scientists developed a model called **plate tectonics** to explain how the continents and the ocean floor could move. According to this model, Earth's surface is broken into pieces, or plates. The plates move over the hot, fluid rock, or **magma**, in the mantle.

Uneven heating in the mantle produces slow-moving currents of plasticlike, fluid rock. The cooler, rigid rock of the lithosphere rests on top of this fluid rock. The slow movements in the fluid part of the mantle drag the lithosphere and its plates sideways. As the lithosphere moves, so do the ocean floor and continental plates.

Quick Check

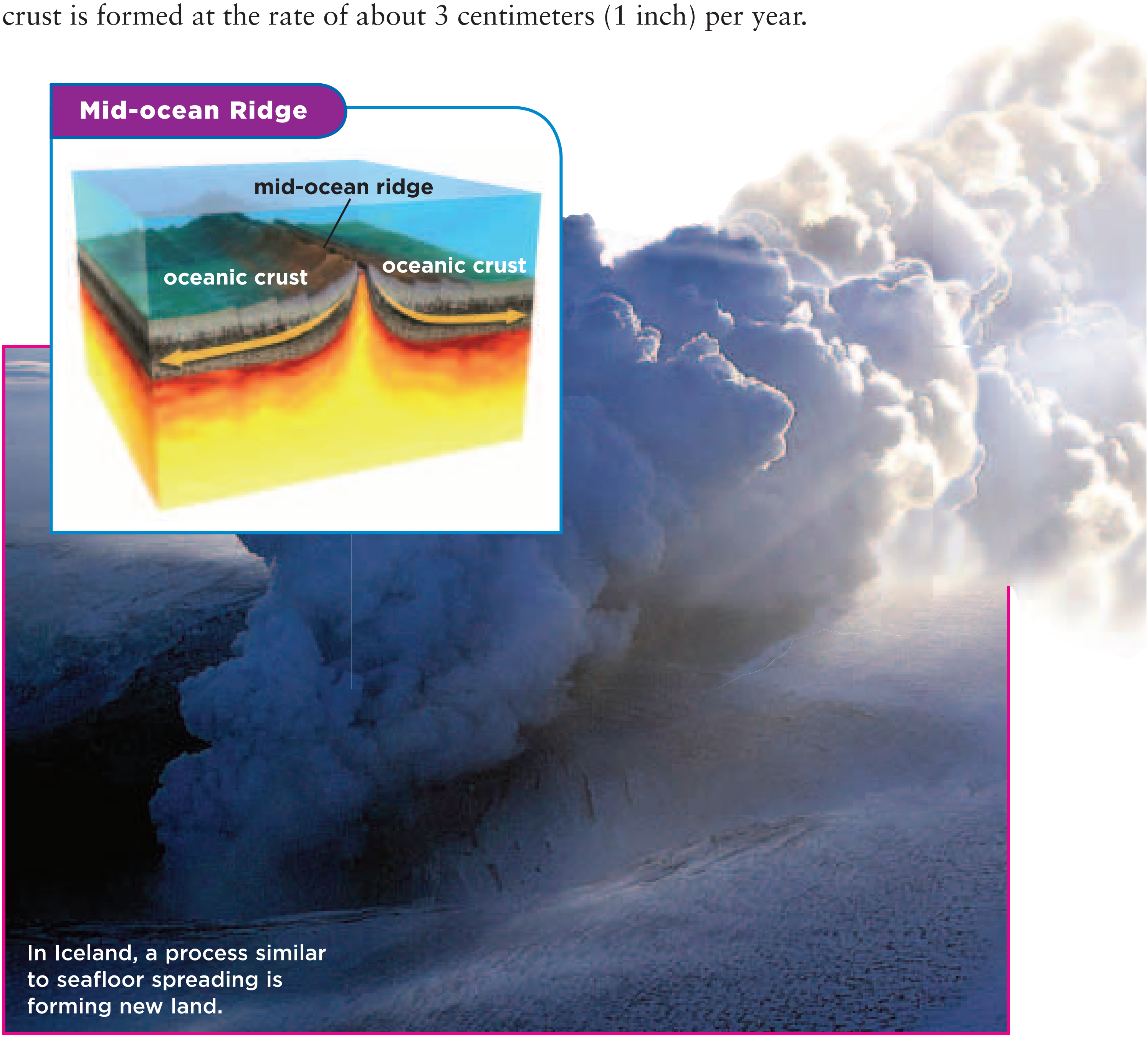
Draw Conclusions What conclusions did Alfred Wegener draw about Pangaea?

Critical Thinking How does the movement of the ocean floor support Wegener's idea of continental drift?

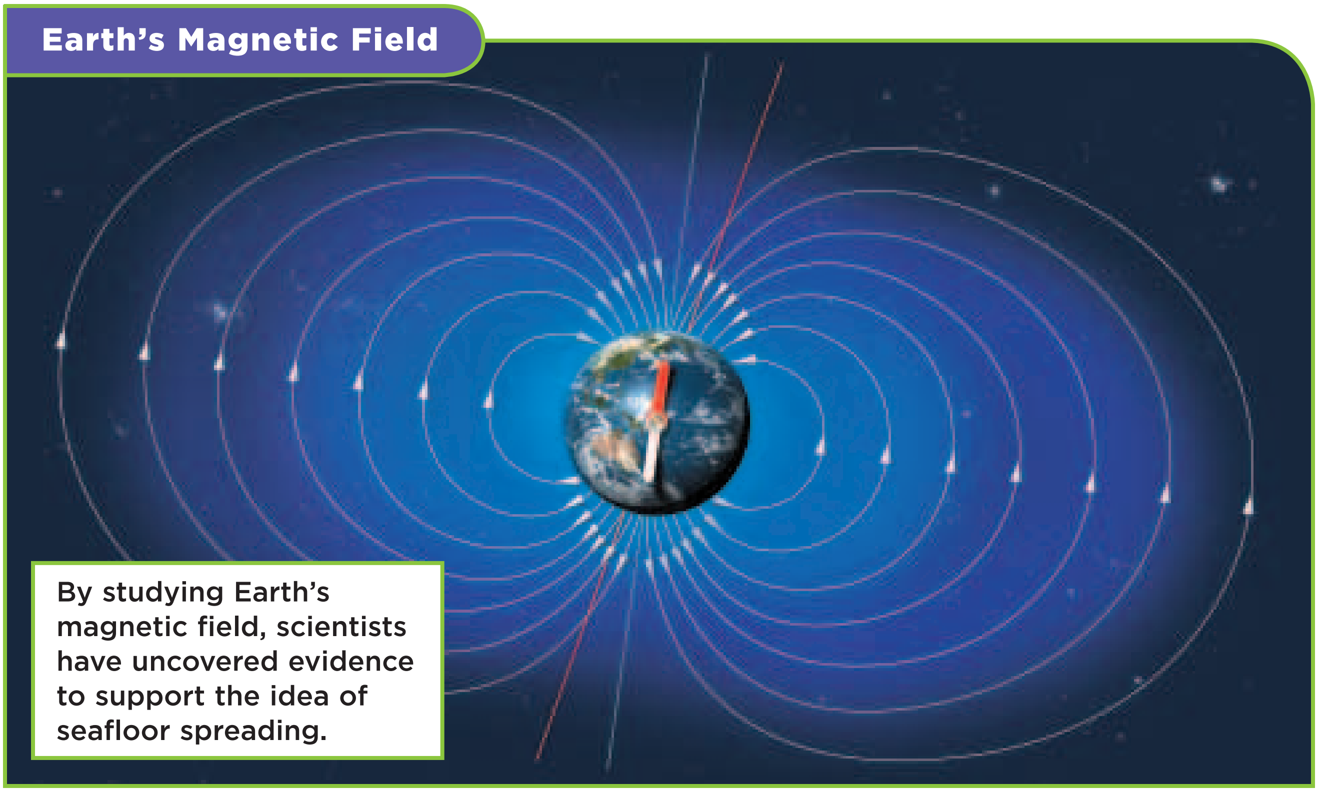
How do oceans change size?

The processes that move continents also help form new crust on the ocean floor. As some crustal plates move apart, magma enters the cracks and flows outward. The magma cools, hardens, and builds up into parallel ridges, or raised structures, on the ocean floor. The new rock exerts a sideways force called *compression*. Magma continues to flow between the plates, forcing them farther apart. This process is called **seafloor spreading**.

Seafloor spreading explains how plates move apart and new crust forms. At the Mid-Atlantic Ridge in the Atlantic Ocean, new seafloor crust is formed at the rate of about 3 centimeters (1 inch) per year.



In Iceland, a process similar to seafloor spreading is forming new land.



By studying Earth's magnetic field, scientists have uncovered evidence to support the idea of seafloor spreading.

Evidence of Seafloor Spreading

Several pieces of evidence support seafloor spreading. For example, the youngest rock on the ocean floor is found at mid-ocean ridges. The farther rock is from the ridges, the older it is. Rock that makes up the continents is generally older than seafloor rock.

The type of rock found on the ocean floor is also significant. Most seafloor rock is volcanic in origin. This means that it formed as magma from the mantle cooled and hardened.

The magnetism of seafloor rock provides further evidence for seafloor spreading. Earth has a north-south magnetic field. This magnetic field changes, and occasionally it reverses completely, resulting in a south-north orientation. Magma contains iron particles, which line up according to the direction of Earth's magnetic field. As the magma cools and solidifies, the iron particles "freeze" in the direction of the magnetic field at that time.

When scientists studied rock along the seafloor, they found that the magnetism in the rock alternated from one direction to the other. This pattern occurred in strips, and the pattern matched on both sides of the mid-ocean ridges. They concluded that rock had hardened along the ridge, preserving evidence of this magnetic record. Over time, the rock had then spread apart.

Quick Check

Draw Conclusions Why would continental rock generally be older than seafloor rock?

Critical Thinking Summarize the evidence that supports seafloor spreading.

What happens at plate boundaries?

Plates can move in three ways. They can move apart from each other, they can collide, and they can slide past each other.

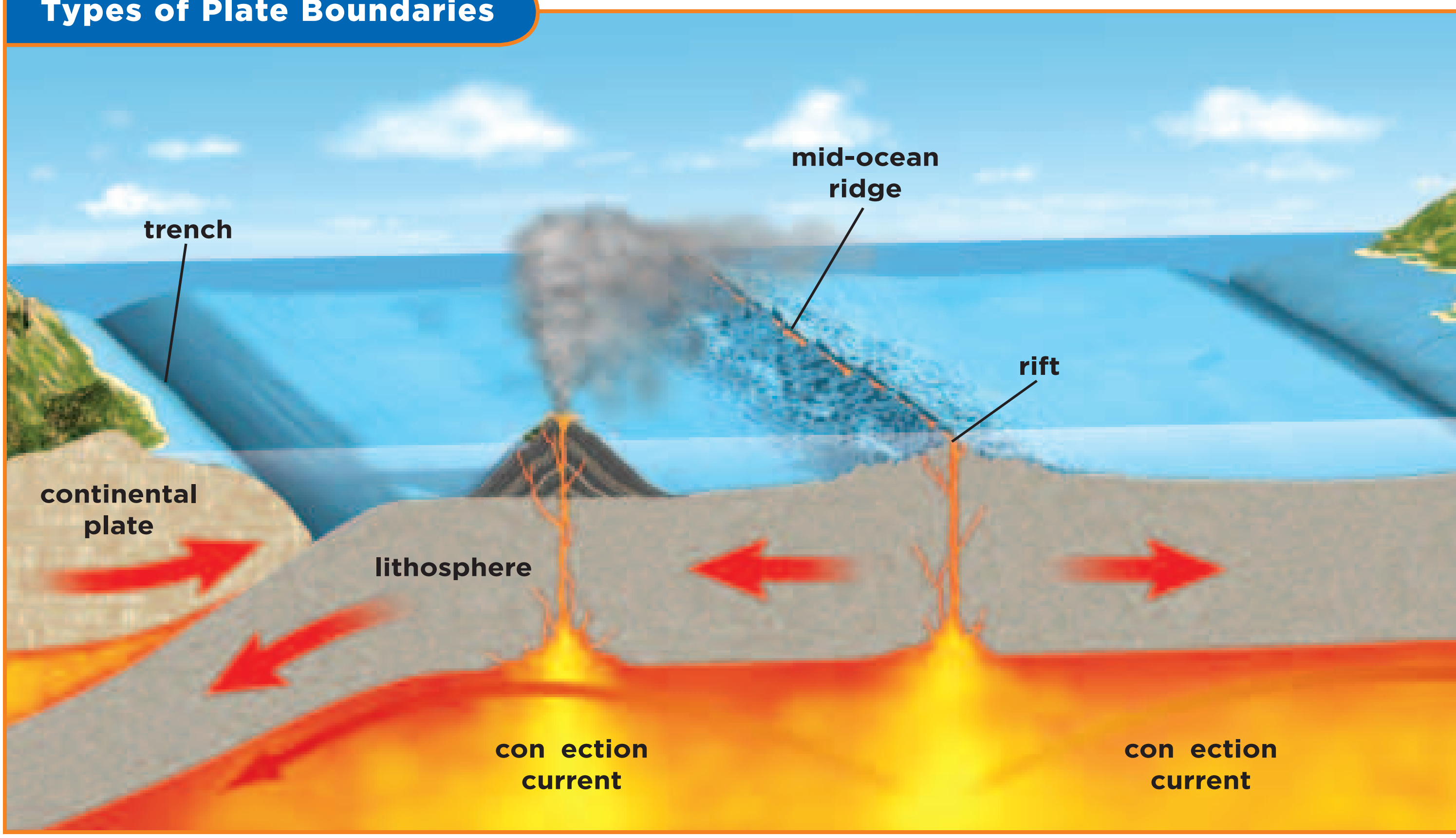
Locations where plates move apart are called *divergent boundaries*. Seafloor spreading occurs at divergent boundaries. Divergent boundaries also occur on land. Iceland is located on a divergent boundary at the northern end of the Mid-Atlantic Ridge. The Great Rift Valley in Africa is also a divergent boundary. There, the continent of Africa is splitting. The split may one day form a new ocean. Some divergent boundaries are less visible, occurring within a continental plate.

Locations where plates collide are *convergent boundaries*. If both colliding plates include continents, the pressure lifts and crumples the plates, forming mountains. Earthquakes and volcanic activity can occur at convergent boundaries.

Sometimes one colliding plate carries part of an ocean floor, and the other carries part of a continent. Then the oceanic plate slides under the continental plate in a process called *subduction*. The edge of the oceanic plate is pushed down into the mantle and melts. Some of the magma beneath rises through cracks between the plates. At the surface, a volcano forms.

When plates move toward each other on the ocean floor, one plate sinks under the other. This movement forms an *ocean trench*.

Types of Plate Boundaries



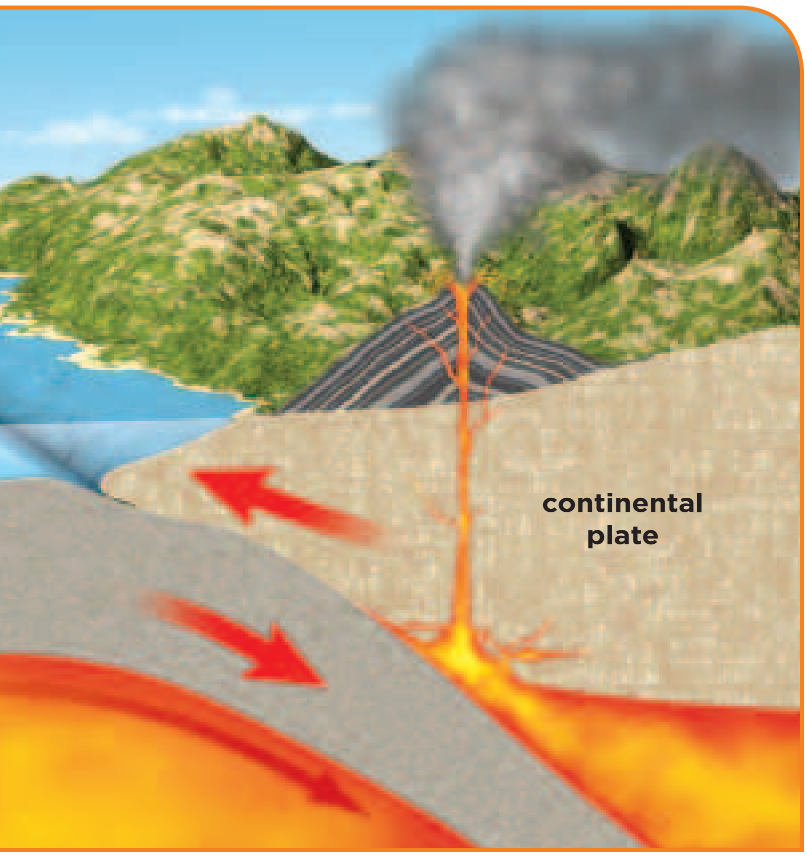
Sliding Plates

Some plates simply slide past each other. The boundary between these plates is a *transform boundary*. Earthquakes can occur along these boundaries as strain on the rock builds up and then is quickly released. Rock along these boundaries shatters and breaks. Eventually, this rock may pile up and form narrow ridges and valleys.

Quick Check

Draw Conclusions If a continental valley begins to widen, what conclusion might you draw about the region's plate movement?

Critical Thinking Where would it be easiest to drill through Earth's crust and reach the mantle?



Quick Lab

Earth's Sliding Plates

1. **Make a Model** Tape two pieces of construction paper to the covers of two similar-sized textbooks.
2. Place the books next to each other. Draw a "road" that crosses from one piece of construction paper to the other.
3. Using building blocks or dominoes, construct a small "house." Place it on top of the crack where the two books meet.
4. **Observe** Slowly slide one book past the other. What happens to the "road" and "house"? Record all your observations by drawing a sketch and labeling the details.
5. Rebuild your "house" to match its appearance in step 3.
6. **Observe** Now tap one book sharply along its shorter side. What happens to the "road" and "house"? Record all observations.

FACT The Indian subcontinent slowly drifted north and joined Asia about 50 million years ago.

Tectonic-Plate Movement

Read a Map

In which direction is the South American Plate moving?

Clue: Use the key, and examine the plate's boundaries.

Where are the plates?

Earth's crust has seven major tectonic plates. Some of the plates are diverging, or moving apart. Others are converging, or pushing together.

Mid-ocean ridges occur along diverging plates. The Mid-Atlantic Ridge is located where the South American Plate is moving away from the African Plate.

Convergent boundaries can be found at many large mountain chains. The Himalayas are located where the Indian Plate is colliding with the Eurasian Plate. The Alps are located where the African Plate is colliding with the Eurasian Plate.

Most transform boundaries are located on the ocean floor. On land the most noticeable transform boundary is the San Andreas Fault between the North American Plate and the Pacific Plate. This fault is the site of many powerful earthquakes.

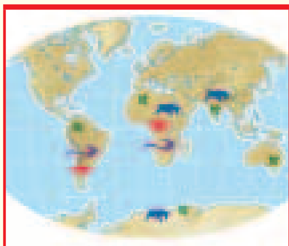
Quick Check

Draw Conclusions India continues to move into the Asian continent. What will happen to the Himalayas?

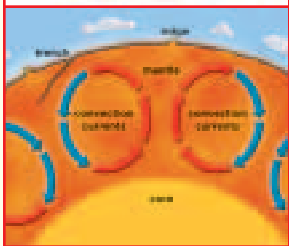
Critical Thinking How might the movement of Earth's tectonic plates affect you?

Lesson Review

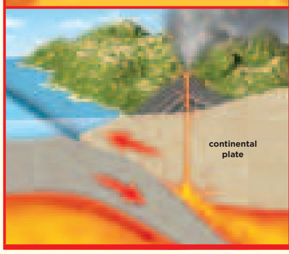
Visual Summary



Evidence suggests that **continental drift** has caused continents to change their positions over time.



Convection currents in the mantle are the cause of continental drift.



Earth's surface is composed of **plates** that move, causing the surface to change.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add details to explain how Earth's continents move.

Think, Talk, and Write

1. **Main Idea** What evidence supports the idea that Earth's crust moves?
2. **Vocabulary** The model that Earth's crust is broken into huge pieces that move over the mantle is called ________.
3. **Draw Conclusions** If two continents are separated by an ocean and have matching coastlines, what conclusion can you draw?

Text Clues	Conclusions

4. **Critical Thinking** What planning is needed when constructing buildings at convergent or transform boundaries?
5. **Test Prep** **Which of the following is evidence that supports seafloor spreading?**
   - **A** changing magnetic fields in rock
   - **B** chains of crumpled mountains
   - **C** subduction of a plate
   - **D** transform boundaries
6. **Test Prep** **Which of the following does NOT form at a convergent boundary?**
   - **A** an ocean trench
   - **B** a mountain
   - **C** a volcano
   - **D** a mid-ocean ridge

Writing Link

Explanatory Writing

How do scientists map the seafloor? What kinds of equipment do they use? What information do they include in their maps? Write a report summarizing your findings.

Math Link

Calculate Seafloor Spreading

Scientists estimate that the seafloor can spread by about 3 cm each year. Calculate how long it would take for 1 km of new seafloor to be added.

What Is the Difference Between High and Low Elevations?

Earth is not all smooth and flat; it has areas that vary in elevation. Many mountain ranges are the result of the movement of tectonic plates. Some lower elevations, such as trenches and rifts, were also formed by tectonic-plate movements. Other low elevations, such as basins and valleys, resulted from extinct volcanoes.

Elevations are measured with both positive and negative integers. Knowing how to use integers can help you find the differences between high and low elevations on Earth.

Use Integers

To add or subtract integers, use these tips:

- Adding a negative number is the same as subtracting a positive number.

  $36 + (^{-}2) = 34$

- Subtracting a negative number is the same as adding a positive number.

  $36 - (^{-}2) = 38$

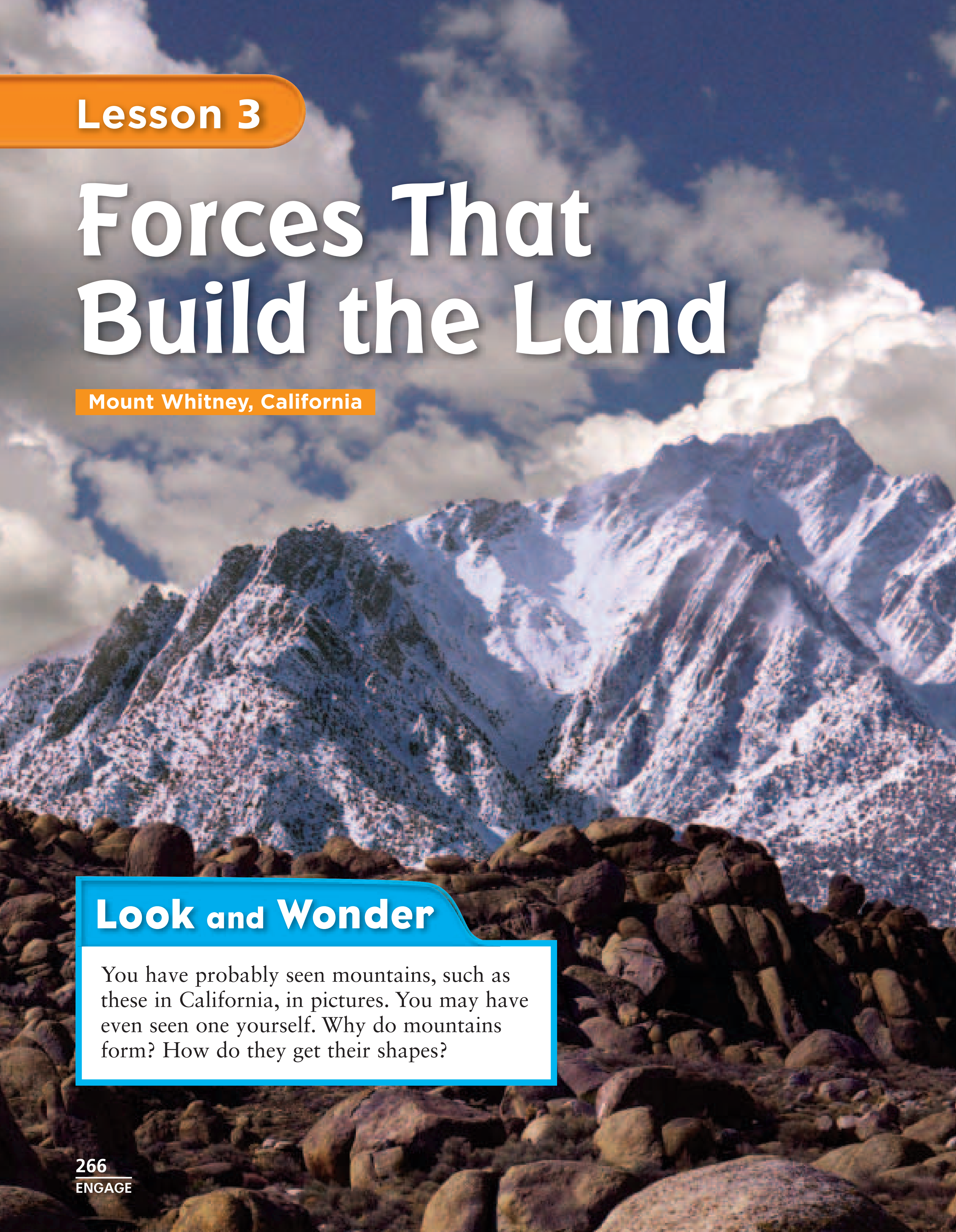
Death Valley

Mount Everest

Place	Elevation (in meters)	Elevation (in feet)
Mount Everest, Nepal/China	8,850	29,035
Mount McKinley, Alaska	6,194	20,320
Mount Hood, Oregon	3,426	11,239
Denver, Colorado	1,609	5,280
Mount Davis, Pennsylvania	979	3,213
Miami, Florida	0.91	3
Death Valley, California	−86	−282
Bentley Subglacial Trench, Antarctica	−2,555	−8,383

Solve It

1. What is the difference in elevation between Mount Hood and Death Valley in meters and feet?
2. What is the distance in meters and feet from the top of Mount Everest to the bottom of the Bentley Subglacial Trench?
3. Make up your own integer problem about elevation. Trade papers with a classmate, and solve each other's problem.



Lesson 3

Forces That Build the Land

Mount Whitney, California

Look and Wonder

You have probably seen mountains, such as these in California, in pictures. You may have even seen one yourself. Why do mountains form? How do they get their shapes?

Explore

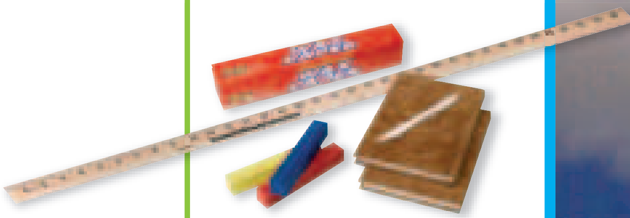
Inquiry Activity

How do mountains form?

Purpose

What happens when rock in Earth's crust moves? Make a model to demonstrate the results of pressure on layers of rock in Earth's crust.

Materials



- modeling clay
- metric ruler
- sheet of waxed paper
- 2 hardcover books (of similar thicknesses)
- plastic knife

Procedure

1. **Make a Model** Make three clay layers, each 15 cm square and 1 cm thick. Pile the layers like a sandwich, and gently push on the top so that the layers stick together. Place the layers in the center of the waxed paper.
2. **Observe** Place two books so that the spines touch opposite ends of the clay. Slowly and firmly push the books toward each other. Describe what happened. Flatten the clay.
3. **Observe** Use the knife to cut a "fault" across the clay at a 45-degree angle. Place the books so that the spines touch opposite ends of the clay. Slowly push the books toward each other again. Describe what happened. Flatten the clay.
4. **Observe** Move the books to the other sides of the clay. Slowly push the books in opposite directions along the "fault." Draw a picture of the layers.

Step 2

Step 3

Draw Conclusions

5. **Interpret Data** Your model represents forces on layers of Earth's crust. Which step modeled the formation of layers uplifted along a fault? Which step modeled folded mountains? Which step modeled movement without uplift? Explain your answers.

Explore More

How could you manipulate your model to demonstrate a fault where the layers on top of the fault move down and the others move up? On which side would the mountain form? Explain.

Read and Learn

Main Idea

Many landforms result from changes and movements in Earth's crust.

Vocabulary

fault, p. 268
focus, p. 270
aftershock, p. 270
seismic wave, p. 271
epicenter, p. 271
seismograph, p. 272
magnitude, p. 274
vent, p. 276

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Reading Skill

Infer

Clues	What I Know	What I Infer

Technology SCIENCE QUEST

Explore Earth's moving plates with a seismologist.

What forces change Earth's crust?

The forces that move continents can also change the continents' shapes. Plates slide past each other at transform boundaries, and the pieces of rock rub together. This force, called *shearing*, works like the blades of a pair of scissors and causes the rock to break. Plates collide at convergent boundaries. The force of this collision, called compression, squeezes the rock. At divergent boundaries, plates separate as new crust forms between them. The force of this separation is called *tension*. Tension makes the crust longer and thinner. When force exceeds the rock's strength, the rock breaks, forming a fault. A **fault** is a break or crack in the rock of the lithosphere along which movements take place. Faults are usually located along the boundaries between tectonic plates.

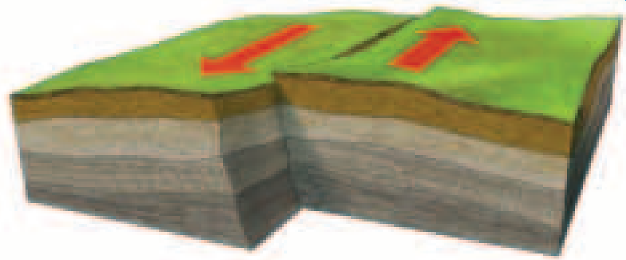
Three Kinds of Faults

Forces cause different kinds of faults. Shearing forms *strike-slip faults*. Tension produces normal faults. In a *normal fault*, the rock above the fault moves down. Look at the diagram on the next page. Can you see how this lengthens the rock layers? Compression produces reverse faults. In a *reverse fault*, the rock above the fault moves up.

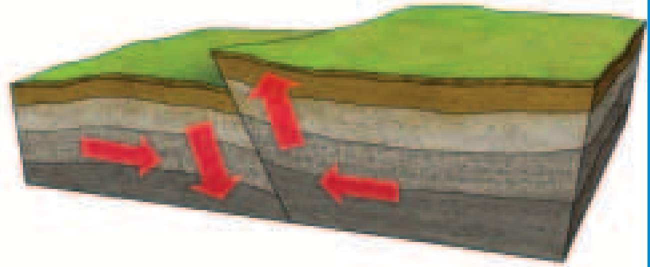
The Teton Range in Wyoming is made up of fault-block mountains.

Types of Faults

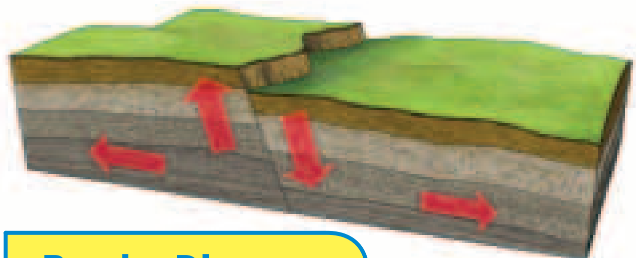
A **strike-slip fault** is produced at a transform boundary. The plates slide past each other without moving up or down. Slabs of rock move past each other in different directions. The San Andreas Fault is an example of a strike-slip fault.



A **reverse fault** is produced at a convergent boundary. The plates push together. Rock above the fault surface moves upward. The Himalayas in central Asia were formed at a reverse fault.



A **normal fault** is produced at a divergent boundary. The plates pull apart. Rock above the fault surface moves down. The Sierra Nevada in California were formed at a normal fault.



Read a Diagram

How does a reverse fault differ from a strike-slip fault?

Clue: Look for the arrows that illustrate plate movement.

Uplifted Landforms

Mountains form where plates push against each other. Sometimes the plates compress rock. Mountains made up mostly of rock layers folded by being squeezed together are *folded mountains*. At other times, the rock breaks. Mountains made by huge, tilted blocks of rock separated from the surrounding rock by faults are *fault-block mountains*.

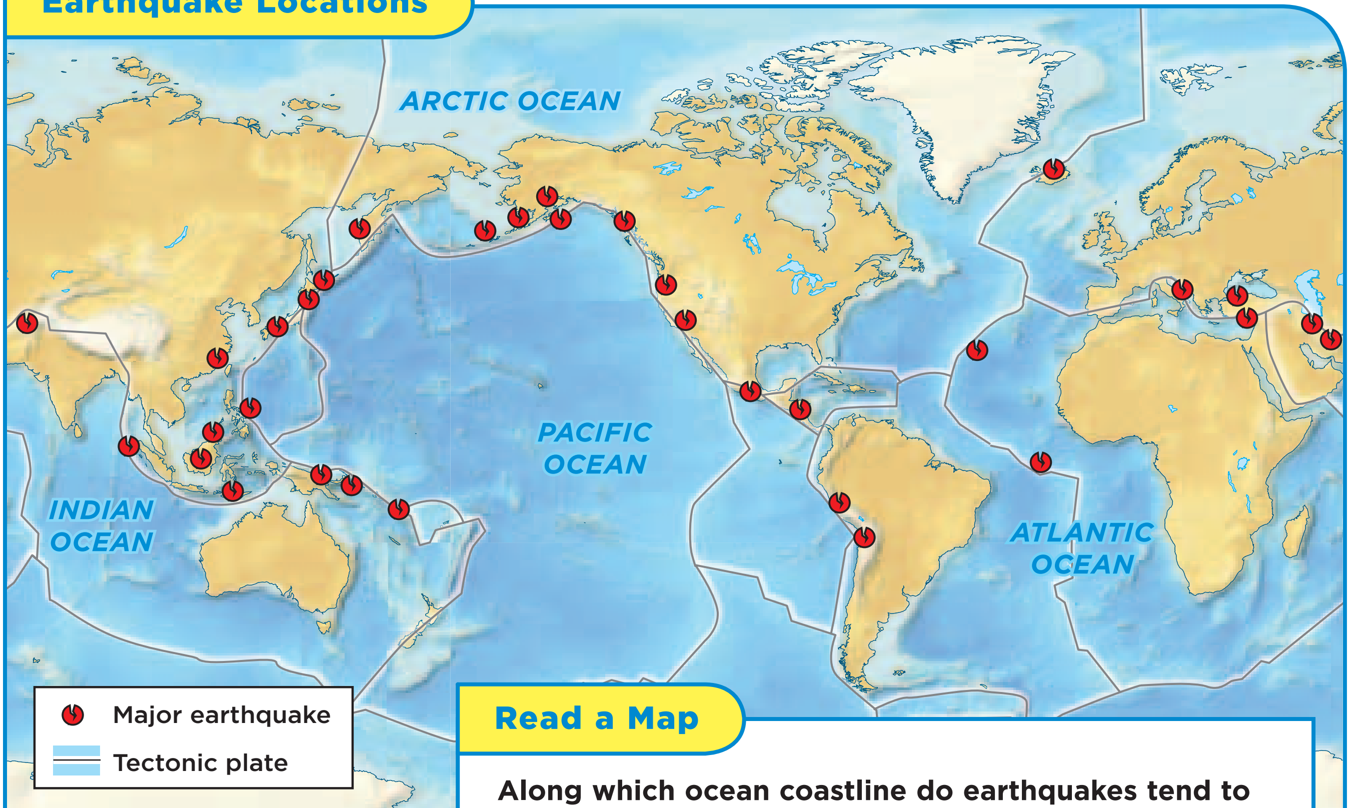
A large area of high, flat land that was formed by movement of Earth's crust is called a *plateau*. The Colorado Plateau formed when rock layers were pushed upward. The Colorado River, cutting through part of that region, eventually formed the Grand Canyon.

Quick Check

Infer Why are faults often produced along plate boundaries?

Critical Thinking Why do some mountains form as folded mountains and others form as fault-block mountains?

Earthquake Locations



Read a Map

Along which ocean coastline do earthquakes tend to occur closest to the shore?

Clue: Where are most of the earthquake icons located?

What are earthquakes?

Stretching a rubber band takes energy. When you stretch it past the breaking point, it snaps. This releases the energy you put into stretching it.

This rubber-band model helps explain an earthquake. Most earthquakes occur when the ground near tectonic plates shifts and changes position. Forces at plate boundaries stretch, push, and bend large sections of rock. Energy can build up in the rock for years or even decades. When the rock breaks or slips, energy is released, and Earth's crust moves.

Earthquakes can also occur away from plate boundaries. Here the condition of rocks and soil may cause movements and shifting that can produce earthquakes.

The point below the surface of Earth where an earthquake begins is called the **focus**. Many smaller earthquakes, called **aftershocks**, can follow a major earthquake. Aftershocks can be almost as strong as the original earthquake. They can continue for days, weeks, or months after the first earthquake.

FACT "Moonquakes" (earthquakes on the Moon) are far less frequent than those on Earth and are not as strong.

Earthquake Waves

The sudden movement of an earthquake causes rock to vibrate. A vibration that travels through Earth and is produced by an earthquake or volcanic eruption is called a **seismic wave** (SIGHZ•mik). Seismic waves spread out in all directions from an earthquake's focus. The location on the surface directly above the focus is called the **epicenter** (EP•i•sen•tuhr). People located at or near the epicenter are the first to feel the earthquake.

Quick Check

Infer Why do most earthquakes occur near or along a fault?

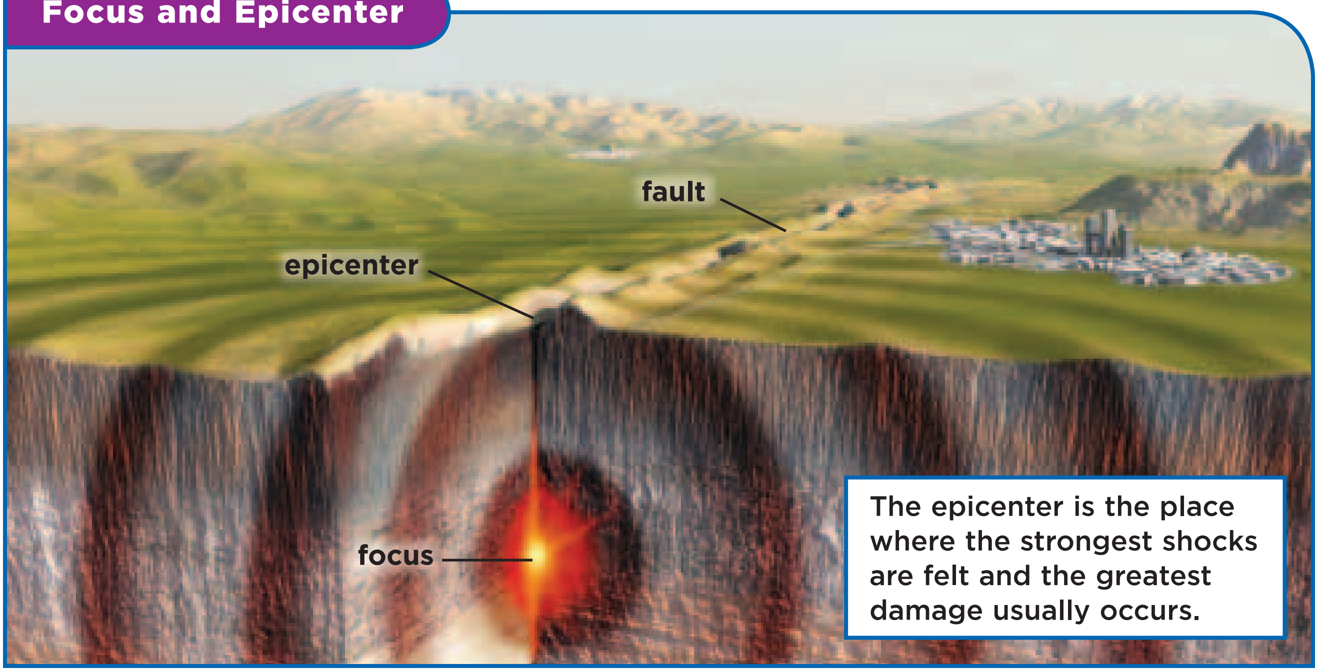
Critical Thinking Do all earthquakes occur at plate boundaries? How do you know?

Quick Lab

Making Mountains

1. **Make a Model** Place a sheet of aluminum foil on a flat surface such as a desk or table. Arrange some rocks and pebbles on the foil to represent various landforms.
2. **Experiment** Press your hands down flat on the edges of the foil. Slowly slide your hands closer together. Watch the surface of the foil carefully for any changes.
3. **Observe** What happens to the foil surface as your hands move? What happens to the rocks and pebbles representing various landforms?
4. **Infer** What would happen if you moved your hands faster or at different angles?

Focus and Epicenter



The epicenter is the place where the strongest shocks are felt and the greatest damage usually occurs.

What can we learn from seismographs?

Earthquakes cause different kinds of seismic waves. There are two main types of seismic waves: surface waves and body waves. Each type vibrates and travels in a different way and at a different speed.

Waves near Earth's surface are called surface waves. They are generally the most destructive type of seismic wave. They move more slowly than body waves and travel along the surface of Earth like ripples on a pond.

Body waves travel through the interior of Earth. There are two types of body waves: primary waves (P waves) and secondary waves (S waves).

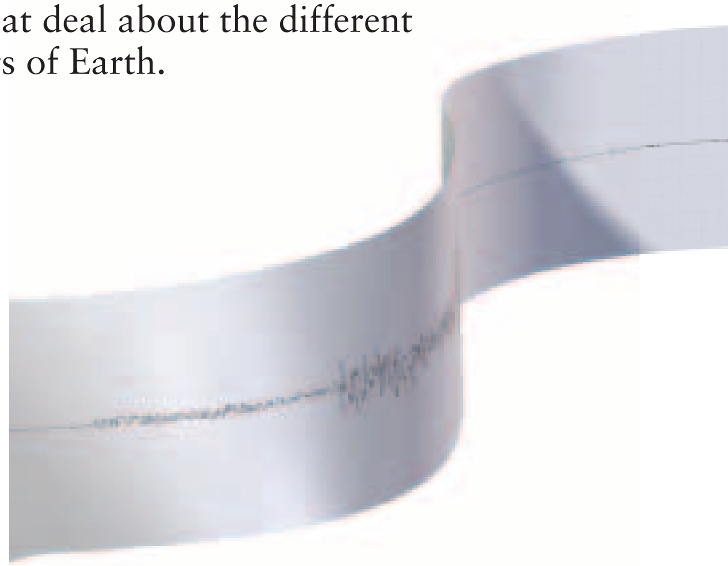
P waves are the fastest seismic waves. They travel through gases, liquids, and solids by pushing and pulling against the material they pass through.

When P waves push, they compress, or bunch up, the material. When P waves pull, they stretch or expand the material. This pushing and pulling causes the material to vibrate forward and backward in the direction in which the waves are moving. During an earthquake, P waves move in the same direction as the shaking rock.

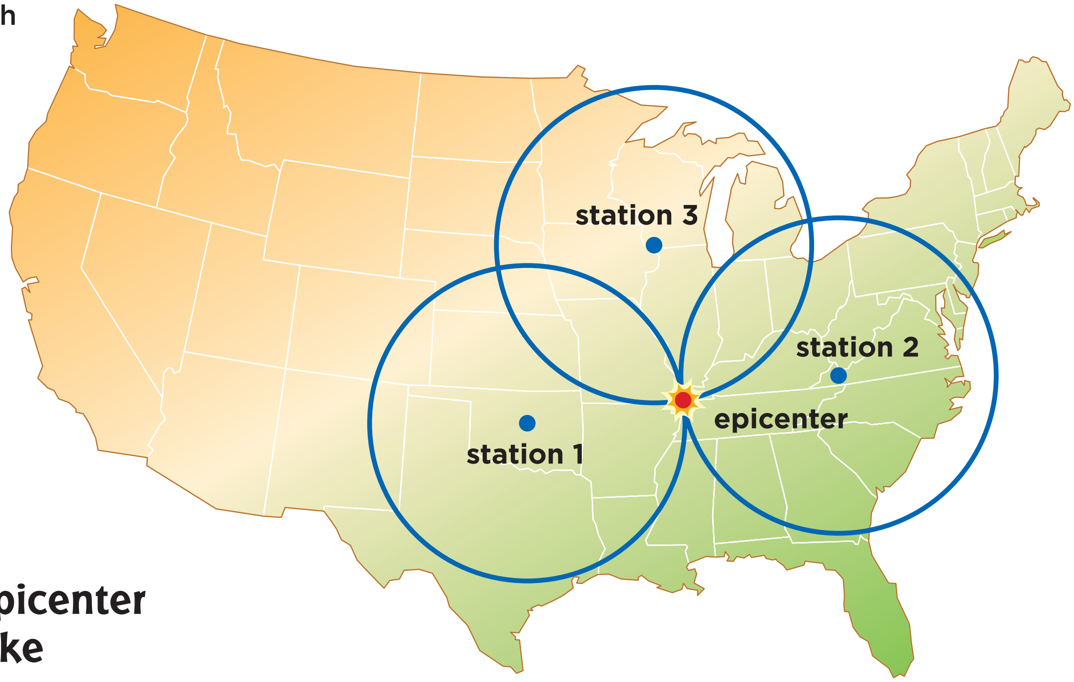
S waves are much slower than P waves and travel only through solids. If an S wave is moving ahead, the vibrations move either up and down or from side to side. This causes the material that the wave is passing through to shake up and down or from side to side. S waves vibrate at a right angle to their direction of travel.

Sensitive instruments on Earth's surface record these vibrations. A **seismograph** (SIGHZ•muh•graf) is an instrument that detects, measures, and records the energy of earthquake vibrations at a given location. Scientists can also use seismographs to find an earthquake's epicenter.

By using instruments such as these to study waves, scientists have learned a great deal about the different layers of Earth.



▶ The point at which all three circles come together is the epicenter of the earthquake.



Locating the Epicenter of an Earthquake

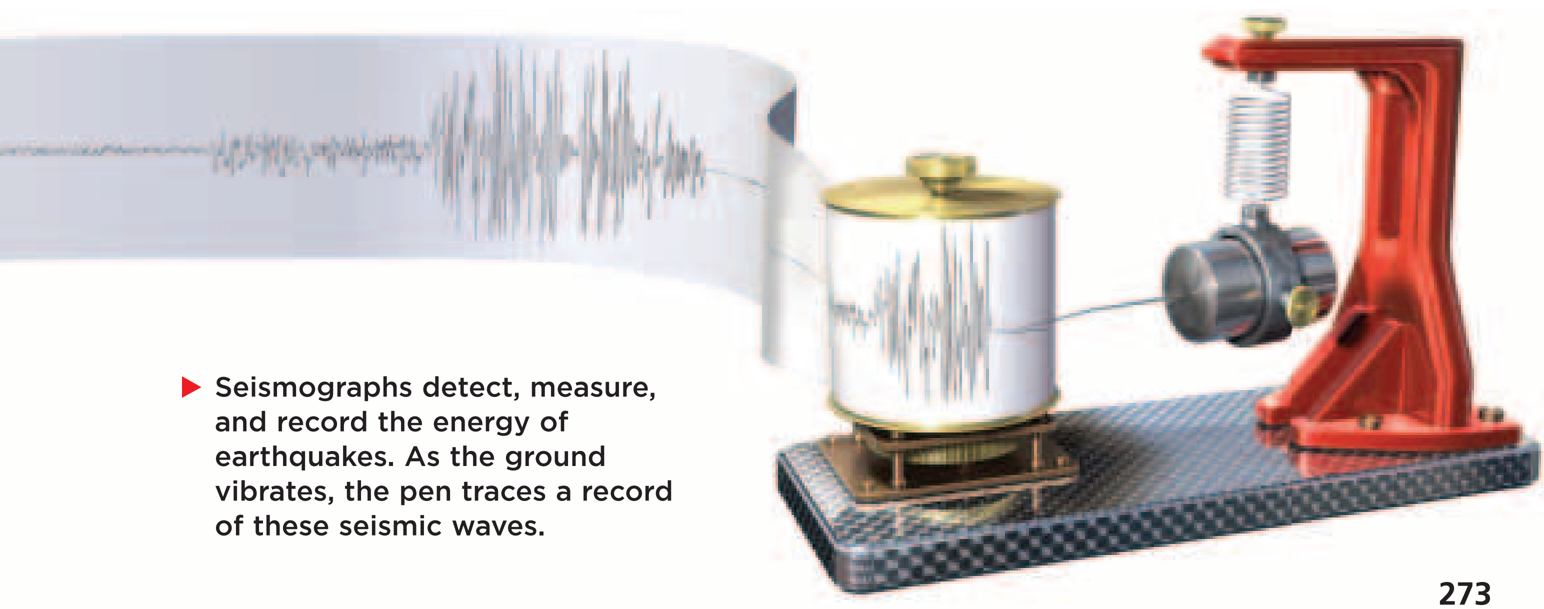
When an earthquake occurs, seismic waves move out in all directions. Scientists at seismograph stations measure how much time it takes for the waves to reach each station. This tells them only the distance from the station to where the earthquake occurred. It does not tell them the earthquake's location. To find the location, three stations are needed.

The distance is charted around each station in a circle. The point where the three circles intersect is the epicenter.

Quick Check

Infer Look at the waves plotted by the seismograph below. Which waves look as though they would be the most destructive?

Critical Thinking Why are three stations needed to locate the epicenter of an earthquake?



▶ Seismographs detect, measure, and record the energy of earthquakes. As the ground vibrates, the pen traces a record of these seismic waves.

How destructive is an earthquake?

In October 2005, an earthquake caused great damage to parts of Pakistan and India. Where will the next earthquake happen? How powerful can earthquakes be?

The height of a wave on a seismograph indicates the **magnitude**, or the measure of the energy released during an earthquake. The strength of an earthquake can be measured in several ways. One measure is magnitude, and another is the extent of damage in an area.

Two Measures of Earthquakes

The Richter (RIK•tuhr) scale is a set of numbers that describes an earthquake's magnitude on a scale of 1 to 10. An increase of 1 on the scale means a tenfold increase in magnitude.

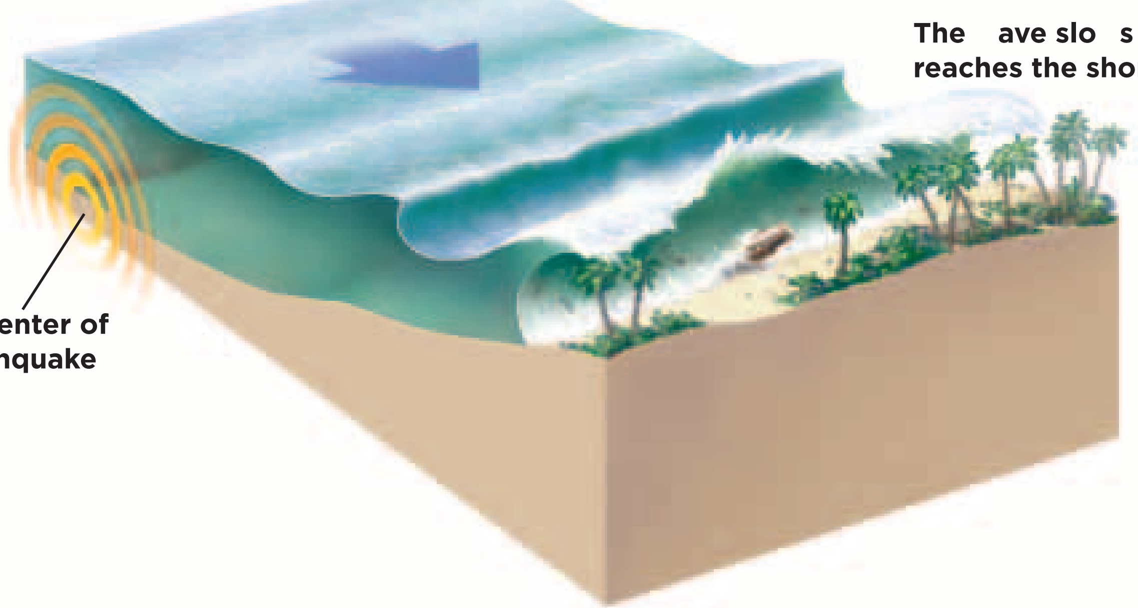
The strength of an earthquake can also be measured by its *intensity*, or the strength as it is felt on Earth's surface. The Mercalli (mer•KAH•lee) scale rates what people feel and observe when an earthquake occurs. It is based on observed effects, not on mathematics. Because of this difference, the Mercalli scale is less reliable than the Richter scale.

Tsunamis

In December 2004, an earthquake in the Indian Ocean launched a *tsunami* (tsew•NAH•mee), a series of huge waves caused by an earthquake or volcanic eruption beneath the ocean floor. The tsunami broke over the coasts of several nations. It caused extensive damage and loss of life.

Water in a tsunami moves away from the epicenter of the earthquake in all directions. Tsunamis have long wavelengths and low amplitudes, or wave heights. The speed of a tsunami depends on the depth of the water.

How a Tsunami Moves Across the Ocean



Summary of the Richter Scale

Magnitude	Description
1–2+	recorded on local seismographs but not generally felt
3–4+	often felt, no damage
5+	widely felt, slight damage near epicenter
6+	damage to poorly constructed buildings and other structures within tens of kilometers of epicenter
7+	"major" earthquake, serious damage within up to 100 km (60 mi) of epicenter
8+	"great" earthquake, great destruction and loss of life in areas more than 100 km (60 mi) from epicenter
9+	"rare great" earthquake, major damage over a large region more than 1,000 km (600 mi) from epicenter

Summary of the Mercalli Scale

Intensity	Description
II	felt by people at rest or in places more favorable to sensing tremors
IV	felt indoors and outdoors; similar to vibrations of passing trucks; windows, doors, and dishes rattle
VI	felt by almost everyone, walking is unsteady, pictures fall off walls, furniture may move or fall over
VIII	walls may collapse, monuments may fall
X	most buildings are destroyed, large landslides occur, train tracks are bent slightly
XII	nearly total damage, objects are thrown into the air, some landforms are moved

In the open ocean, tsunamis move at speeds of 500 to 1,000 kilometers (300 to 600 miles) per hour. However, a tsunami slows down as it approaches a shore. The length of each wave decreases, but the height increases. The water piles up, and it is often pulled away from the coastline as the tsunami approaches land. Finally, the tsunami crashes onto the shore as a giant wall of water. Fortunately, most earthquakes do not cause tsunamis.

Protecting Against Earthquake Hazards

There is no way in which people can prevent earthquakes. However, we can help protect ourselves against the damage they can cause. For example, scientists design some buildings in earthquake-prone areas with "shock absorbers" to minimize the damage caused by seismic waves. Also, many highways in these areas are supported by special, reinforced columns.

Earthquake-Safety Steps

- Assemble an emergency kit with a flashlight, a radio, and first-aid supplies.
- Make an emergency escape plan for moving away from dangerous surroundings.
- If you live on the coastline, know the route to higher elevations farther inland.
- If an earthquake strikes, stay away from windows.

Quick Check

Infer During an earthquake, a refrigerator moves, and pictures fall off the wall. How strong is the earthquake?

Critical Thinking Why is it useful to have two scales for measuring earthquakes?

How do volcanoes form?

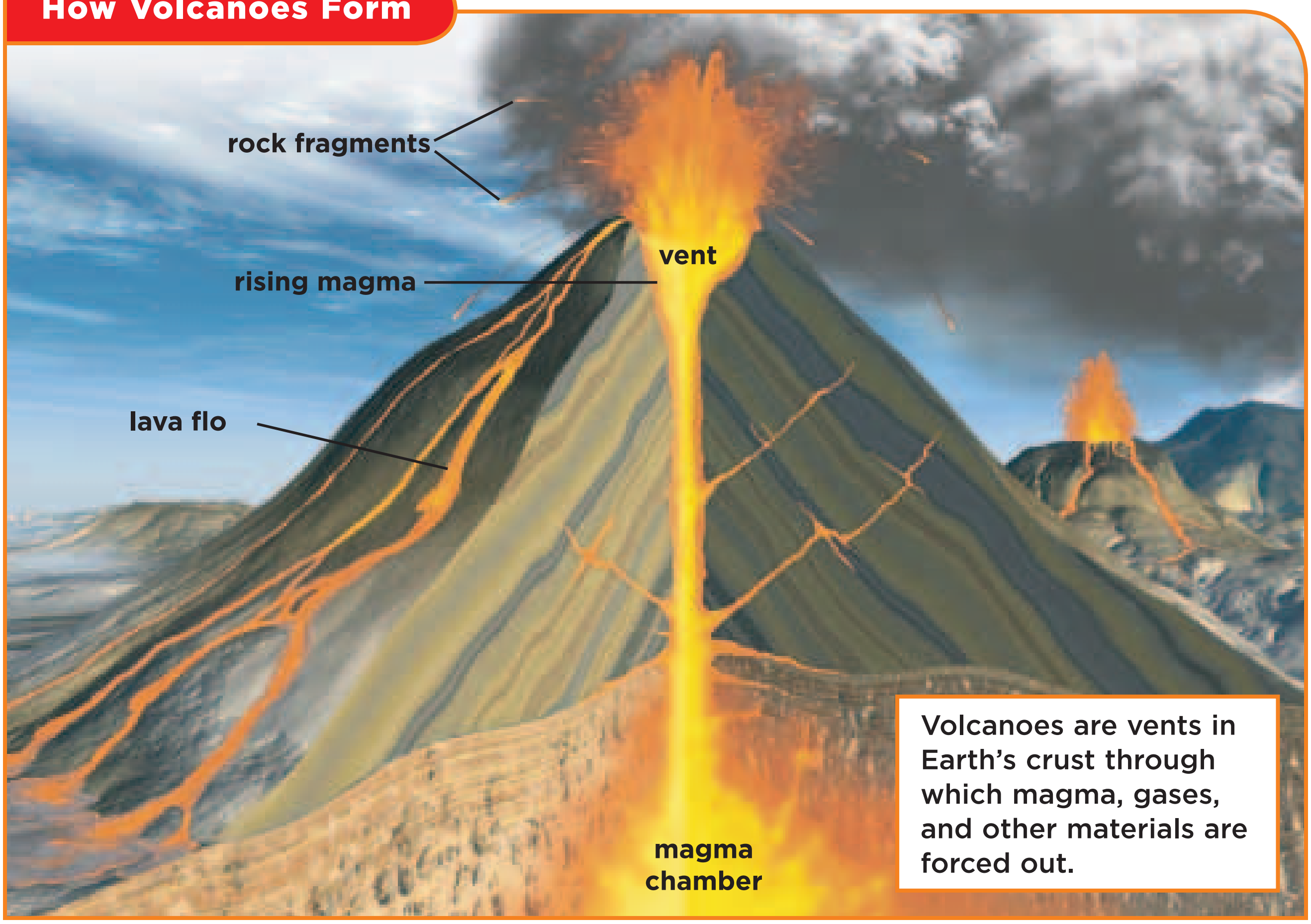
Volcanoes are formed by powerful forces within Earth. As one crustal plate moves under another, the rock in the mantle and lower crust melts and becomes magma. Melting rock produces gases that mix with magma. Over time, the gas-filled magma rises, because it is less dense than the solid rock around it. Rising magma can build up in a weak part of overlying rock, forming a magma chamber. *Magma chambers* are the reservoirs from which volcanic materials erupt.

When magma reaches the surface, it erupts through a central opening called a **vent**. Once magma reaches the surface, it is called lava. After eruptions, lava cools and hardens, forming a mound. After many eruptions, this mound can grow. A *crater* is the space around the vent at the top of a volcano.

Some volcanoes are located in the middle of a plate. Scientists believe these volcanoes form over a hot spot, a very hot part of the mantle. As a plate moves over a hot spot, rising plumes of magma break through. The Hawaiian Islands were formed as the Pacific Plate moved over a hot spot.

Most volcanic eruptions, like most earthquakes, occur along the boundaries between shifting plates. Volcanoes and earthquakes change the surface of Earth in ways that we can immediately see.

How Volcanoes Form



Volcanoes are vents in Earth's crust through which magma, gases, and other materials are forced out.

Types of Volcanoes

There are three main kinds of landforms produced by volcanic eruptions. One kind is a *cinder cone volcano*, a landform mainly made up of small rock particles, or cinders. As erupting lava shoots into the air, it breaks into small pieces. These fragments cool and harden as they fall back to the ground. The fragments pile around the vent, forming a cone with steep sides.

A second kind of volcanic landform is a *shield volcano*, a landform made up of many layers of rock. As fluid lava flows out to the surface from a vent, it spreads out in all directions, cools, and hardens into rock. Successive layers of lava rock build up to form a volcano with broad, gently sloping sides that resemble a shield carried by ancient warriors.

The third kind of volcanic landform is a *composite volcano*, a landform made up of layers of thick lava flows alternating with layers of ash, cinders, and rocks. These layers form a symmetrical cone with steep sides that are concave, or curving inward.

Sometimes a volcano's crater collapses into the vent. This forms a very wide crater called a *caldera* (kal•DER•uh).

Volcanoes that have erupted recently are active volcanoes. Some volcanoes are dormant, or sleeping. They have not erupted for a long time, but they have erupted in recorded history. If a volcano has never been observed to erupt, it is said to be extinct.

Quick Check

Infer Why do shield volcanoes take a long time to form?

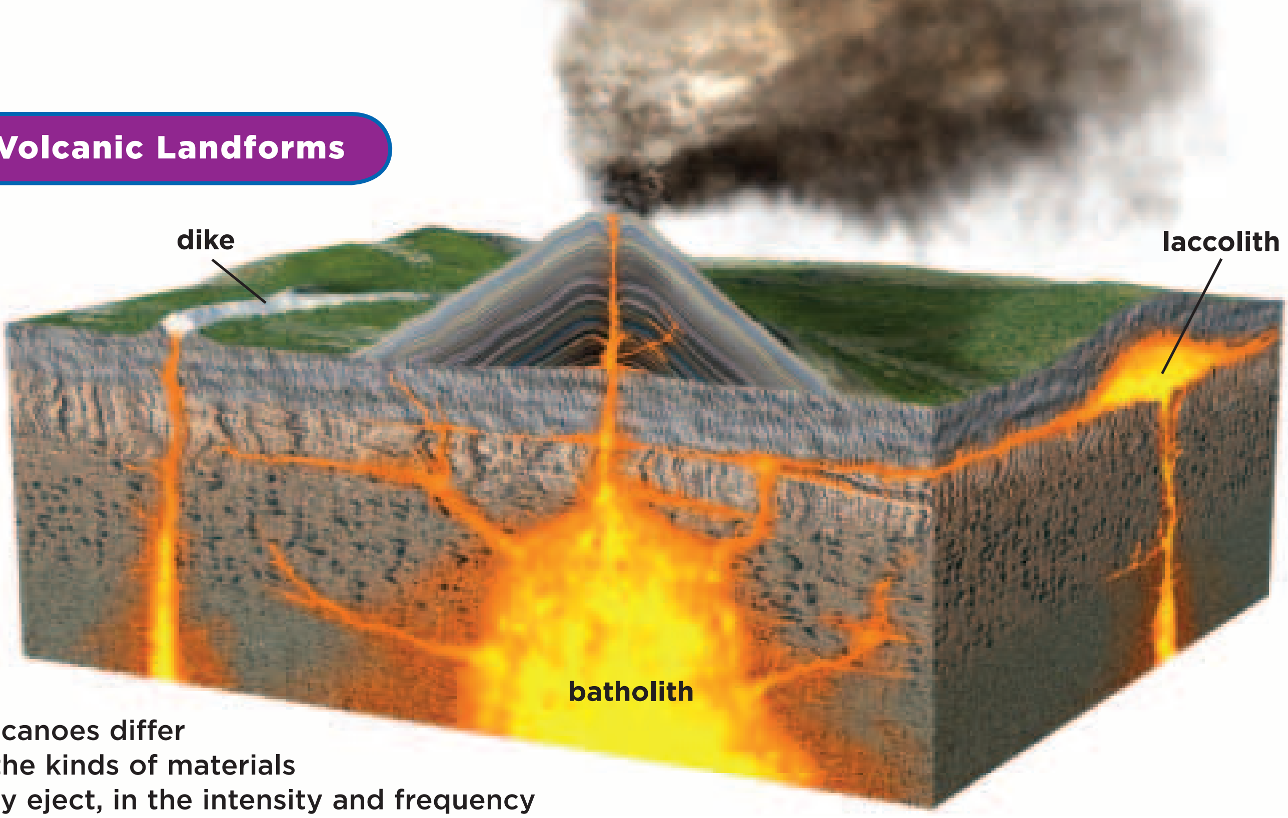
Critical Thinking Why do volcanoes at hot spots eventually become extinct?

▲ Mt. Capulin in New Mexico, a cinder cone volcano

▲ Hawaii's Mauna Loa, a shield volcano

▲ Italy's Stromboli, a composite volcano

Volcanic Landforms



Volcanoes differ in the kinds of materials they eject, in the intensity and frequency of eruptions, and in the types of landforms that result.

What are other volcanic landforms?

A string of island volcanoes, or an *island arc*, can form where one oceanic plate is driven under another. Part of the sinking plate melts, and magma moves up through the crust along a line parallel to where the plates meet. The Aleutian Islands and the Philippine Islands are volcanic island arcs. Where plates move apart, volcanoes can form at gaps along the plates' edges. These volcanic landforms are called *rift volcanoes*.

Magma can affect many land features. When magma rises, it pushes against rock layers above it. This can form a large, dome-shaped structure. Weathering and erosion can then strip away the warped layers, exposing the volcanic rock beneath. The Black Hills of South Dakota are *dome mountains*. If magma hardens in vertical cracks across horizontal layers, a *dike* forms.

When the rocks around a dike are worn away, the dike looks like a long ridge. When magma hardens between horizontal layers of rock, a flat *sill* is formed. Sometimes, a sill's magma is thick and does not spread out very far horizontally. Instead, it pushes upward. This forms a dome-shaped laccolith (LA•kuh•lith). The largest and deepest magma formation is a batholith (BA•thuh•lith). Batholiths are large pockets of magma that reach deep into the crust.

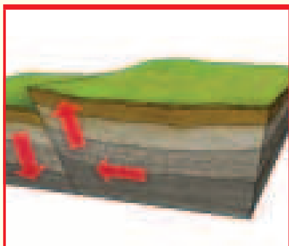
Quick Check

Infer Why do so many island chains and island arcs form in the Pacific Ocean?

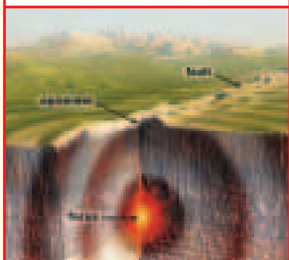
Critical Thinking What is the relationship between active volcanoes and earthquakes?

Lesson Review

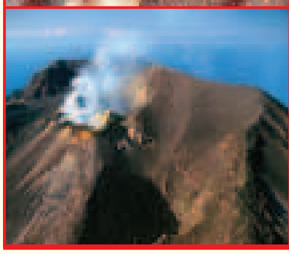
Visual Summary



Faults are breaks or cracks in rock that normally form at plate boundaries.



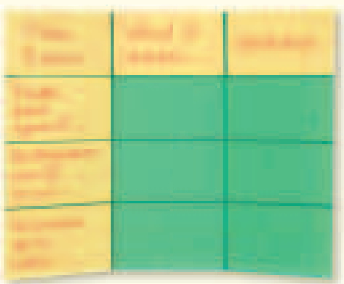
Earthquakes usually occur at plate boundaries. Seismographs help locate and measure earthquakes.



Volcanoes form when magma breaks through the crust.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the phrases, and include a sketch or diagram that summarizes each example of Earth's forces.



Think, Talk, and Write

1. **Main Idea** What kinds of landforms can result from movements in the crust?
2. **Vocabulary** The point on Earth's surface directly above an earthquake's focus is called the ________.
3. **Infer** Why do most earthquakes and volcanic eruptions occur along plate boundaries?

Clues	What I Know	What I Infer

4. **Critical Thinking** Why might seismic waves from the same earthquake damage one area more than another?
5. **Test Prep** **Which is NOT a part of a volcano?**
   A magma chamber
   B vent
   C crater
   D inner core
6. **Test Prep** **Which of the following does NOT cause an earthquake?**
   A lava moving to the top of a volcano
   B water penetrating Earth's surface
   C motion along breaks in Earth's crust
   D high temperatures in Earth's inner core

Writing Link

Persuasive Writing

A scientist warns that a nearby volcano shows signs of becoming active. Write a speech for your community telling citizens the best way that they can protect themselves from danger.

Math Link

Calculate Volcanoes

Alaska has about 40 active volcanoes, or about 8 percent of all the active volcanoes on Earth. Calculate how many active volcanoes there are on Earth.

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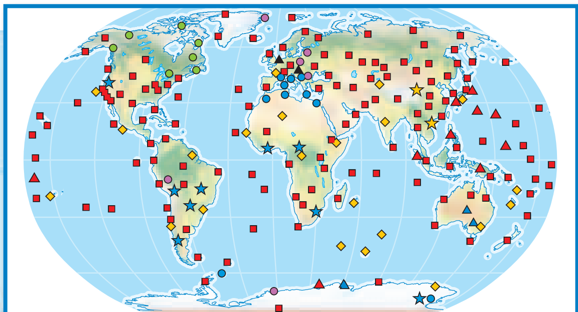
QUAKE PREDICTORS

Scientists have a good idea of where earthquakes will happen, but it is much more difficult to predict when an earthquake will occur. By developing more advanced tools, scientists have become better at understanding and predicting quakes. Today, anyone can gather real-time seismic data by using the Internet, which gives scientists and the public a continuous, global view of Earth's earthquake activity.



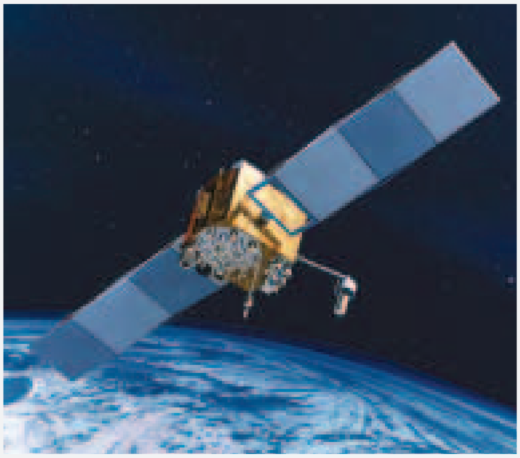
▲ GSN stations operated by different countries record seismic activity.

1870s **1961**

1870s Tracking Earthquakes from the Ground
Geophysicist John Milne experiences earthquakes firsthand in Japan. He knows that there must be a way to measure the vibrations of Earth's crust during an earthquake. He works with a team of scientists to create a new tool that can detect different types of earthquake waves and estimate their speeds. It is the first seismometer. By 1913, seismometers are placed in 40 earthquake observatories around the world.

1961 Organizing Earthquake Information
The World-Wide Standardized Seismic Network (WWSSN) is established. Scientists all over the globe can now share information to monitor both earthquakes and nuclear testing. Today the WWSSN continues as the Global Seismic Network (GSN), consisting of 128 permanent seismic recording stations spread out evenly over Earth's surface.

2001 Tracking Earthquakes and Plate Motions from Space
The Southern California Integrated GPS Network (SCIGN) uses Global Positioning System (GPS) technology to track the movement of the North American and Pacific plates. This enables scientists to get accurate information about the shifting of plates during an earthquake. GPS includes a group of satellites that send signals used to calculate the precise position of receivers on the ground. The same system is used to give driving directions in some cars.



2003 Computer Modeling
Scientists at NASA's Jet Propulsion Laboratory develop computer models of the San Andreas fault system. Data from SCIGN is entered into these models to help scientists understand earthquakes that occur. In a decade, these models may be able to forecast some types of earthquakes with far greater accuracy.

2001 **2003**

Write About It

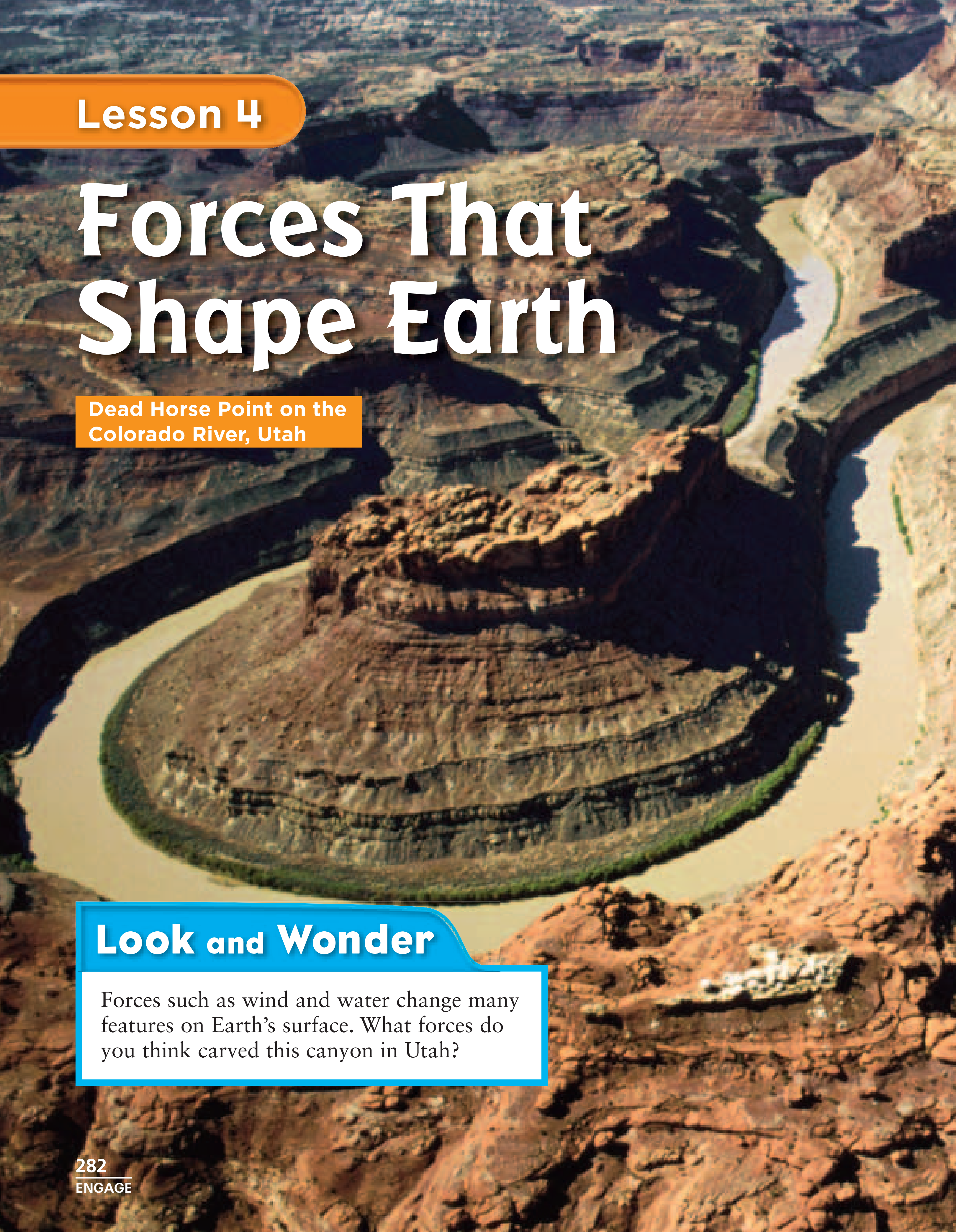
Draw Conclusions

1. Before the invention of the seismometer, how do you think people measured earthquakes?
2. Why are satellites such a useful source of information about movement on Earth's surface?

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Draw Conclusions

- Review the facts and details.
- Think about what they suggest about the topic.



Lesson 4

Forces That Shape Earth

Dead Horse Point on the Colorado River, Utah

Look and Wonder

Forces such as wind and water change many features on Earth's surface. What forces do you think carved this canyon in Utah?

Explore

Inquiry Activity

How does the steepness of a slope affect stream erosion?

Form a Hypothesis

A stream causes erosion by carrying sediment and other materials away. Do you think a stream in a steep streambed causes more erosion than a stream in a more level streambed? Write your answer in the form of a hypothesis: "If a streambed is steeper, then . . ."

Test Your Hypothesis

1. Make a model of a streambed by filling the aluminum pan with the mixture of sand, gravel, and pebbles. Place a single book or wood block under one end of the model.
2. Use the watering can to pour a thin stream of water down the middle of your model. Be sure to pour the water in a steady flow. Describe what happens.
3. Smooth out the streambed, and use books or wood blocks to prop up one end of the pan and make the streambed slightly steeper. Repeat step 2, using the same amount of water. Describe what happens.

Draw Conclusions

4. **Interpret Data** Organize your data in a chart. Did your observations support your hypothesis?
5. **Infer** What would happen if you made the streambed even steeper? Form a hypothesis, and then test it.

Explore More

What would happen if you used soil-supporting vegetation, such as grass, in your model? What if you made the river carry a larger volume of water? Form a hypothesis, test it, and then share your results.

Materials

- aluminum pan
- mixture of sand, gravel, and pebbles
- books or wood blocks
- small watering can

Step 2

Read and Learn

Main Idea
Several forces cause changes to Earth's surface over time.

Vocabulary
weathering, p. 284
erosion, p. 286
deposition, p. 286
sediment, p. 286
mass wasting, p. 287
till, p. 289
moraine, p. 289
soil, p. 290
humus, p. 290

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Reading Skill
Sequence

First → Next → Last

What is weathering?

Forces within Earth build up the crust into mountains, plateaus, and other landforms. At the same time, processes such as weathering break down the crust. **Weathering** is the breaking down of rock into smaller pieces by natural processes.

Physical Weathering

Physical weathering (also called mechanical weathering) is the breaking down of rock by physical changes. It can be caused by freezing water, moving water, plants, or animals.

Frost wedging occurs when water seeps into a crack in rock and freezes. The freezing water expands and forces the rock apart. When the ice melts, water seeps deeper into the crack. Eventually the rock breaks into smaller pieces.

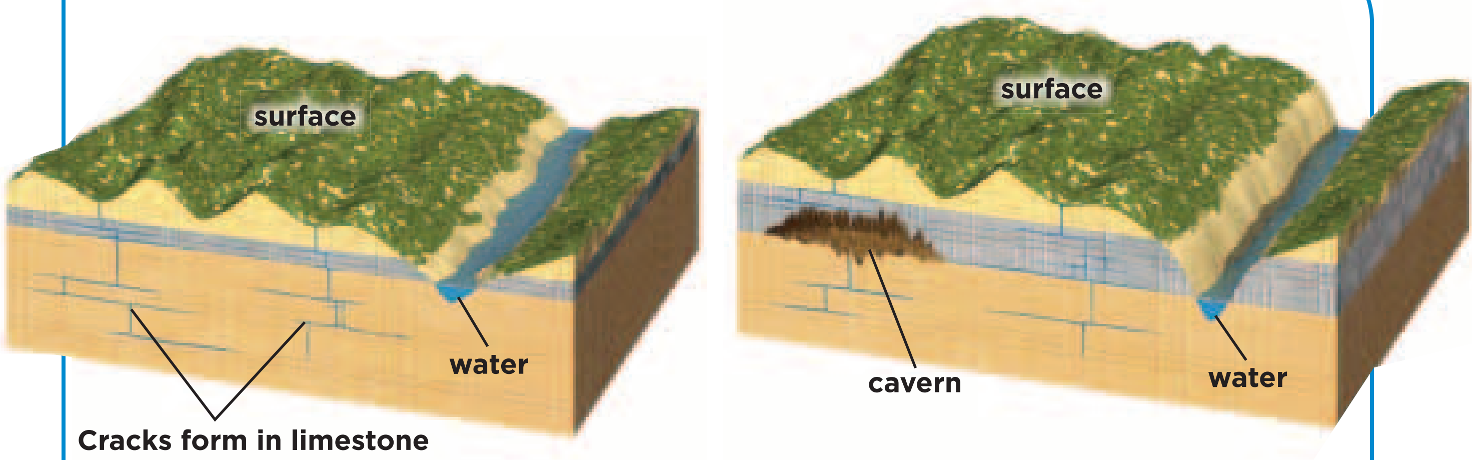
Moving water carries pieces of rock. The water churns and splashes as it moves through rapids or along shores. Pieces of rock carried by the water collide and break apart.

Plant roots can enter cracks in rock. As the roots grow, they force the cracks to widen. Eventually, this force may be enough to break the rock.

Animals indirectly cause weathering. Burrowing animals such as ants, worms, and moles bring rock pieces to the surface and expose them to weathering.

▼ Weathering agents can be either nonliving or living in origin.

Cavern Formation



Carbonic acid in water reacts with limestone underground. The product of this reaction dissolves in groundwater and is carried away. Eventually, a cavern forms. When the level of groundwater lowers, the cavern drains. This is an example of chemical weathering.

Read a Diagram

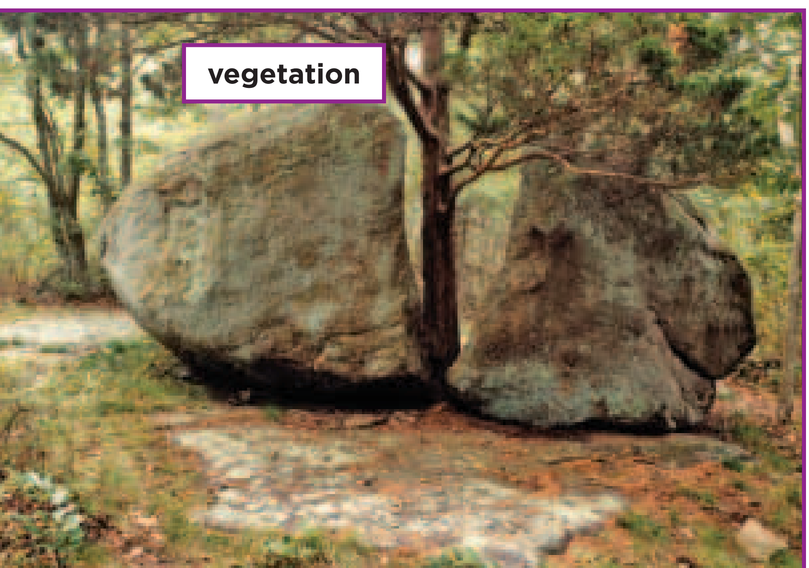
How does a cavern form?

Clue: Follow the path the water takes as it seeps through the soil.

Chemical Weathering

Some forces that cause weathering are chemical in nature. *Chemical weathering* is the breaking down of rock by changes in its chemical composition. Oxygen and acids are powerful agents of chemical weathering.

Air contains oxygen, and many types of rock contain iron. When rock that contains iron is exposed to air and water, a chemical reaction occurs. Oxygen combines with the iron in the rock and forms rust. The rusty rock is not as hard as the original rock was, so it breaks apart more easily.



When carbon dioxide in air dissolves in rainwater, it forms carbonic acid, a weak acid. Carbonic acid chemically reacts with limestone. If water with carbonic acid in it seeps into ground that contains limestone, the limestone dissolves in the water and is then carried away. In time, this process can eventually form a cavern.

Quick Check

Sequence Describe the steps that occur when freezing water breaks down rock.

Critical Thinking How do chemical changes produce weathering?

▲ Wind and water can carve soft rock into different shapes, such as these delicate arches in Arches National Park in Utah.

Which forces carry and drop?

Some forces shape Earth's surface by moving materials from place to place. **Erosion** is the picking up and removing of rock pieces and other particles. Particles moved by erosion usually end up in a different place. **Deposition** is the dropping off of particles in another location.

Wind contributes to the erosion and deposition that help change the land. Wind may pick up tiny rock fragments formed by weathering. When the wind slows, the particles fall to the ground.

Wind also can shape the land by building sand into dunes. Wind blows sand particles over the tops of dunes. The dunes change shape as the wind pushes them, making formations called drifts. Some sand dunes help protect the land behind them from damage by wind and rain during a storm.

Water can also erode the land, producing unique landforms. Bryce Canyon National Park and Arches National Park, both in Utah, show how freezing and thawing can affect the landscape. Water from infrequent rain and melting snow carries away weathered rock. Softer rock weathers and erodes faster than harder rock. Over time, the remaining rock may take the shape of columns, arches, or other formations.

Flowing Water

Water is a major cause of erosion. Moving water carries particles as it flows downhill. The faster a river flows, the larger the particles it can carry. Large particles roll, slide, or bounce along the bottom and dig into the riverbed, making the river deeper. When the river slows down, some of the particles are deposited as **sediment**, or loose pieces of minerals, rock, and organic material. The sediment forms a barrier in the river, and water then flows around the sediment.

Deposition can change the course of a river and cause the river to turn, or meander (mee•AN•duhr). Meandering occurs in rivers with shallow slopes and slow-moving water. Rivers with steep slopes are usually straighter and flow more swiftly.

At the seashore, some waves cause erosion. Gentle waves tend to carry sand back to the beach. However, as strong waves recede, they carry sand off the beach and deposit it farther offshore. Over time, a sandy beach may disappear completely. Beaches usually erode slowly. However, a severe storm can erode a beach within only a few hours.

Two other agents of erosion are gravity and glaciers. Earth's gravity pulls materials from high places to low places. This downhill movement, called **mass wasting**, can happen slowly. After an earthquake or a heavy rain, it can happen quickly. Glaciers move over the land like huge, slow bulldozers. As they travel, they scrape and push rocks and soil in front of them and to their sides.

Quick Lab

Layering Sediments

1. Fill a jar halfway with a mixture of soil, sand, and gravel. Then fill it to the top with water. Allow the water to soak into the mixture. Screw the lid of the jar on tight.

2. Predict what will happen if the materials in the jar are shaken and then allowed to settle. Draw a picture showing your prediction.
3. Shake the jar for 10 seconds. Place the jar on a table. Observe the results.
4. **Interpret Data** Compare your observations to your prediction. Which layer formed first? Which formed last? Explain your observations.

Quick Check

Sequence Explain the steps in the formation of a sand dune.

Critical Thinking What will eventually happen to every arch in Arches National Park? Explain.

How can moving water change the land?

A river flowing from a high elevation can make dramatic changes to the land. As a river travels, it carves a channel. The flowing water slowly erodes the riverbed, cutting through softer layers of rock over long periods of time. Deep canyons, streams, and valleys are formed by moving water.

Sediment is transported downhill, causing additional erosion and making more cuts in the bedrock. Eventually, the sediment reaches the sea and is then deposited offshore.

How Glaciers Form

Glaciers form when more snow falls in winter than melts in summer. Over the years, the snow builds up. The weight of the new snow squeezes the snow underneath, causing it to change to ice. When the ice sheet is about 100 meters (328 feet) thick, it begins to flow downhill because of its weight.

Glaciers that form over a wide area can join and become a continental glacier. When a continental glacier reaches the edge of a continent, the ice breaks off and forms icebergs.

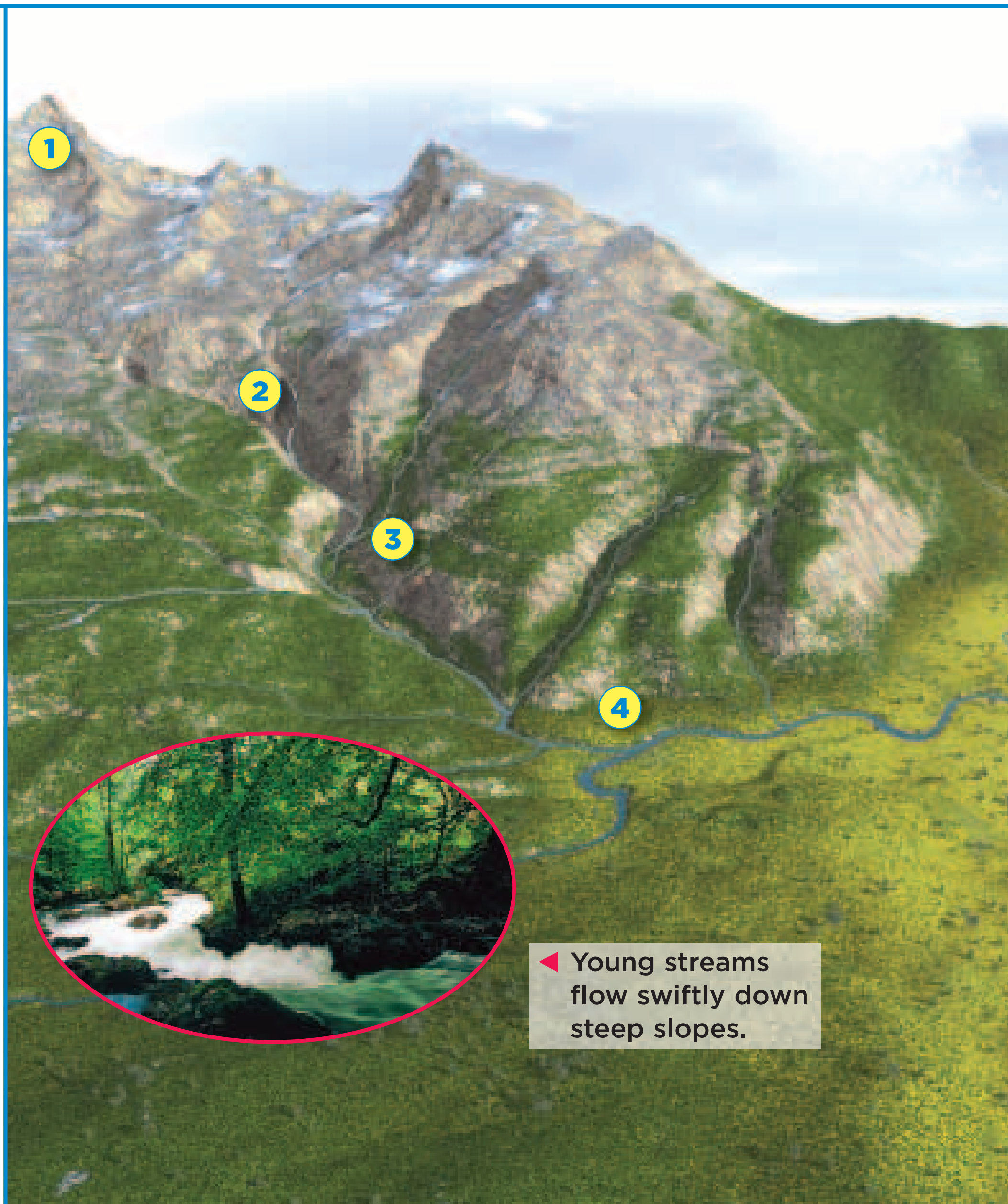
The Life of a Stream

In common usage we say that a river has more water than a stream. However, scientists consider all rivers to be streams, and all streams go through similar stages of development.

1. The *source* of a stream is often in a mountainous area. Here the force of gravity causes water to flow quickly. Some streams flow from springs, lakes, or the ends of glaciers.

2. The fast-flowing stream picks up and carries a great deal of sediment and often carves out V-shaped valleys. Fast-moving streams are often used for rafting.

3. As the smaller stream flows downhill, it collects more water, increasing in size and straightening out the valley.



◀ Young streams flow swiftly down steep slopes.

Moving and Melting Glaciers

Glaciers can change the land as they move. They can transport rocks and deposit them in new areas. Glaciers can also change the ground beneath their path and carve into the land. If a glacier moves through a narrow valley, it digs deeply into the valley's walls and base, changing the valley's shape from a V shape to a U shape.

When glaciers move, rocks and other substances carried by the glacier are deposited as a mixture called **till**. As a glacier melts, till is deposited in front of or along the sides of the glacier. These deposits often take the form of a ridge or mound, called a **moraine** (muh•RAYN). As the glacier melts more, a moraine may act like a dam, causing the area the glacier dug into the land to fill with water. The Great Lakes were formed in this way.

Quick Check

Sequence Describe the process by which glaciers form.

Critical Thinking How does gravity affect stream erosion?

▼ A slow, meandering river may flow at a rate of less than 1 kilometer (0.6 miles) per hour.

4 As the river reaches flatter land, it slows down. As it slows, it deposits some of the sediment it has carried.

5 The slow-moving river meanders across flat land, forming large curves. Water flows faster along the outside of a curve, eroding or wearing away the bank.

6 When a river empties into a larger body of water such as an ocean or a bay, it deposits the remaining sediment it has carried. These deposits can form a delta that extends from the river's mouth.

Read a Diagram

Describe how water flows from a river's source to its mouth.

Clue: Follow the course of the river from start to finish.

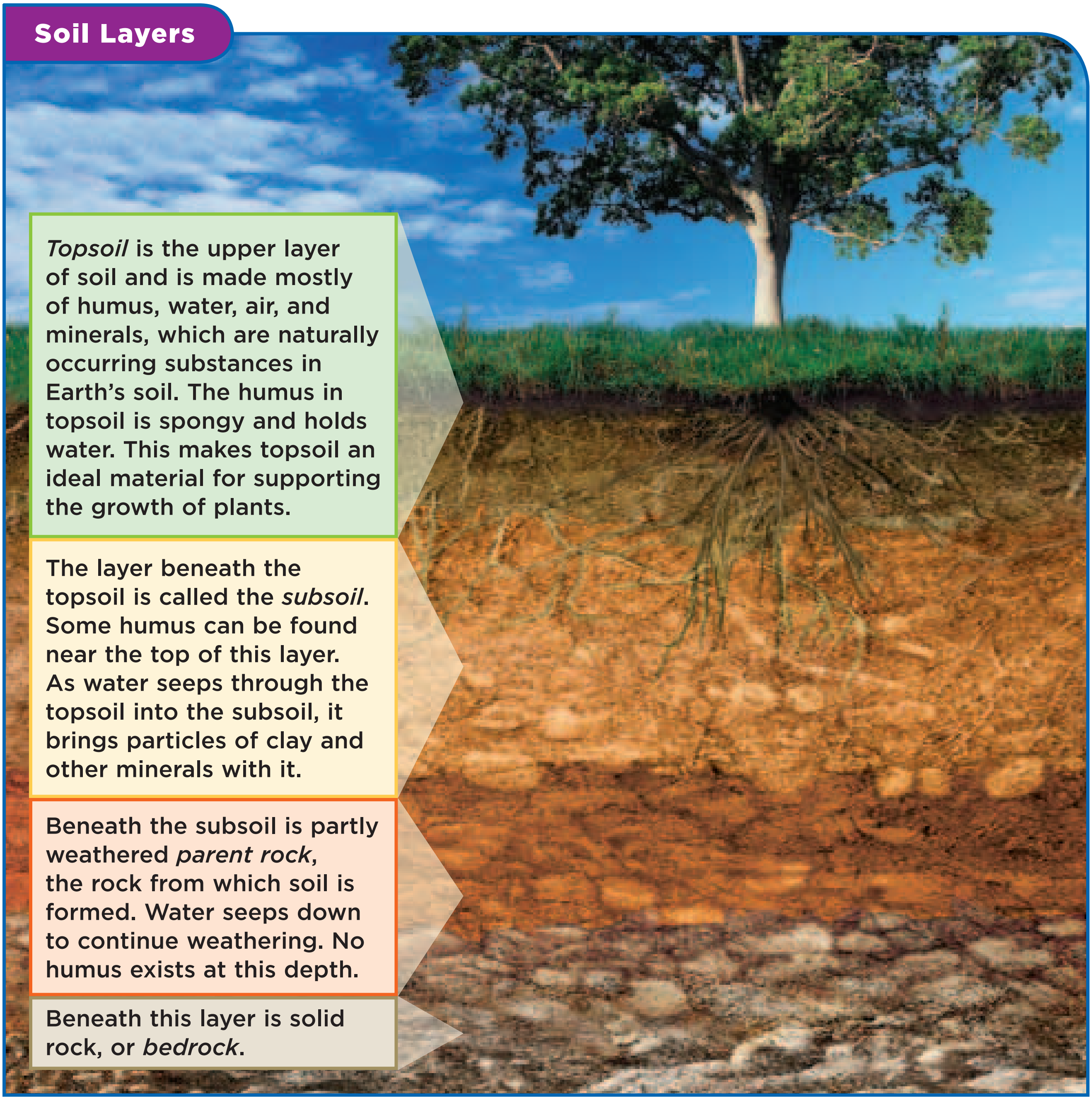
LOG ON *Science in Motion* Watch the life of a stream at www.macmillanmh.com

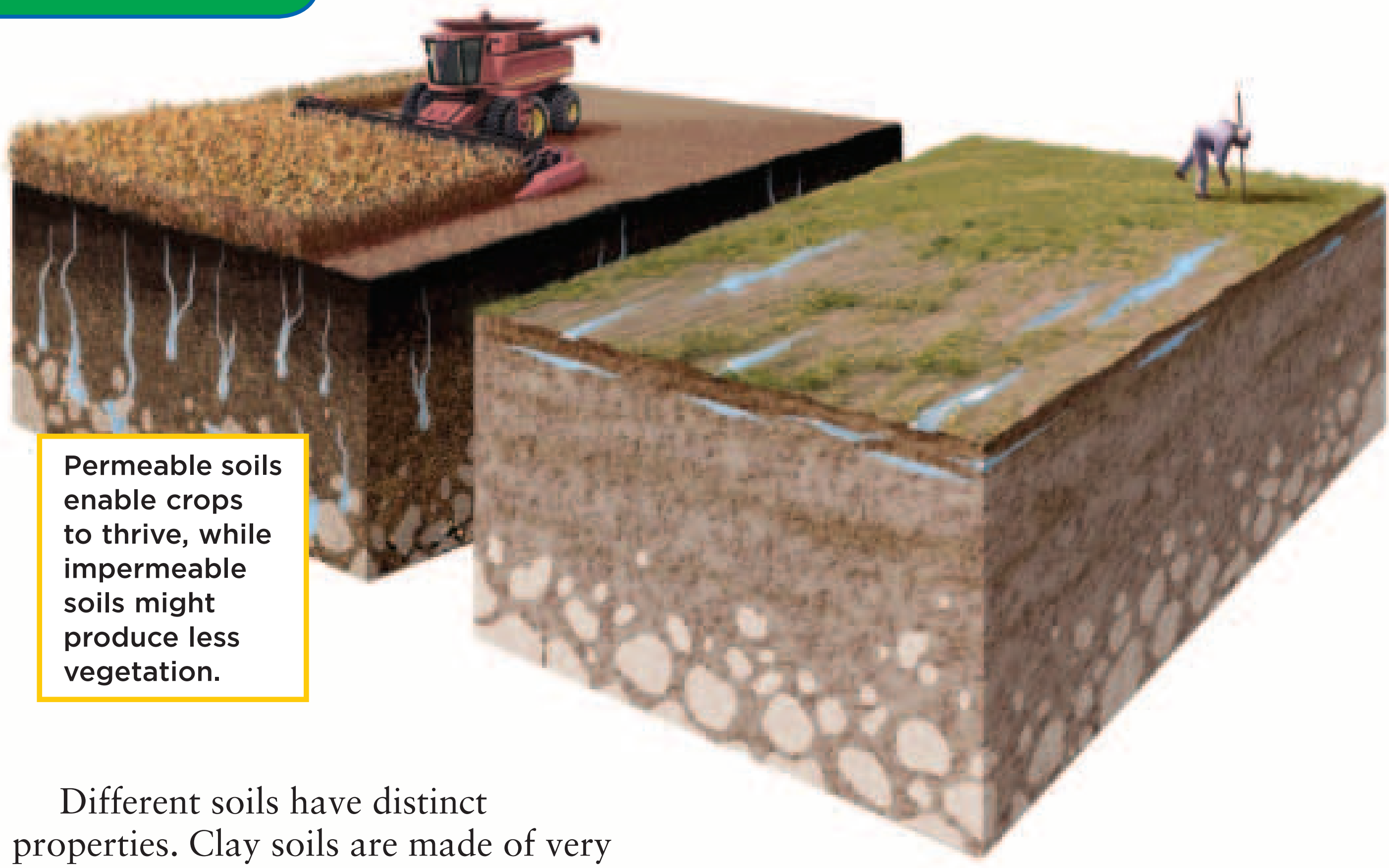
How is soil formed?

Weathering results in loose rock pieces that can become part of the soil, which supports rooted plants. **Soil** is a mixture of weathered rock, air, water, living things, and humus (HYEW•muhs). **Humus** is material made of decayed plant and animal remains. Bacteria, fungi, worms, and insects all contribute to the formation of humus.

Soil begins as rock. The rock, which is the parent material, is weathered. Over time, the rock breaks into smaller pieces, forming a thin layer of soil. Plants and animals grow in and on the soil. When they die, their remains enrich the soil. Eventually, the soil develops distinct layers called *soil horizons*.

Soil Layers





Permeable soils enable crops to thrive, while impermeable soils might produce less vegetation.

Different soils have distinct properties. Clay soils are made of very fine particles. Sandy soils are made of particles that are coarser.

All soils have spaces called pores between the rock fragments. If the pores in the soil are connected, water can pass through the soil easily. This soil is said to be *permeable* (PUR•mee•uh•buhl). Sandy soils are permeable. If the pores are not connected, or if there are few or no pores, water cannot pass through easily. This kind of soil is *impermeable* (im•PUR•mee•uh•buhl). Clay soils are nearly impermeable.

Uses of Soil

Most living things depend either directly or indirectly on soil. Soil is the material that most plants need in order to grow. Many animals live in soil. Decomposition, a vital part of the food web, takes place primarily in the soil and enriches it. People can then grow crops in this enriched soil and continue the cycle. Around the world, farmers grow crops that are adapted to the types of soil in their regions. Different crops need different types of soil as well as different climates in order to grow well.

Quick Check

Sequence Explain the steps by which soil forms.

Critical Thinking Why do gardeners appreciate having earthworms in their gardens' soil?

Why is soil important?

Almost everything you consume is somehow connected to the soil. The fruits and vegetables you eat, the bread for your sandwiches, and even the milk you drink can all be traced back to the soil. Soil contains minerals that organisms need to survive. Growing plants use up the minerals from the soil. These minerals are resupplied naturally by rain and runoff. Decaying plants and animals also resupply some minerals.

However, the minerals in soil cannot be replaced as easily as you can replace the soil in a flower pot. Soil is a resource that must be conserved.

Wasteful Practices

Soil is sometimes ruined by improper care. Growing too many plants in an area or growing the same kinds of plants in a field year after year can deplete soil of important nutrients.

These practices do not allow time for the soil's minerals to be replenished. Paving over land or cutting down forests also makes soil unusable. Dumping wastes into the soil changes its composition, affecting organisms that would normally live there and replenish soil nutrients.

Even building dams can damage the soil downstream. The water and nutrient-rich sediments held in a dam are not available to plants downriver. These plants might die. With less water and less plant life, soil can become dry and blow away. Unfortunately, this soil is then lost.

Quick Check

Sequence How might building dams damage soil?

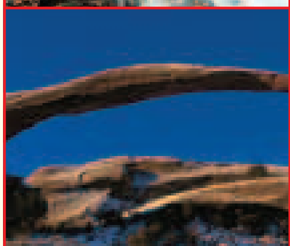
Critical Thinking How might a farmer help protect soil by planting different crops from year to year?

Soil loss (inset) may be prevented by soil-conservation practices, such as planting trees as windbreaks.

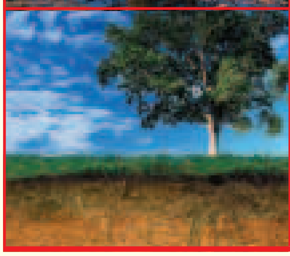
Lesson Review

Visual Summary

Water, plants, animals, and chemical activity all contribute to **weathering**.



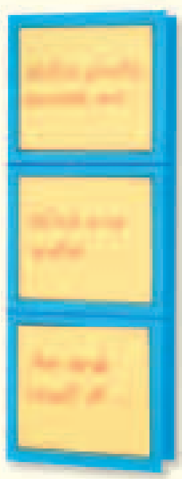
Wind and water are powerful agents of **erosion** and **deposition**.



Soil provides nutrients and a habitat for living things, and it must be conserved.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the phrase and provide additional details.



Think, Talk, and Write

1. **Main Idea** What processes shape Earth's surface?
2. **Vocabulary** The breaking down of rock into smaller pieces by natural processes is called ________.
3. **Sequence** Describe how soil is formed.

First → Next → Last

4. **Critical Thinking** Why is it so important to conserve soil?
5. **Test Prep** **Till that forms in front of or along the sides of a glacier is called**
   - **A** a plateau.
   - **B** a moraine.
   - **C** a valley.
   - **D** humus.
6. **Test Prep** **The dropping off of particles by a river as it flows is called**
   - **A** erosion.
   - **B** weathering.
   - **C** deposition.
   - **D** meandering.

Writing Link

Explanatory Writing

Write an essay that tells how growing and shrinking glaciers may cause sea levels to rise or fall. Explain how these events would affect people.

Math Link

Calculate River Length

The Colorado River is 2,334 km long. About 19 percent of its length runs through the Grand Canyon. For how many kilometers does the river flow through the Grand Canyon?

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The Danger of Shifting Sand

Beaches all over the world are eroding. I had learned from reading books how many beaches are changing shape, losing sand, and becoming narrower. However, I had thought that erosion had no real effect on my life—until my grandparents' dream home crashed into the sea.

After many years of working hard and saving their money, my grandparents bought a beautiful house on the beach. I used to love to visit them there. Their house stood high up on stilts, which protected their home from the water. I would sit in the front room, facing the ocean, and listen to the rhythm of the pounding waves, breathing in the salty ocean air. It was thrilling.

One afternoon, my family received a devastating phone call. My grandparents' house had collapsed. Over time, the rolling waves had pulled sand off the beach and back into the ocean. Without the support and protection of the sand, the seawater had slowly weakened the stilts on which their house once stood.

Now, my grandparents' dream is just a memory. However, the lesson we learned is still with us all: the sea can be a mighty foe. It can erode the beaches and change the land. The sea can also destroy homes—and dreams.

▲ Stilts elevate these houses above the surf and shifting sand.

Write About It

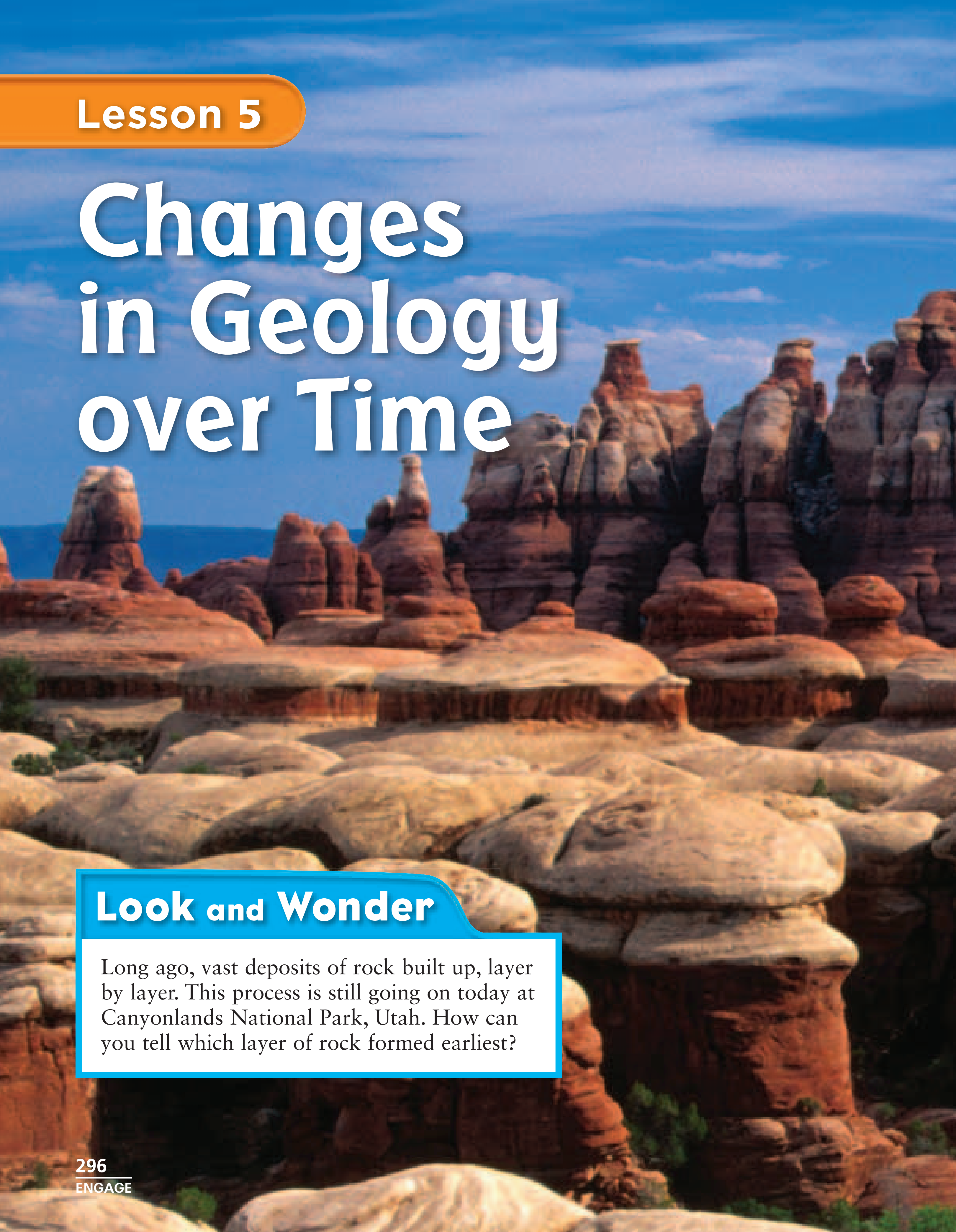
Narrative Writing Tell a personal story about the effects of beach erosion and the need to protect beaches. Use descriptive details, and retell events in a logical order. Use the first-person point of view, and add dialogue, if appropriate. Using print and online research, include information about why beaches are important.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Personal Narrative

A good personal narrative

- tells a story from personal experience
- expresses the writer's feelings by using the first-person point of view
- uses descriptive language
- has an interesting beginning, middle, and end
- shares events in a sequence that makes sense
- uses time-order words, such as *before* and *after*, to connect ideas and show the sequence of events



Lesson 5

Changes in Geology over Time

Look and Wonder

Long ago, vast deposits of rock built up, layer by layer. This process is still going on today at Canyonlands National Park, Utah. How can you tell which layer of rock formed earliest?

Explore

Inquiry Activity

Which rock layer is the oldest?

Purpose

Scientists gather information about Earth's history by looking at the order in which different layers of rock are found and comparing the different layers. Use stacks of clay to make similar observations.

Procedure

1. Make an ordered column of clay from the colors you have been given. Each layer represents a different layer of sedimentary rock. Look at your model carefully. Which color represents the oldest layer of rock in your column? Which represents the newest layer? Explain.
2. **Observe** Arrange the class's layered stacks on a table. Label the stacks *A*, *B*, *C*, and *D*. Look for layers with the same colors as yours. Look for patterns. Which layer in stacks A and B is the oldest? The youngest? Explain.
3. **Interpret Data** Using the same procedure, determine the oldest layer in all of the stacks. What is the youngest layer? In what order were the layers formed?

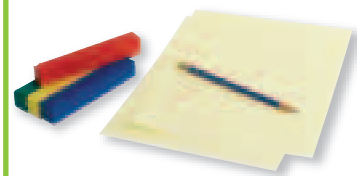
Draw Conclusions

4. **Infer** If these were actual layers of rock in a landscape, could you determine exactly how old any one layer was? Why or why not?
5. **Interpret Data** How is stack D different from the others? If layers of rock are missing, how can you explain this?

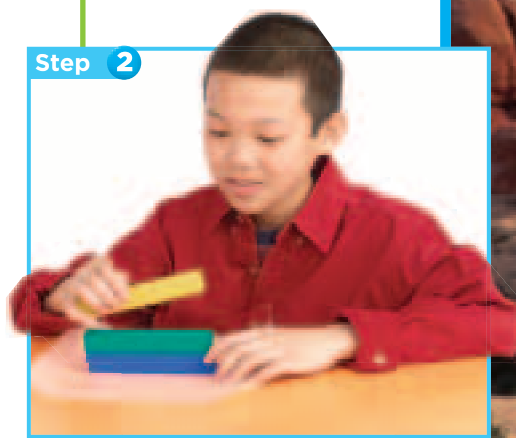
Explore More

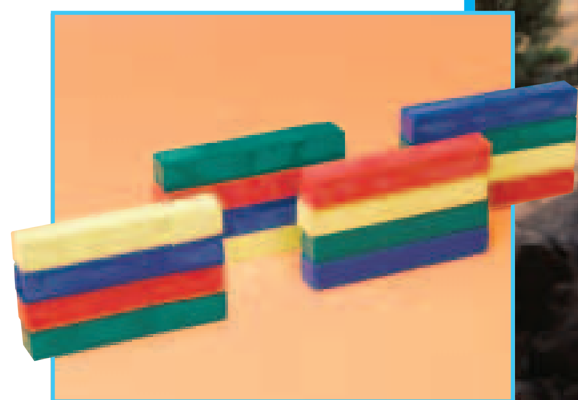
Scientists use the relative ages of geologic layers to help tell the geologic history of Earth. Use research books to find more information about how scientists use relative age to explain different events in Earth's history.

Materials



- 4 slabs of modeling clay, each a different color (red, yellow, green, and blue)
- notebook paper
- pencil





Read and Learn

Main Idea

Earth's geologic history is determined by studying the relative and absolute ages of rocks and fossils.

Vocabulary

relative age, p. 298
fossil, p. 300
half-life, p. 302
absolute age, p. 302
era, p. 302
period, p. 302

LOG ON e-Glossary at www.macmillanmh.com

Reading Skill

Infer

Clues	What I Know	What I Infer

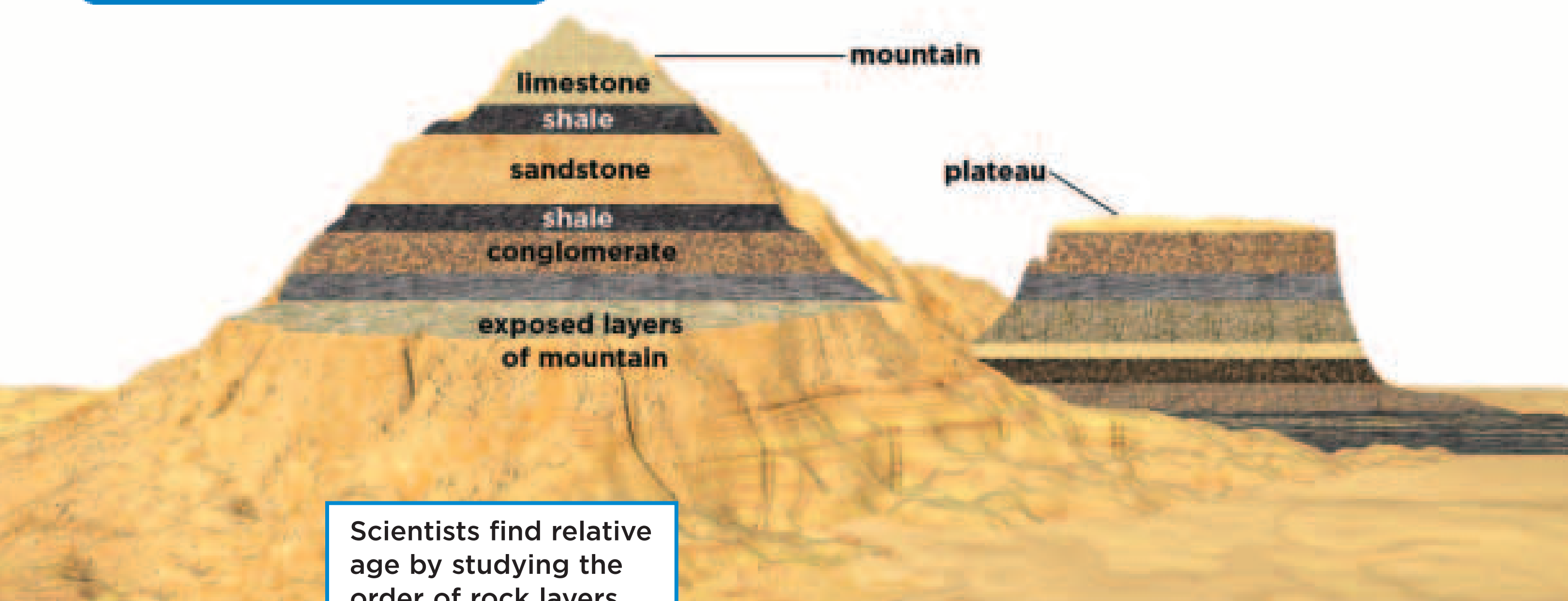
What is relative age?

Two ideas help scientists determine the age of rock. One is *original horizontality*, the idea that sedimentary rock forms in horizontal layers. The second idea is *superposition*. This idea says that in a series of rock layers, the bottom layer is the oldest, and the top layer is the youngest.

Scientists use these two ideas to help them infer a rock layer's **relative age**. This is its age compared to other rock layers. By looking at rock layers in an exposed hill or canyon wall, scientists can tell which layers are older than others.

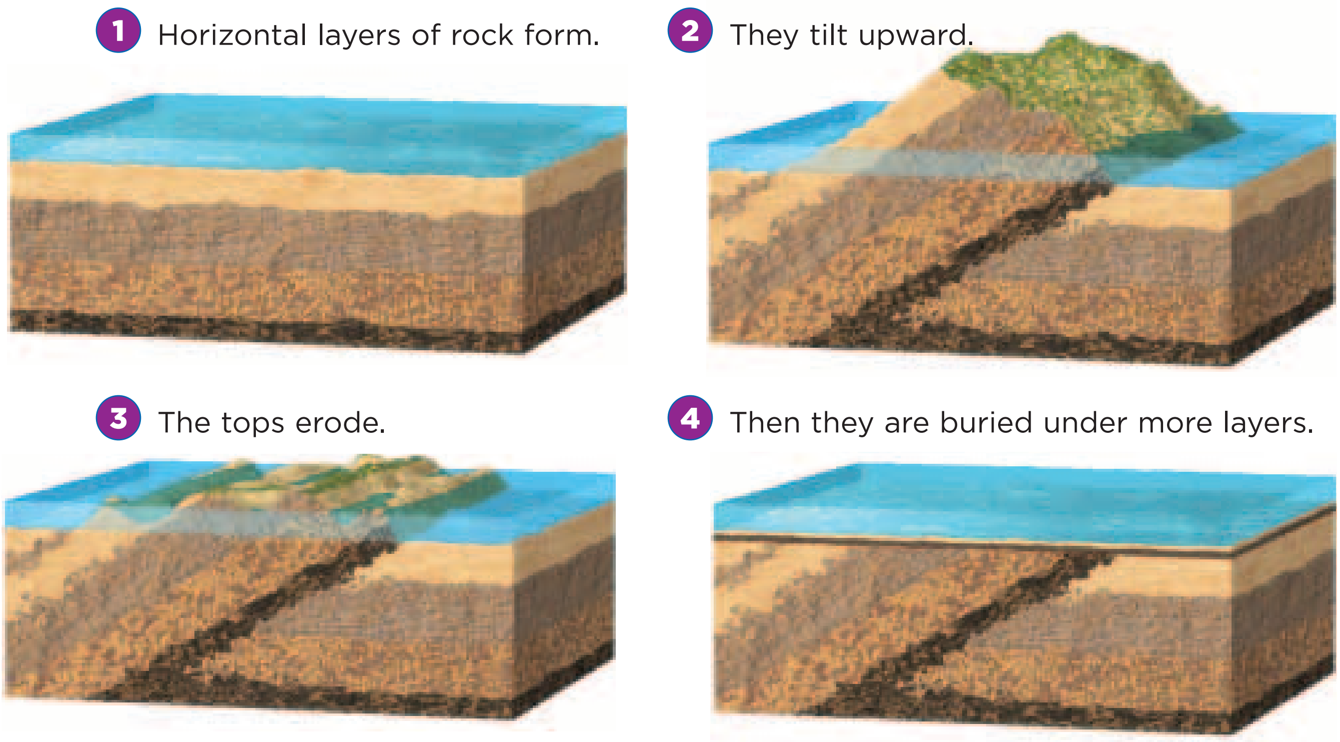
Scientists can also infer the ages of rock layers in different areas. They might find out that sandstone in a plateau is the same as the sandstone in a distant mountain range. By comparing rock layers across a large region, scientists can make a geologic column. A *geologic column* is a listing of Earth's rock layers ordered from oldest to youngest. Today, we know how long it takes sediment layers to build up. Based on this, scientists have inferred that it takes millions of years to make layers that are kilometers thick.

Geologic Columns and Layers



Scientists find relative age by studying the order of rock layers.

Changes to Rock Layers



▲ **Forces within Earth can tilt, fold, or overturn rock layers. For this reason telling the history of rock layers can be difficult.**

Telling a Story with Rock

If all rock layers formed simply by building one flat layer of rock on top of another, relative age would be easy to find. However, this does not always happen. Earth's plates move, and volcanoes erupt. Layers of rock are pushed up or pulled down. These changes are what make relative ages of rock so interesting.

Suppose a layer of limestone builds up. On top of it form layers of conglomerate—rock composed of gravel, pebbles, and stones—followed by layers of shale and then by layers of sandstone. These materials accumulate in that order. Later, magma flows upward and hardens into solid rock. Then earthquakes occur, lifting the rock layers upward. The history of that area can be seen in the rock layers left there over long periods of time.

Many events and circumstances can lead to the changes that occur in rock layers. The diagram on this page summarizes some of the causes.

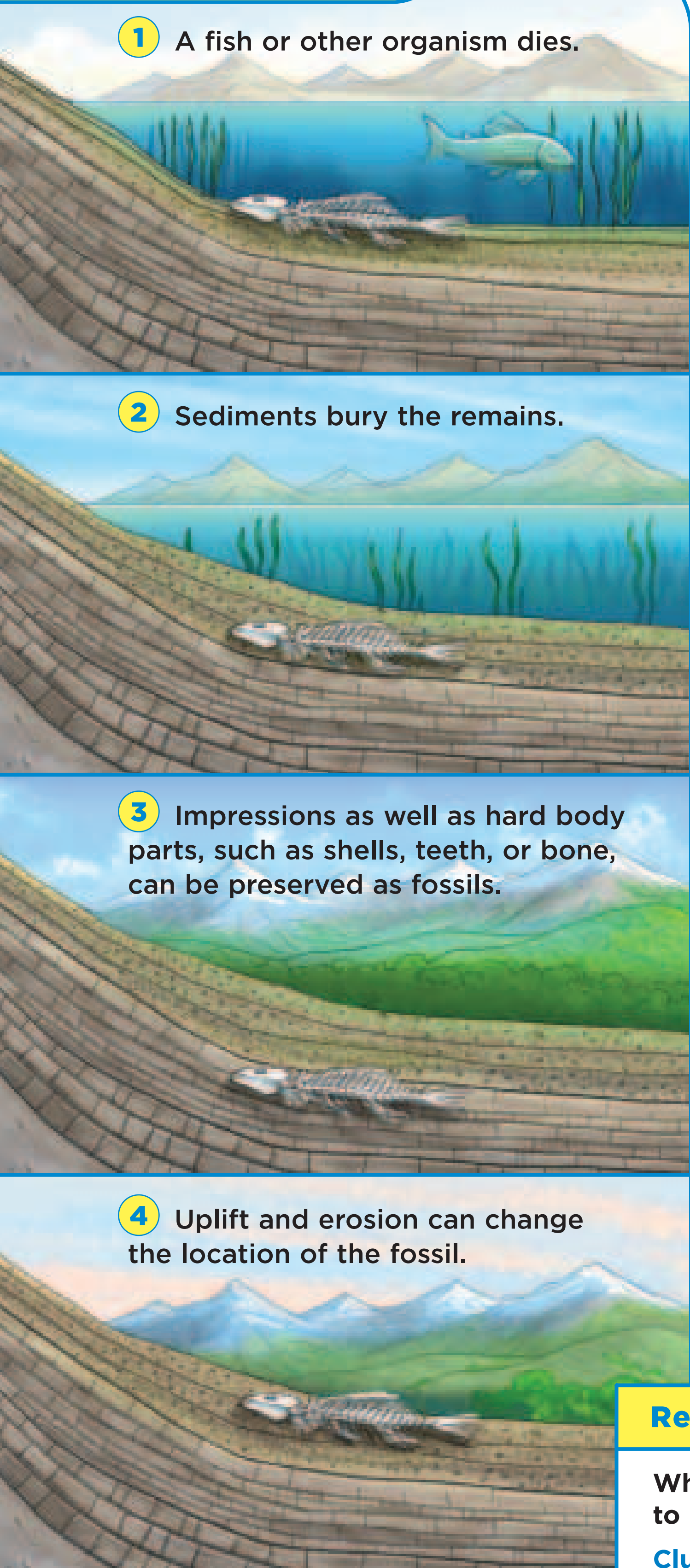
Quick Check

Infer Cross-sections of rock layers on each side of a large highway are the same. What can you infer?

Critical Thinking What processes might put younger rock beneath older rock?

FACT The youngest layer of rock is not always on top of all the others.

Fossil Formation



What are fossils?

Rock layers often contain fossils. **Fossils** are the remains, traces, or imprints of living things preserved in Earth's crust.

Normally, a dead organism decays quickly. Sometimes, however, an organism is covered by sediment soon after it dies. The soft parts of the body decay, but the hard parts, such as the bones or teeth of an animal, last long enough to be preserved. Atom by atom, minerals in the sediment replace the hard parts of the body. Eventually, the surrounding sediment and the body harden into rock, and a fossil forms.

Fossils can also form in other ways. An insect might be trapped by flowing tree sap. Over time, the sap hardens into amber, preserving the insect. Fossils of imprints, such as footprints, are made when animals walk across wet sand or soil. If an imprint dries and is covered quickly, the fossil is preserved. A plant imprint is made in the same way.

What Fossils Tell Us

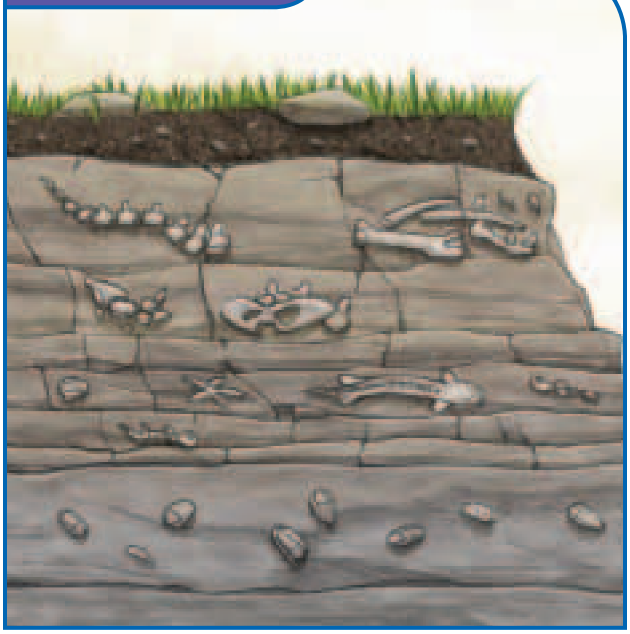
Because fossils are found in rock layers, we can determine their relative ages based on the layers in which they are found. Some fossils can also provide clues to a rock layer's relative age. These fossils are index fossils. *Index fossils* are remains of living

Read a Diagram

What processes caused the skeleton to be covered by different layers?

Clue: Look at how the position of the fish's skeleton changed over time.

Fossil Layers



▲ Identifying fossils in certain rock layers enables scientists to estimate when those layers formed.

things that were widespread but lived during a relatively short part of Earth's history. For example, trilobites were sea animals that lived on Earth for millions of years. Then they suddenly died out, or became extinct, all over Earth at about the same time. The presence of fossils of the same kinds of trilobites in various rock layers indicates that these rock layers all formed at about the same time, even if the layers are found in different areas.

Fossils provide clues to what Earth was like in the past. For example, coal deposits in Pennsylvania and West Virginia contain fossils of ferns. Modern ferns similar to the type found in these fossils grow in warm, moist areas such as tropical rain forests. This discovery enables us to infer that Pennsylvania and West Virginia had a tropical climate a long time ago.

Quick Lab

Modeling a Fossil

1. **Make a Model** Place a layer of modeling clay in a small disposable pan. Make an imprint of a seashell or another object provided. Press the object down into the clay, and then remove it carefully. Look at the impression that is left. What details do you notice?
2. **Communicate** Trade clay models with another student in your class. Look at the fossil model carefully. Can you tell what object made the imprint? Describe the clues that helped you figure it out.
3. **Infer** Over long periods of time, what might happen to an imprint fossil such as this one?
4. **Infer** How would these same skills of observation be used by scientists who find real fossils? How does this help scientists learn more about organisms of the past?

Quick Check

Infer Explain how scientists can determine the kind of climate a place had long ago.

Critical Thinking How can fossils give us clues about ancient environments?

What is absolute age?

Finding the relative age of a rock layer or fossil is useful. However, we sometimes need to know its actual age. Until the discovery of radioactivity, scientists could not tell how old a rock layer or fossil really was. Radioactive elements in rock decay, or break apart, into other elements. This decay occurs at a constant rate, called half-life. **Half-life** is the time it takes for half the mass of the original element to change into the decay product.

Each radioactive element has its own half-life. When the amount of the original element is compared to the amount of decay product present, scientists can then figure out how long the decay process has been going on. Through this process, scientists are able to determine the absolute age of a rock layer. **Absolute age** is a rock layer's age in years.

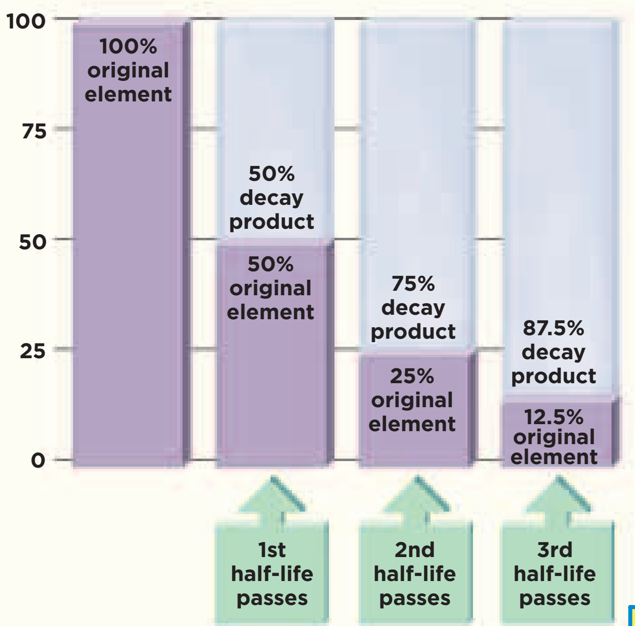
Suppose a rock layer contains the radioactive element uranium 235, or U-235. U-235 has a half-life of 700 million years. Then suppose you find out that the ratio of original element to decay product is 1:4. That means only one fourth, or 25 percent, of the original element is left. How can you find the rock layer's age?

One fourth is half of one half, so two half-lives have passed since the rock was formed. The age of the rock is 2 × 700 million years, which is 1,400 million years or 1.4 billion years.

Scientists use fossil clues, the ages of rock layers, and evidence of crustal motion to tell the story of Earth's geologic history. This history is measured in long stretches of time called **eras**. Each era is described by the kinds of life that were dominant in that era. An era is split into **periods**, which are shorter amounts of time. Periods often are associated with major changes in Earth's crust.

You can compare eras and periods by looking at a geologic time scale. A geologic time scale shows major events and life-forms on Earth during each era. Our knowledge is based on fossils that have been found dating to that era.

Half-life

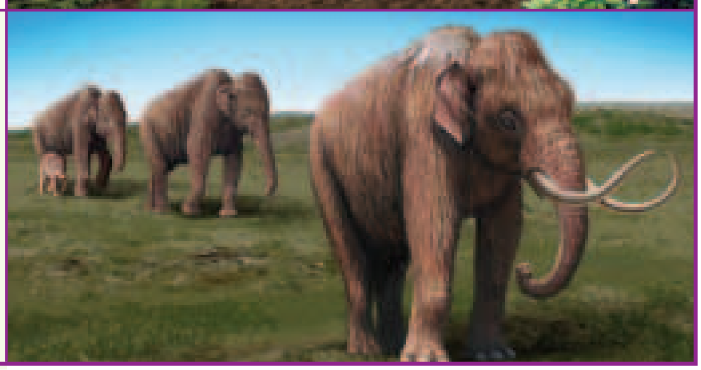


Each element decays at its own rate. This rate is used to find absolute age.

Read a Graph

After the fourth half-life, what percent of the original element still remains?

Clue: Find out what fraction remains, and then convert that into a percent.

Earth Long Ago	
Precambrian The Precambrian (pree•KAM•bree•uhn) era began with Earth's formation and lasted for almost 4 billion years. During this era, the earliest life-forms developed in the seas. Multicellular marine organisms developed at the end of the era. Few fossils from organisms of this era have been found.	
Paleozoic The Paleozoic (pay•lee•uh•ZOH•ik) ("early life") era began about 600 million years ago. Life became abundant in the seas and on land. Insects, amphibians, trilobites, fish, and reptiles appeared during this era. The first forests also developed. Many living things became extinct at the end of the Paleozoic era.	
Mesozoic Fossil remains from the Mesozoic (mez•uh•ZOH•ik) ("middle life") era indicate the appearance of dinosaurs, mammals, birds, and flowering plants. The supercontinent Pangaea began to break up during this era. Sea levels rose, and climates became milder. Rock from the end of the Mesozoic suggests that many forms of life became extinct at the end of this era.	
Cenozoic The Cenozoic (see•nuh•ZOH•ik) ("recent life") era is the era in which we live. In this era, mammals have dominated. Fossils show that some early mammals were very large. Several ice ages have occurred in this era. After the most recent, the Pleistocene (PLIGHS•tuh•seen) ice age, the Great Lakes formed.	

Quick Check

Infer Trilobites disappeared from the fossil record 450 million years ago. What can you infer from this information?

Critical Thinking What evidence is there that ice ages come and go?

Is Earth still changing?

Earth is a dynamic planet. It is always changing. New land forms when plates interact. For example, the island of Surtsey, near Iceland, formed in 1963 as a result of volcanic eruptions. A new Hawaiian island, Loihi, is slowly building beneath the Pacific Ocean's surface. In 1883, the volcano Krakatau, on an island in Indonesia, erupted, destroying most of its island. Today a new volcano called Anak Krakatau is forming in this area.

The surface of Earth is not alone in changing; the life on its surface changes, too. Over the billions of years of Earth's history, many organisms have emerged, and many have also become extinct. Some species became extinct because they could not adapt to new conditions. For example, at the end of the Permian and the Cretaceous (kri•TAY•shuhs) periods of the Mesozoic era, something produced great changes in Earth's surface. Most living things could not survive in the new conditions and became extinct.

▲ Surtsey Island is a new island formed off the coast of Iceland by volcanic activity.

Some present-day species are in danger of becoming extinct. While extinction is a natural occurrence, many species are endangered because of human activities.

At the same time, new species are being discovered every year. In 1977, scientists studying the sea discovered a previously unknown kind of life: tube worms, which live on the ocean floor near hot geothermal vents. Later, they discovered organisms living off the minerals emitted by these vents. In the 1990s, another new kind of life was discovered living near the mouths of lobsters.

In addition, animals once thought to be extinct are being rediscovered. In 2005, researchers in Arkansas believed that they had spotted a woodpecker which had been thought to be extinct.

▼ Saber-toothed cats are now extinct.

Quick Check

Infer What effect might environmental change have on organisms?

Critical Thinking How could global warming change Earth's surface?

Lesson Review

Visual Summary

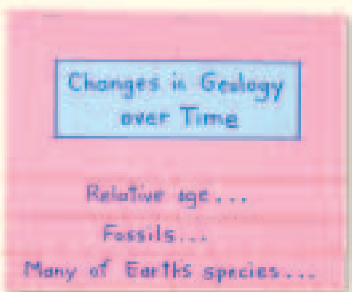
Relative age compares the age of one rock layer to that of other rock layers.

Fossils help determine the relative ages of the rock layers in which they are found and are used to determine the eras of Earth's history.

Many of Earth's species are **extinct**, some are endangered, and new species are being discovered.

Make a FOLDABLES Study Guide

Make a Layered-Look Book. Use the titles shown. On the inside of each fold, explain what you learned about changes in geology.



Think, Talk, and Write

1. **Main Idea** How is Earth's geologic history determined?
2. **Vocabulary** Long stretches of time in history are called _________.
3. **Infer** An animal skeleton embedded in rock has the fossilized remains of another species within it. What can you infer?

Clues	What I Know	What I Infer

4. **Critical Thinking** How do scientists decide what happened during a particular era in Earth's history?
5. **Test Prep** **A rock layer's actual age in years is its**
   A half-life.
   B relative age.
   C absolute age.
   D geologic era.
6. **Test Prep** **Remains of living things that were widespread but lived for only a short part of Earth's history are**
   A endangered fossils.
   B index fossils.
   C imprints.
   D preserved fossils.

Writing Link

Expository Writing

Suppose you found a 200-million-year-old fossil fern in Antarctica. Write an expository essay explaining what the environment of Antarctica might have been like 200 million years ago.

Math Link

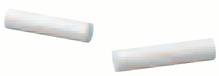
Calculate Half-Life

What is the ratio of radioactive element to decay product after 12,000 years if the radioactive element has a half-life of 6,000 years?

Materials


2 beakers


vinegar


2 pieces of chalk


2 pieces of limestone

Structured Inquiry

What makes chemical weathering happen?

Form a Hypothesis

Limestone is a type of sedimentary rock formed from calcium carbonate. Calcium carbonate is the substance found in chalk. How will calcium carbonate react with an acid such as vinegar? Write your answer in the form of a hypothesis: "If I add vinegar to calcium carbonate, then . . ."

Test Your Hypothesis

1. Add 150 mL of water to a beaker. Label the beaker *Water*.
2. Add 150 mL of vinegar to a second beaker. Label this beaker *Acid*.
3. **Experiment** Place a piece of chalk in each beaker. You may wish to leave the chalk pieces in the beakers overnight.
4. **Predict** Record your observations. What happened to the chalk? What do you think will happen to limestone in the same conditions?
5. **Use Variables** Repeat the experiment, using limestone instead of chalk. You may wish to leave the limestone pieces in the beakers overnight.

The Stone Forest in China contains weathered limestone.

Draw Conclusions

6 Many of Earth's landforms are made of limestone and other similar types of rock. How does the experiment help explain what can happen to Earth's landforms over time?

7 **Infer** Based on the experiment, how do you think chemical pollution in the air and water could change natural landforms?

Guided Inquiry

How do substances affect calcium carbonate?

Form a Hypothesis

You have already tested the effect of one acid, vinegar, on calcium carbonate. How do other substances affect calcium carbonate? For example, would lemon juice have the same effect? Write your answer in the form of a hypothesis: "If I add ________ to calcium carbonate, then . . ."

Test Your Hypothesis

Design an experiment to test your hypothesis. Then write out the materials you will need and the steps you will take. Record your results and observations as you perform your experiment.

Draw Conclusions

Did your experiment support your hypothesis? Why or why not? Present your results to the rest of your class.

Open Inquiry

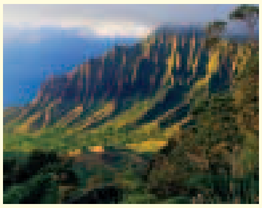
What other tests can you perform on chemical weathering? Would other types of rock respond to acids in the same way? Come up with a question to investigate. Then carry out an investigation to find out the answer.

Remember to follow the steps of the scientific process.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions

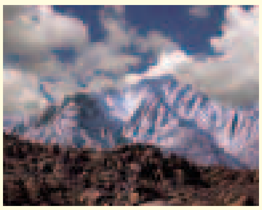
CHAPTER 5 Review

Visual Summary

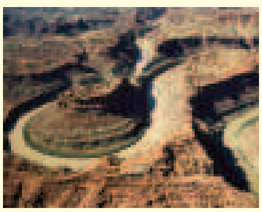


Lesson 1 Earth's surface includes bodies of water and landforms. Earth's layers include the crust, mantle, and core.

Lesson 2 Earth's crust is made of moving plates that slowly but constantly change its surface.



Lesson 3 Many landforms result from changes and movements in Earth's crust.

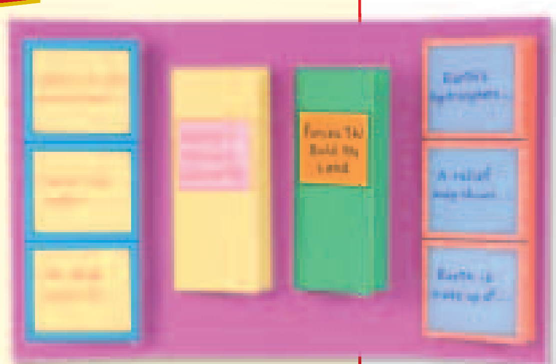


Lesson 4 Several forces cause changes to Earth's surface over time.

Lesson 5 Earth's geologic history is determined by studying the relative and absolute ages of rocks and fossils.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

aftershock, p. 270
continental drift, p. 256
elevation, p. 249
focus, p. 270
fossil, p. 300
humus, p. 290
hydrosphere, p. 244
relative age, p. 298

1. An area's height above or below sea level is called its ________.

2. The part of Earth that contains water is the ________.

3. Wegener's concept of the movement of Earth's crust is called ________.

4. When animal bones or teeth harden into rock, a type of ________ forms.

5. Topsoil contains water, air, minerals and ________.

6. A small earthquake that follows a major earthquake is called a(n) ________.

7. Geologists can compare rock layers to determine a rock layer's ________.

8. The point below the surface where an earthquake begins is the ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. Sequence List the sequence of events leading up to an earthquake at a plate boundary.

10. Personal Narrative Identify your absolute age and your relative age compared to your family, friends, or classmates. Then describe a time when you wished that either your relative age or your absolute age were different.

11. Infer While traveling west from Virginia to California, you see a sign that says *Continental Divide*. What can you infer about the rivers you will cross after passing the sign?

12. Critical Thinking In which part of the United States do you think earthquakes and volcanoes are most common? Explain your answer.

13. Infer Which major kind of landform is shown in the photograph below? Describe the elevation where this type of landform can be found.

Big Idea

14. Describe the major forces that have shaped Earth's landscape.

Performance Assessment

Modeling Plates

Your goal is to model the ways tectonic plates can move at plate boundaries.

What to Do

1. Copy the table below.

Plate Boundary	Description of Model	Observations
divergent		
convergent		
transform		

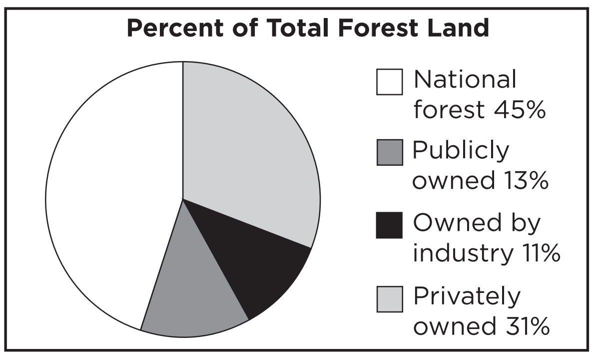
2. Simulate what happens at divergent, convergent and transform boundaries. Record your observations.

Analyze Your Results

▶ What happens to Earth's crust at each type of plate boundary?

Test Prep

1. About 40 percent of a state is covered by forest.



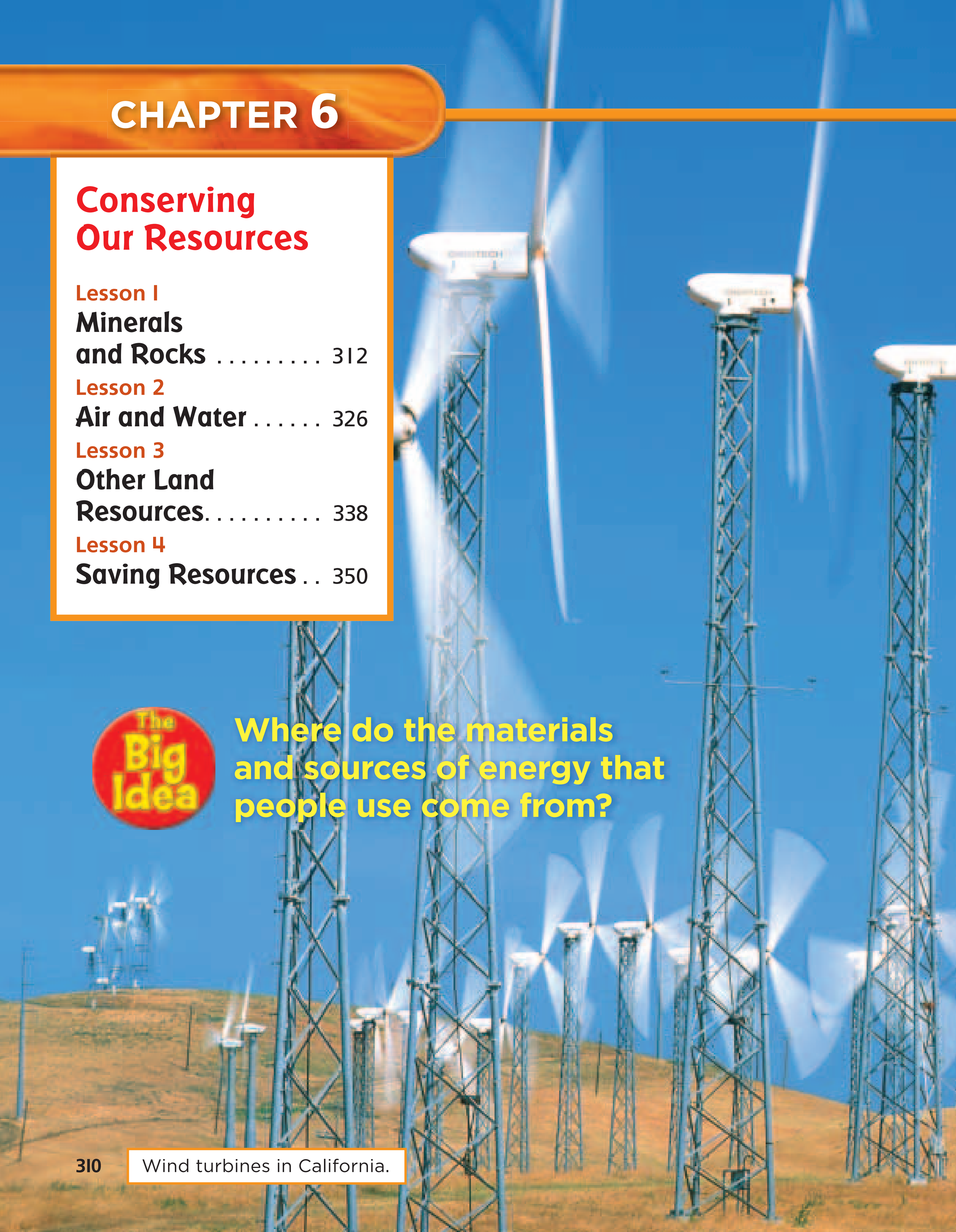
If the state has 39.6 million acres of forests, about how many of those acres are national forests?

A 4.4 million

B 5.2 million

C 12.4 million

D 17.8 million14



CHAPTER 6

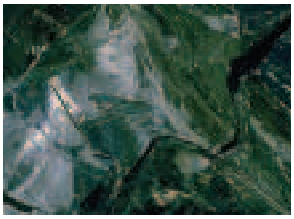
Conserving Our Resources

The Big Idea

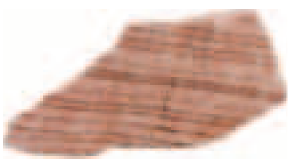
Where do the materials and sources of energy that people use come from?

Wind turbines in California.

Key Vocabulary

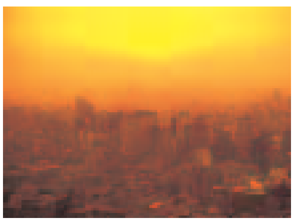


igneous rock
A rock that forms when melted rocks cool and harden into solids. (p. 319)



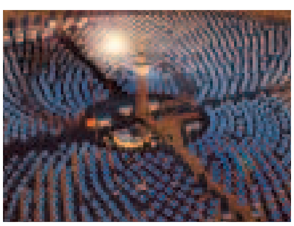
sedimentary rock
A rock that forms when pieces of rocks, minerals, and shells are deposited, buried, and become squeezed and cemented together. (p. 320)

metamorphic rock
A rock that forms from another rock that has been changed by heat, pressure, or a chemical reaction. (p. 321)



smog
A mixture of smoke and fog, formed when smoke and fumes collect in moist, calm air. (p. 345)

landfill
A specially designed place where garbage is deposited into a lined pit. (p. 346)



solar cell
A device that uses sunlight to produce electricity. (p. 355)

More Vocabulary

crystal, p. 315

rock cycle, p. 322

atmosphere, p. 328

ozone layer, p. 329

water cycle, p. 330

precipitation, p. 330

watershed, p. 331

water table, p. 333

aquifer, p. 333

reservoir, p. 333

renewable resource, p. 340

nonrenewable resource, p. 340

pollution, p. 344

acid rain, p. 345

biodegradable, p. 346

toxic waste, p. 346

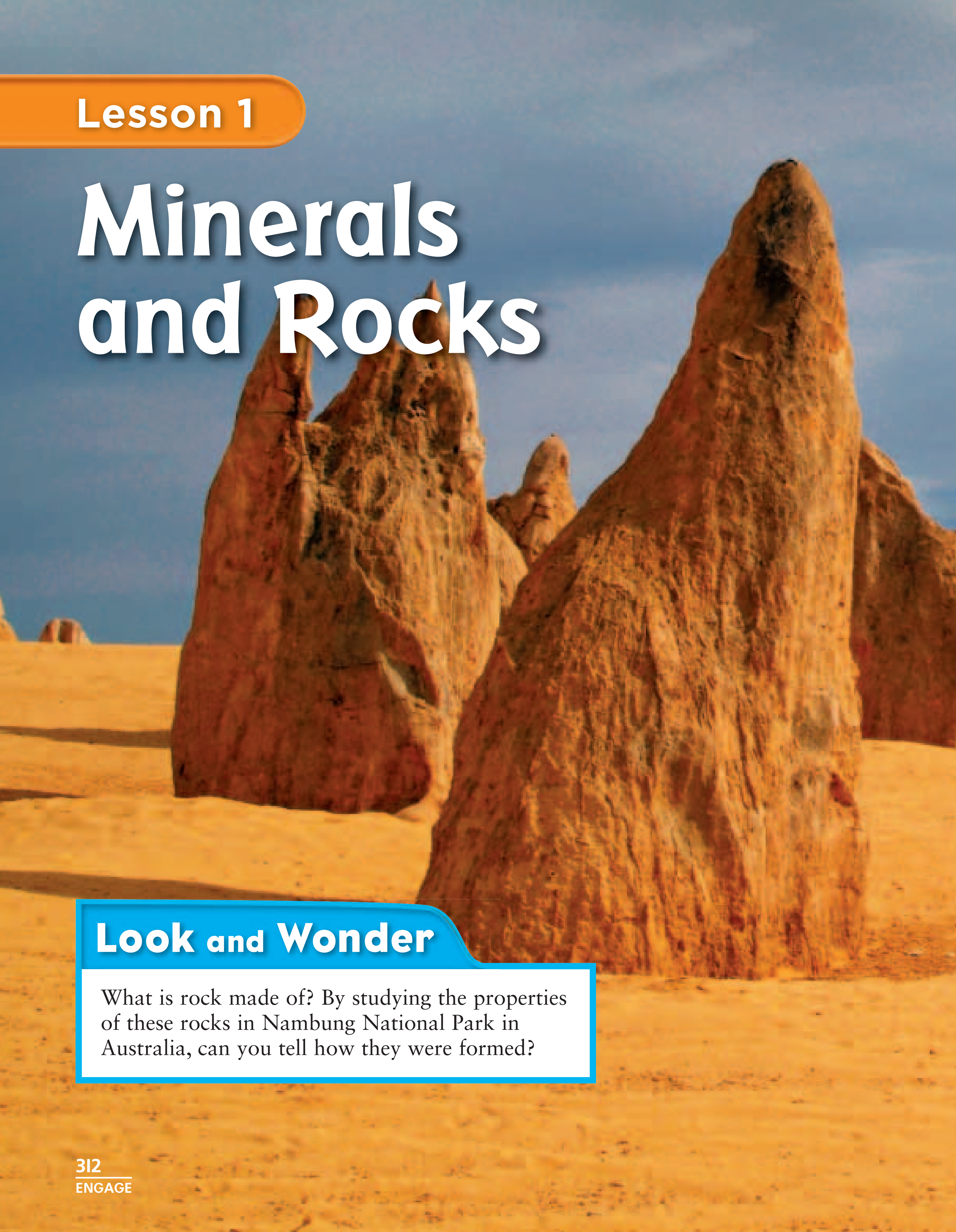
geothermal energy, p. 354

biomass, p. 354

hydroelectricity, p. 355

Lesson 1

Minerals and Rocks



Look and Wonder

What is rock made of? By studying the properties of these rocks in Nambung National Park in Australia, can you tell how they were formed?

Explore

Inquiry Activity

What is granite made of?

Purpose

Compare the properties of various rocks to determine what substances are found in granite.

Procedure

1. **Observe** Look carefully at the granite sample with your hand lens. Is it made of more than one substance? What does your sample look like? Try to be as descriptive as possible in your observations.
2. **Communicate** Examine the other samples. What properties can help you tell one substance from another? Share your ideas and observations with other students.
3. **Compare** Compare the properties of each of the other substances to the properties of the granite. List the properties of each sample on your chart.

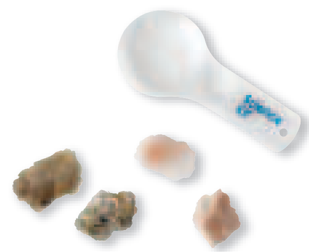
Draw Conclusions

4. **Infer** Based on your investigation, which of these substances does your granite sample contain?
5. **Interpret Data** Which properties were most useful in comparing the mineral and granite samples?

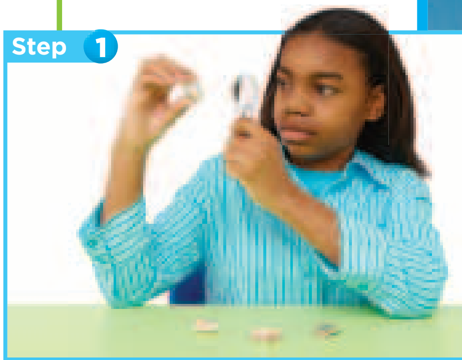
Explore More

Compare different rock samples provided by your teacher to the granite sample. How many different substances does each new sample appear to contain? Are the substances the same as or different from those in granite? Use a chart like the one shown to compare these samples' properties.

Materials



- sample of granite
- hand lens
- samples of other substances, including quartz, mica, and feldspar



Read and Learn

Main Idea

Earth's crust is made of minerals that have different properties.

Vocabulary

mineral, p. 314
crystal, p. 315
igneous rock, p. 319
sedimentary rock, p. 320
metamorphic rock, p. 321
rock cycle, p. 322

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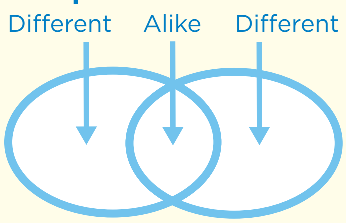
Reading Skill

Compare and Contrast



What are minerals?

What do talc, aluminum foil, copper wire, diamonds, and table salt have in common? They are all made of minerals. **Minerals** are the naturally occurring solid materials of Earth's crust. Minerals, like all kinds of matter, are made up of elements. An element is a substance that cannot be changed into a simpler substance. Some minerals, such as native copper, consist of only one element. Most minerals, however, are compounds made up of two or more elements. Rock usually contains a mixture of minerals.

Properties of Minerals

Minerals exist in a variety of colors and textures. Minerals have varying degrees of hardness, and they break apart in different ways. No two minerals are identical. Each has properties that set it apart from all other minerals. *Color* is the most obvious physical property of a mineral. Color is useful in identification. However, some minerals can be different colors, and different minerals can share the same color.

Crystal Structures

This happens when the outer surface of a mineral is discolored. Scratching the mineral sample can reveal the mineral's actual color.

Texture is another property of minerals that provides a clue to identification. Some feel smooth. Others feel rough. The texture of a mineral depends on the sizes and shapes of the substances in it. In a coarse mineral, the pieces are large enough to see and feel. In a smooth one, the pieces are quite small and may sometimes be difficult to see. A *glassy* mineral looks and feels smooth.

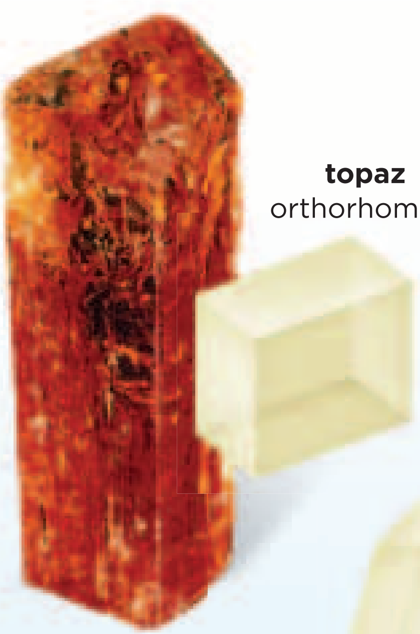
Minerals are usually made of crystals. A **crystal** is a solid that has a structure arranged in orderly, fixed patterns. A crystal's shape depends on the way its structure is arranged. Each of the minerals shown on these pages has a different crystal structure. Scientists generally begin identifying a sample by examining the shape of the mineral's crystal structure.

The way a mineral breaks is another important property. Some minerals tend to break along flat surfaces. This property is called *cleavage*. Cleavage is described by the number of planes, or directions, along which the mineral breaks. The cleavage of a mineral depends partly on its structure. Not all minerals break smoothly into planes. Some have rough or uneven surfaces when they break.

Quick Check

Compare and Contrast What can be seen when a mineral breaks with cleavage? Without cleavage?

Critical Thinking Why is it useful to examine the crystal structure of an unfamiliar mineral?



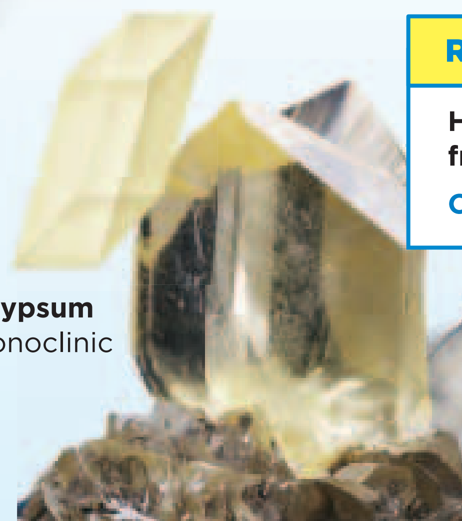
topaz
orthorhombic

feldspar
triclinic

Read a Diagram

How is a hexagonal crystal different from the other crystals shown here?

Clue: Compare the sides of the crystals.



gypsum
monoclinic

What are some other properties of minerals?

Hardness is another important property of minerals. Some minerals scratch easily, and others do not. *Hardness* is a measure of how well a mineral resists scratching. Soft minerals are easily scratched, and hard minerals are more difficult to scratch.

Friedrich Mohs, a German scientist, devised a scale of hardness to compare minerals to one another. This has come to be known as Mohs' scale. Talc, a very soft mineral, is number 1 on the scale. Diamond, the hardest known mineral, is number 10. Minerals higher on Mohs' scale can be used to scratch minerals lower on the scale.

Streak and Luster

If you rub a mineral across a porcelain plate, you will see a streak left on the plate. *Streak* is the color of the mark left when a mineral is rubbed against a hard, rough surface. The streak is always the same for a particular mineral, even when the mineral's surface varies in color.

Streak can be useful in identifying minerals. During the California Gold Rush of 1849, some people uncovered a sparkling metal and were sure they had found gold. The material looked like gold. However, a streak test would have shown that what they thought was gold was really iron pyrite. Gold has a yellow streak, but iron pyrite has a streak that is greenish-black in color.

Mohs' Hardness Scale

Read a Diagram

Which substances could you scratch with a steel file?

Clue: The lower the hardness number, the softer the mineral.

Properties of Minerals						
Mineral or Mineral Group	**Color (more common colors)**	**Luster (type of shine)**	**Streak (porcelain-plate test)**	**Cleavage (number of planes)**	**Hardness (on Mohs' scale)**	**Density (compared to water)**
gypsum	colorless, gray, white, brown	pearly	white	varies	2	2.3
quartz	colorless, various colors	glassy or greasy	white	none	7	2.6
pyrite	brassy, yellow	metallic	greenish black	none	6	5.0
calcite	varies widely; colorless, white, pale blue, green	glassy	colorless, white	3	3	2.7
galena	steel gray	metallic	gray to black	3	2.5	7.5
feldspar	pink, gray, green, yellow, white	glassy or pearly	colorless	2	6	2.6
mica	colorless, silver, black	pearly or metallic	white	1 (thin sheets)	2–3	3.0
hornblende	green to black	glassy or pearly	gray to white	2	5–6	3.4
bauxite rock	gray, red, brown, white	none	gray	none	1–3	2.0–2.5
hematite	black, gray, reddish brown	metallic	red, reddish brown	none	5–6	5.3

People who did not know the streak property of gold simply trusted their eyes. Because of this mistake, iron pyrite came to be known as "fool's gold."

Luster is another useful property of minerals. Luster refers to the way that minerals reflect light. Minerals with a metallic luster appear shiny, like metal. Minerals with a nonmetallic luster can be described as glassy, pearly, oily, earthy, waxy, or silky. Graphite has a metallic luster. Quartz has a glassy luster, and talc has an oily luster.

Some minerals have other special properties that can be used to identify them. For example, arsenic gives off a garlicky odor when it is heated. Copper is a very good conductor of electricity. Magnetite attracts elements such as iron, nickel, and cobalt and is a naturally formed magnet.

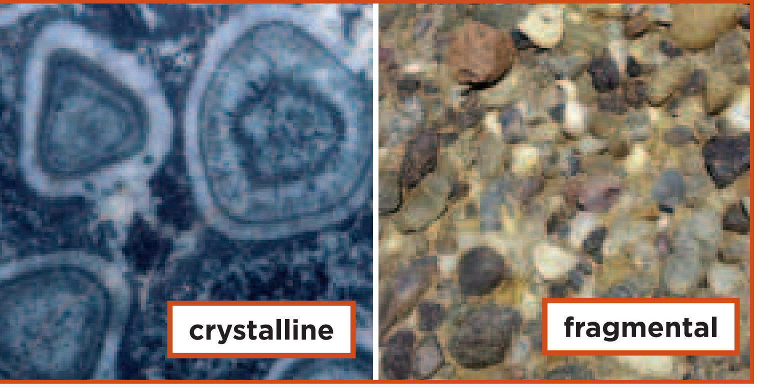
▲ Magnetite, or lodestone, attracts these metal objects.

Quick Check

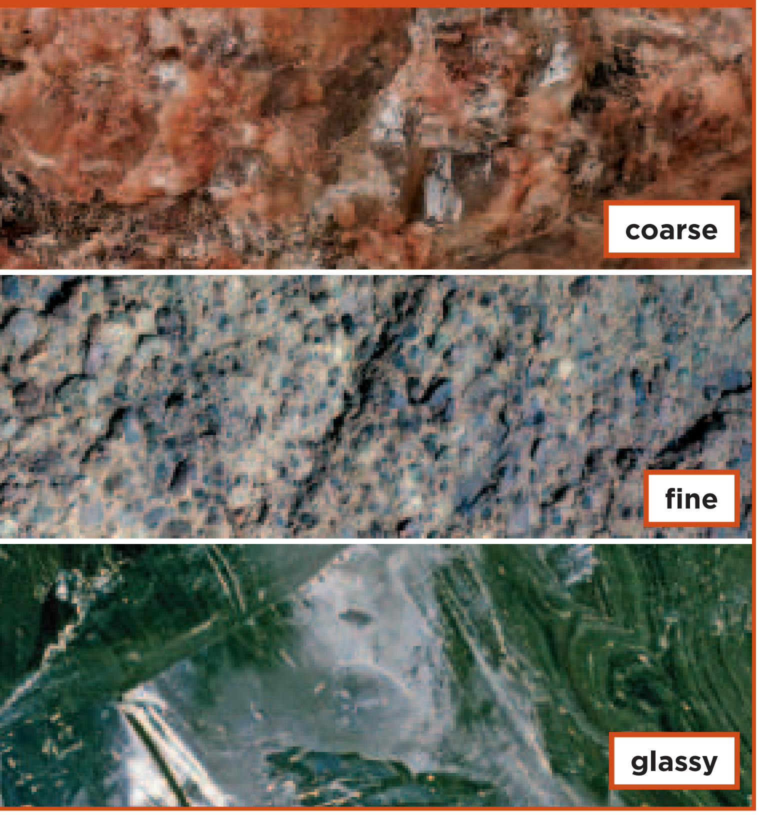
Compare and Contrast Compare the properties of galena and hornblende shown in the table of mineral properties. In what ways are the two minerals different? In what ways are they similar?

Critical Thinking Why should you test several properties when identifying minerals?

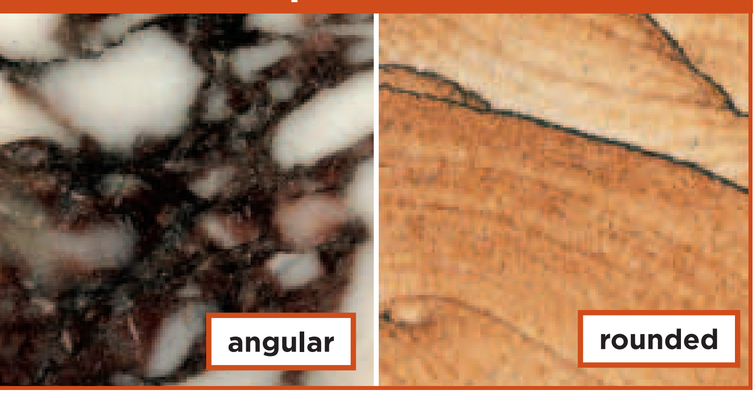
Structure of Rock



Texture of Rock



Shape of Rock



How do rocks differ?

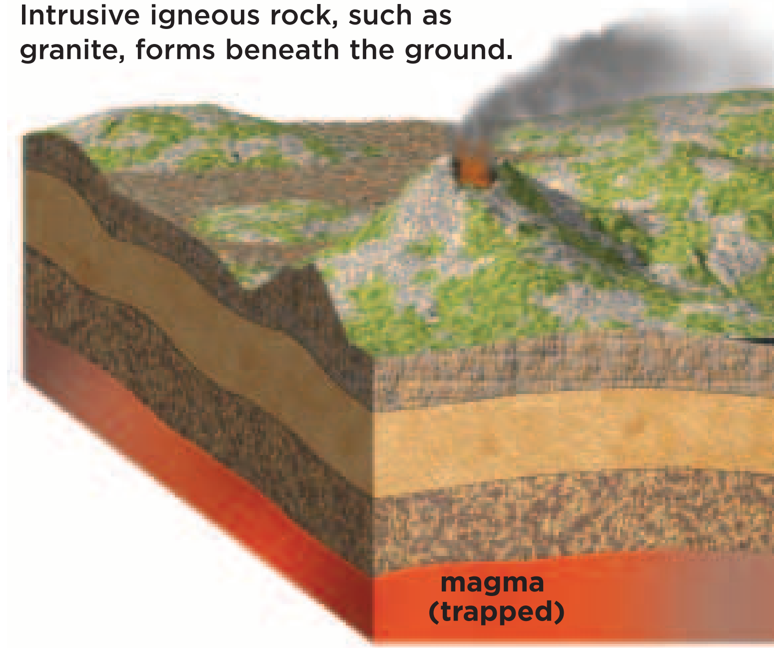
Rock is a naturally formed, solid material made up of one or more minerals. When you look at a piece of granite with a hand lens, you may be able to see crystals of quartz (brown), feldspar (pink), and biotite (black), which is a type of mica (MIGH•kuh).

Minerals can be identified by their individual properties. Most rock consists of a mixture of minerals. Types of rock are identified by the minerals that they contain and the conditions under which they were formed.

Certain properties help identify types of rock. These include features such as texture and structure. Texture depends on the size, shape, and arrangement of the mineral crystals in the rock. Structure is the way the minerals fit together. The chart on this page illustrates these properties.

Igneous Rock

Extrusive igneous rock, such as obsidian, forms above ground level. Intrusive igneous rock, such as granite, forms beneath the ground.



The properties of rock come from its composition and the way it was formed. The formation process is the basis for classifying rocks into three main groups: igneous (IG•nee•uhs), sedimentary, and metamorphic.

Igneous Rock

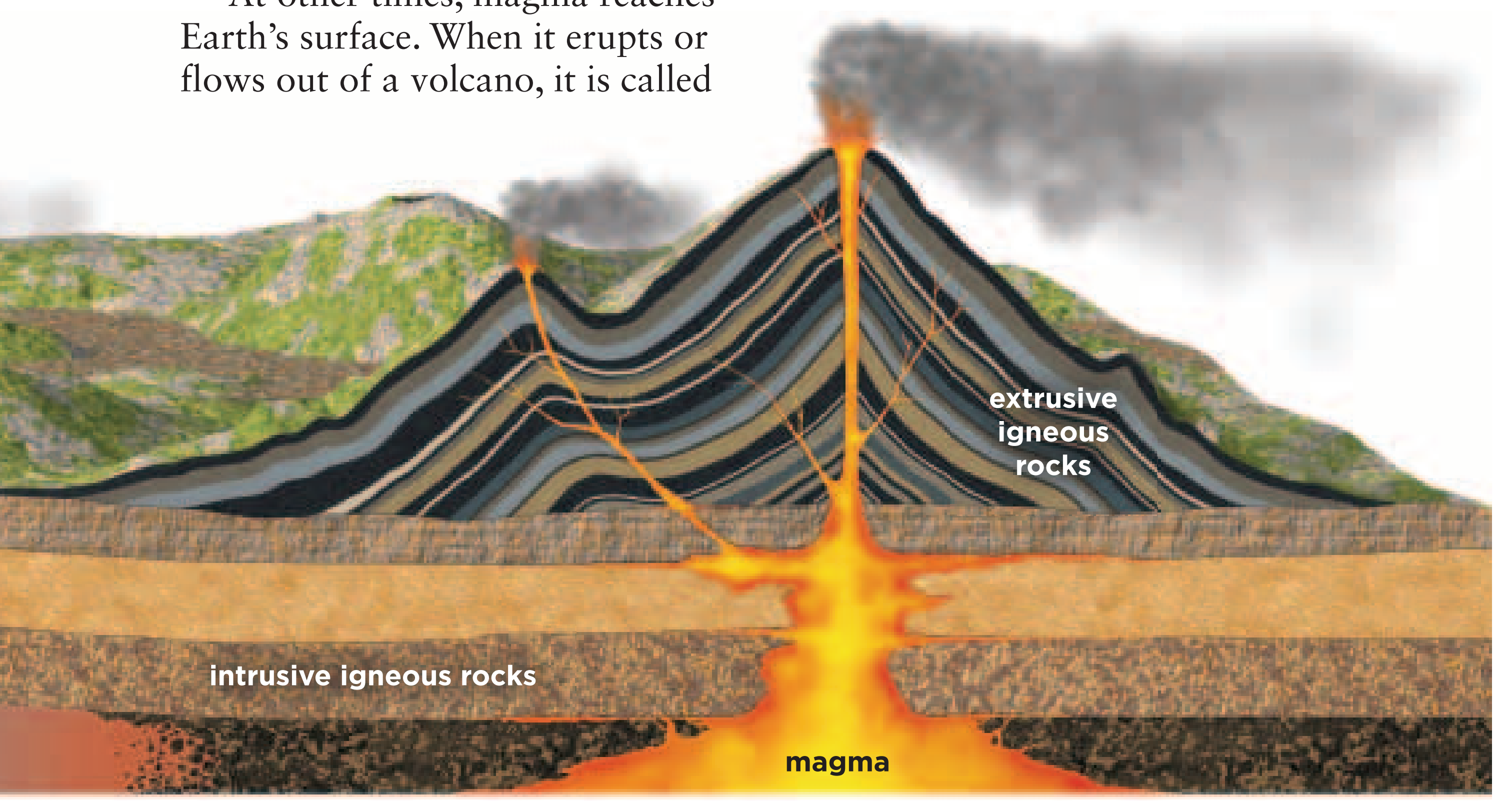
Igneous rock forms when melted rock cools and hardens into a solid. Sometimes igneous rock develops underground. As magma pushes its way up through cracks, it may become trapped. The trapped magma cools slowly, sometimes over several centuries. Igneous rock that forms in this way is *intrusive rock*. During this prolonged cooling, the crystals of the minerals in the rock grow larger. The large mineral crystals of intrusive rock produce a coarse texture. Gabbro and granite are types of igneous rock that develop in this way.

At other times, magma reaches Earth's surface. When it erupts or flows out of a volcano, it is called lava. Exposed to the temperature of the air, lava cools and hardens quickly. Igneous rock that forms in this way is called *extrusive rock*. Extrusive rock has a fine texture, because the crystals of the minerals in the rock do not have time to grow large. Rhyolite and obsidian are types of igneous rock that form in this way. Obsidian forms so quickly that a crystal structure does not completely form. Obsidian looks like black glass.

Quick Check

Compare and Contrast How does an igneous rock that has cooled quickly differ from one that has cooled slowly?

Critical Thinking What might explain the presence of coarse-textured igneous rock exposed on the surface of Earth?

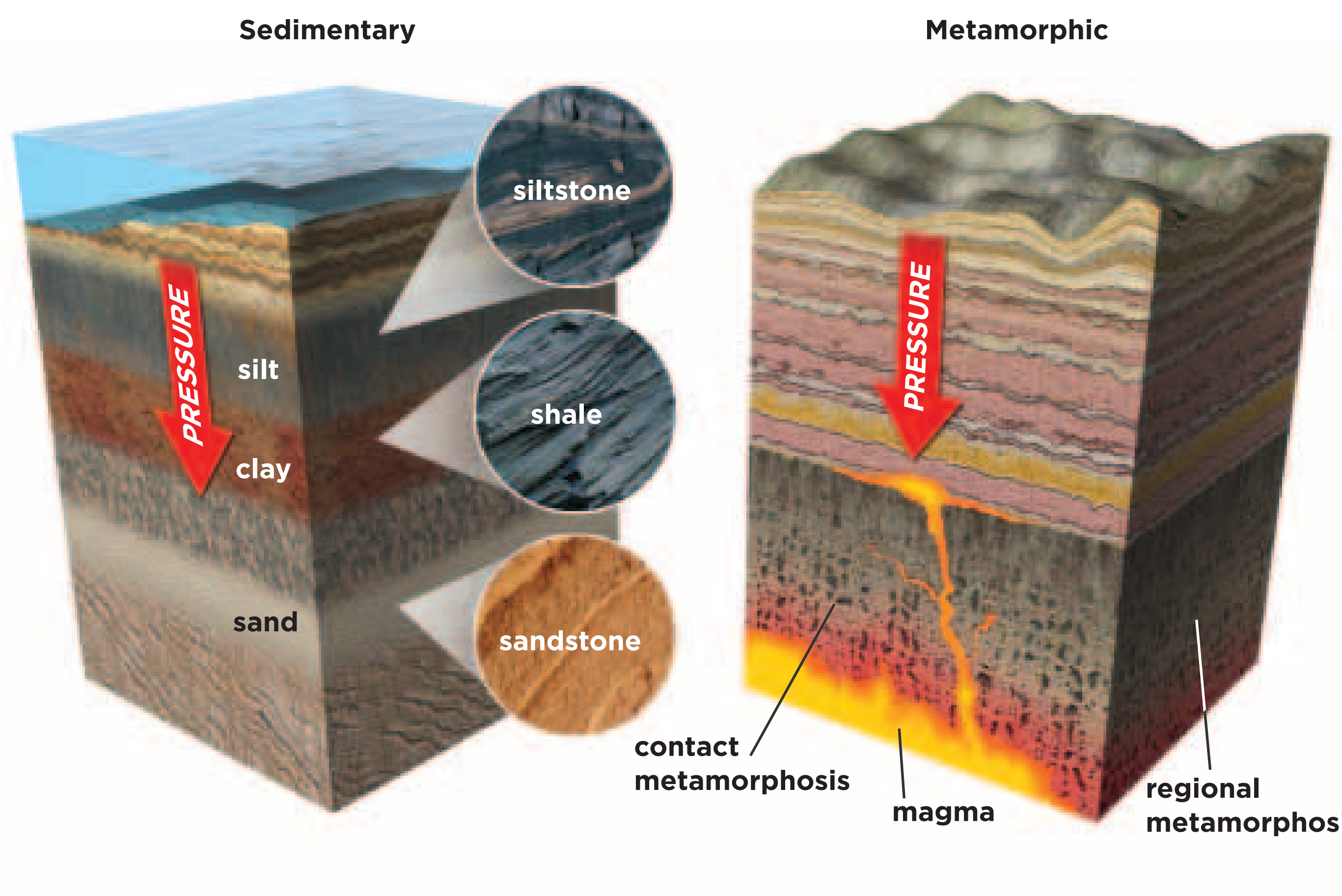


What are sedimentary and metamorphic rock?

Have you ever seen a rock that had pebbles and bits of rock clumped together? It was probably a sedimentary rock. **Sedimentary rock** forms when small pieces of rocks, minerals, and shells are deposited, buried, and then squeezed and cemented together.

This type of rock sometimes contains fossils, the remains or traces of living things from the past. The process of forming sedimentary rock begins with weathering, the gradual breakdown of existing rock into smaller pieces. Wind, water, and ice carry away these small rock pieces, or sediment.

Sedimentary and Metamorphic Rock



Types of Sedimentary Rock

Examples	How It Formed
shale, sandstone, conglomerate	Layers of sediment were compacted and cemented together, forming new rock.
gypsum, halite, limestone	Water dissolved minerals from rock. Over time, the water evaporated, leaving minerals behind.
coquina, coal	Fossils and other remains of living things piled up into layers. Pressure turned the layers into solid rock.

Eventually, the sediment settles in a new location. As new sediment is added, layers form. As layers of sediment build up, the layers above press down upon the fine particles beneath them. The pressure on the lower layers increases. The particles beneath are squeezed and cemented into various layers of rock. Some of the rock layers are dense and solid, and others are porous. The characteristics of some different types of sedimentary rock are shown in the table on the left.

Metamorphic Rock

Rock that has been changed and formed by heat, pressure, or a chemical reaction is called **metamorphic rock** (met•uh•MAWR•fik). The word *metamorphic* means "changed." Metamorphic rock begins as igneous rock, sedimentary rock, or even other metamorphic rock.

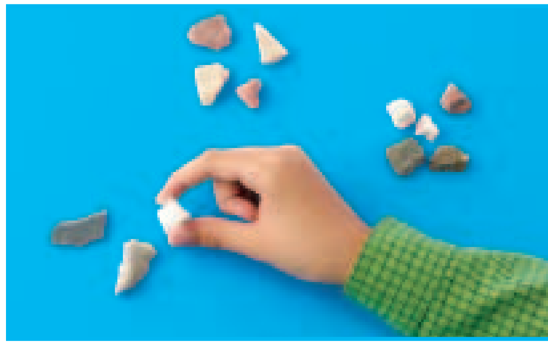
Metamorphic rock usually develops deep underground. High temperatures and pressure from overlying rock layers change the structure and texture of the older rock. Metamorphic rock is normally hard and nonporous.

The high heat and pressure needed to produce metamorphic rock are generated in two basic ways. Rock in a large area, such as a plate boundary, may be exposed to high heat and pressure that change the rock's structure and texture. This is known as *regional metamorphism*. In other cases, magma rises through the crust and can change the structure and texture of the rock it touches. This is called *contact metamorphism*.

Quick Lab

Play the Rock Game

1. **Observe** Using a hand lens, examine the mystery rocks assigned to your group.
2. **Classify** Sort the rocks into piles of igneous, sedimentary, and metamorphic rocks. Record which rocks you placed in each pile.



3. **Interpret Data** Trade places with another group. Use the identification chart provided by your teacher to see whether the other group classified their rock samples correctly. Give the group you are evaluating one point for each correct identification.
4. **Communicate** Choose one of the rocks in your group of samples, and write a possible history for it. Why does the rock have its particular properties?

Quick Check

Compare and Contrast How do the characteristics of sedimentary rock differ from those of metamorphic rock?

Critical Thinking Explain why petroleum is not found in metamorphic rock.

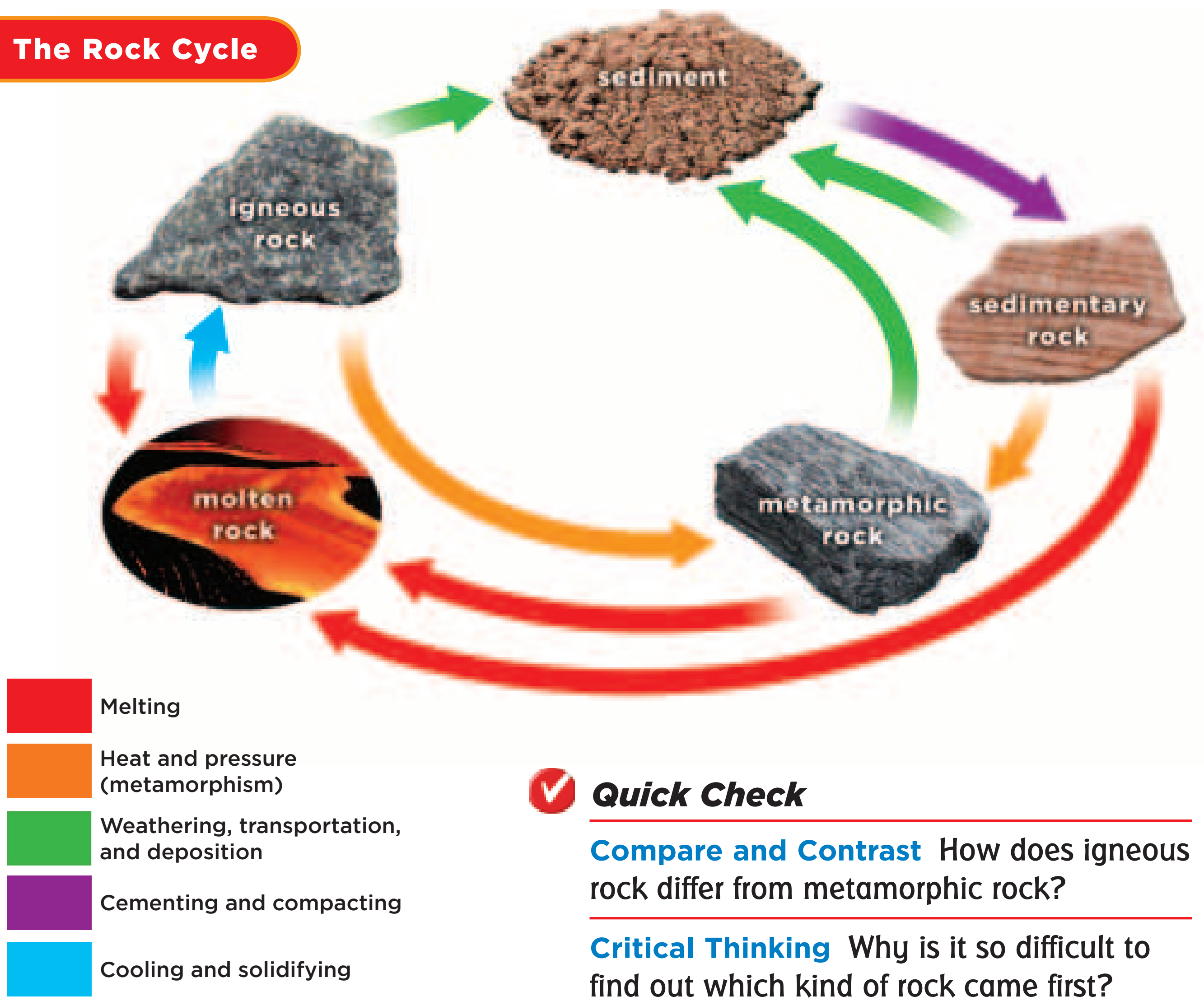
What is the rock cycle?

Which kind of rock came first? Was it igneous rock, which develops from magma or lava? Was it sedimentary rock, which forms from sediment? This is a difficult question to answer. Magma and lava are molten rock, made from rock that already existed. Sediment contains pieces of broken rock. Metamorphic rock forms from other rock.

The answer is that all rock comes from other rock. In a process known as the **rock cycle**, rock can continually change from one kind of rock into another over long periods of time.

The diagram below shows the changes that occur in the rock cycle. Magma cools, crystallizes, and becomes igneous rock. Weathering can break any type of rock into sediment. Sediment may then become sedimentary rock. Under heat and high pressure, sedimentary or igneous rock can become metamorphic rock. Any type of rock that is pushed back into the mantle can melt and turn into magma once again.

The Rock Cycle



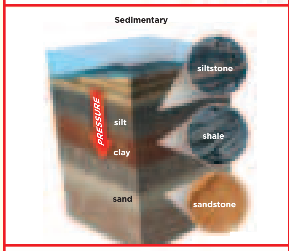
Quick Check

Compare and Contrast How does igneous rock differ from metamorphic rock?

Critical Thinking Why is it so difficult to find out which kind of rock came first?

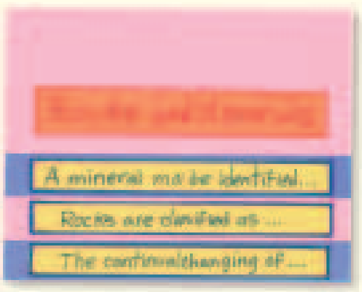
Lesson Review

Visual Summary

	**Minerals** may be identified by observing properties such as color and streak.
	Rocks are classified as **igneous**, **sedimentary**, or **metamorphic**.
	The continual changing of rock from one type into another is called the **rock cycle**.

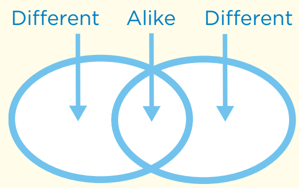
Make a FOLDABLES™ Study Guide

Make a Layered-Look Book. Use the titles shown. On the inside of each fold, complete the statement with information you have learned about rocks.



Think, Talk, and Write

1. **Main Idea** All minerals have different ________.
2. **Vocabulary** When magma or lava hardens, ________ rock is produced.
3. **Compare and Contrast** How are the three kinds of rock alike? How are they different?



4. **Critical Thinking** Is a rock permanent once it forms? Explain your answer.
5. **Test Prep** **What type of rock is formed from another type of rock under heat and high pressure?**
   A lava
   B igneous
   C sedimentary
   D metamorphic
6. **Test Prep** **Which mineral property is related to the reflection of light?**
   A hardness
   B cleavage
   C luster
   D streak

Math Link

Calculate Weight and Mass

At sea level, any object with a mass of 1 kg weighs 2.2 lb. If a crystal of galena weighs 15.4 lb, what is its mass in kilograms?

Art Link

Make a Montage

Collect photographs of sedimentary rocks from your neighborhood, city, or state. Arrange the photographs in a display. Try to have your pictures suggest a theme.

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Inquiry Skill: Use Variables

Can you grow small mineral crystals into larger ones? How does the concentration of a mineral affect a crystal's growth rate? To answer questions such as these, scientists **use variables** by doing a series of experiments, using a different procedure each time. Then they put together the results of all their experiments, like pieces of a giant puzzle, to answer questions.

scanning electron micrograph of sea-salt crystals

Learn It

When you **use variables**, you identify factors in an experiment that can be changed. To make sure the results of experiments are valid, scientists try to test all variables, one at a time. First, scientists perform an experiment. Then, they repeat the test while changing only one variable. So that it is a fair test, they make sure all other factors remain exactly the same.

It is important to record your observations when you change variables in an experiment. Then you can compare and contrast the results to find out how each variable affected the outcome of your original experiment.

Try It

Materials **2 plastic glasses, water, salt, 100 mL graduated cylinder, 2 plastic spoons, 2 pieces of string, 2 pencils**

1. Label one glass *Glass 1* and the other *Glass 2*. Fill each glass halfway with warm water. Pour 50 mL of salt into glass 1 and 100 mL of salt into glass 2. Stir the water in each glass until the salt dissolves.
2. Tie a string around the middle of each pencil. Balance a pencil across the top of each glass so the string hangs down into the water without touching the sides or bottom.
3. Observe the glasses for several days. Write your observations on a chart like the one shown.
4. **Use variables** by repeating this experiment using ice-cold water instead of warm water. Record the results.

5. Repeat the experiment again. This time, change a different variable, such as the size of the glasses, the amount of water, the length of the strings, or the amount of time before you check the strings. Record the results.

6. In which glass did the lump of crystals form faster? Why? Did changing your variable in step 4 change your results? In step 5? Explain.

Variable	My Observations
Test 1: Warm Water	
Glass 1 (50 mL salt)	________________
Glass 2 (100 mL salt)	________________
Test 2: Icy, Cold Water	
Glass 1 (50 mL salt)	________________
Glass 2 (100 mL salt)	________________
Test 3: ____________	
Glass 1 ________	________________
Glass 2 ________	________________

Apply It

1. How would your results differ if you were to **use variables** that have changed? What would happen if you
   - used sugar instead of salt?
   - used soda instead of water?
   - used a paper-towel strip instead of string?
   - did not stir the mixture?
   - used an antacid tablet instead of table salt?
   - used Epsom salts instead of table salt?

2. Choose one of these variables or one of your own. List the variable on your chart, and then repeat the experiment, record the results, and interpret the data. How did changing that particular variable affect your experiment's results?

rock-salt crystals

Lesson 2

Air and Water

Look and Wonder

Water is all around us, and so is the air we breathe. These people in Key West, Florida, are using water and air for recreation, but both water and air are also essential to life on Earth. What happens over time to the water on Earth?

Explore

Inquiry Activity

How can you model Earth's water cycle?

Purpose

Much of the water on Earth undergoes constant change within the water cycle. Make a model to help understand this process.

Procedure

1. **Make a Model** Fill the plastic bottle with about 0.5 L of warm water. Add 2 drops of red food coloring. Place the cap on the bottle. Close it tightly. Cut black construction paper in half lengthwise. Make a ring slightly wider than the base of the bottle. Tape the ends of the paper together. Place the bottle inside this ring base.
2. Place the model in a warm, sunny area. After about an hour, carefully place the sealed bag of ice on top of your bottle. Tape the bag in place if necessary. Leave the bag on top of the bottle for 10 to 15 minutes.
3. **Observe** Remove the bag of ice from the top of the bottle, and describe what you see.

Draw Conclusions

4. **Interpret Data** Did all the water in the bottle stay red? If you put the model back in a warm place, do you think the same thing would happen again?
5. **Infer** If the bottle represents Earth, what does the tinted water represent?
6. **Infer** What does the action of this model suggest about the amount of water on Earth?

Explore More

Can a model Earth and its water cycle support the life of a green plant? Design an experiment. What materials would you need to test your prediction?

Materials

- 2 L plastic bottle with cap
- warm water
- red food coloring
- scissors
  Be Careful.
- sheet of black construction paper
- tape
- sealable plastic bag filled with ice

Step 1

Step 2

Read and Learn

Main Idea

Living things use air and water to carry out their life processes.

Vocabulary

atmosphere, p. 328
ozone layer, p. 329
water cycle, p. 330
precipitation, p. 330
watershed, p. 331
water table, p. 333
aquifer, p. 333
reservoir, p. 333

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Reading Skill

Summarize

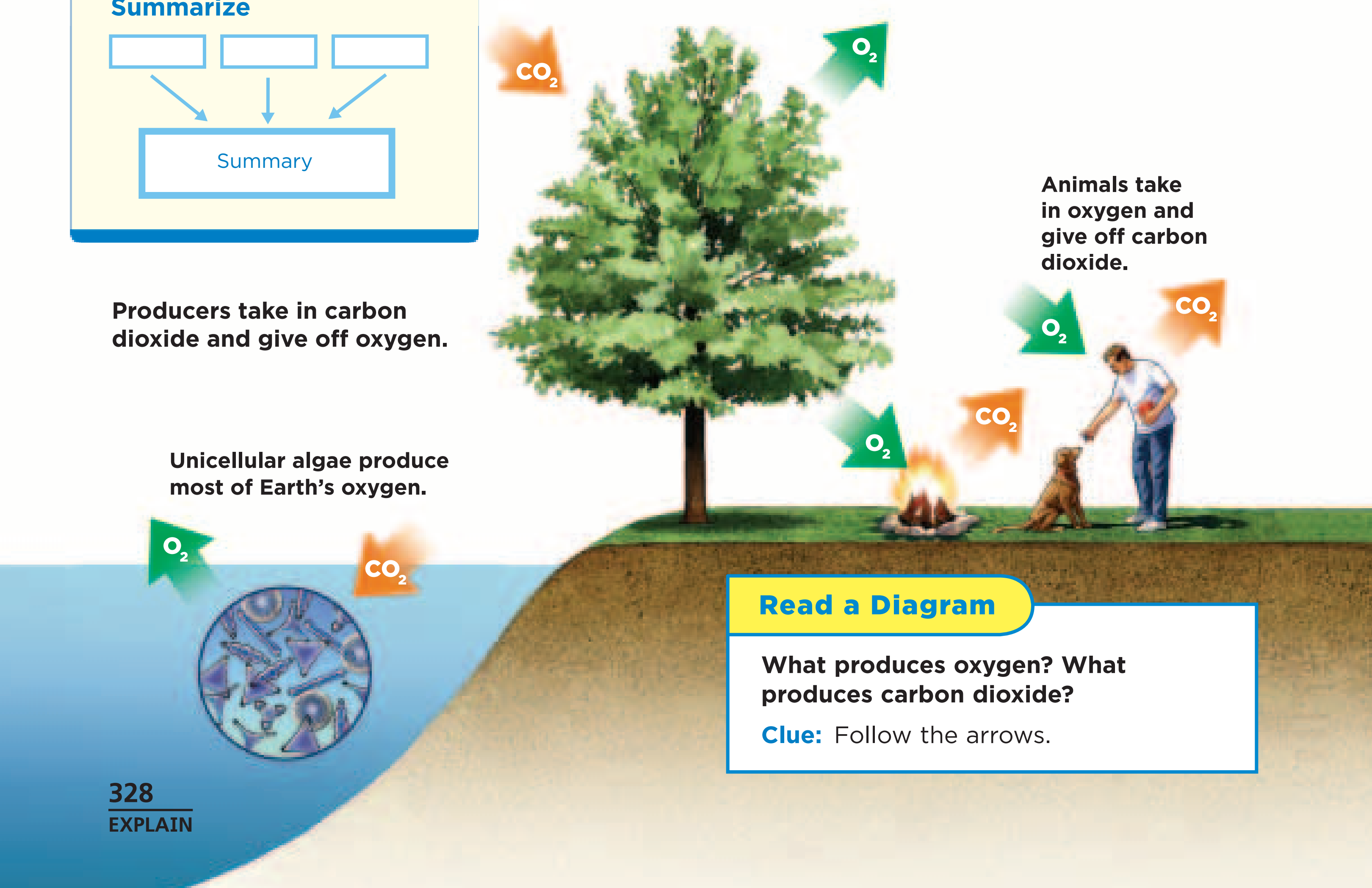
[ ] [ ] [ ] → Summary

How is air useful?

Earth's air sustains life. It protects the planet from small meteors and radiation, or energy waves, and it provides a source of energy. Air is part of the **atmosphere**, the layer of gases that surrounds Earth. Air makes life possible. It consists mostly of nitrogen and oxygen. It also contains water vapor, argon gas, and traces of other gases.

Living things use oxygen for respiration, the breaking down of food to produce energy. As a result of cellular respiration, organisms release carbon dioxide into the air as a waste product. At the same time, plants and other producers take in carbon dioxide to make food. During photosynthesis, producers release oxygen as a waste product. The exchange of oxygen and carbon dioxide among living things is called the oxygen–carbon dioxide cycle.

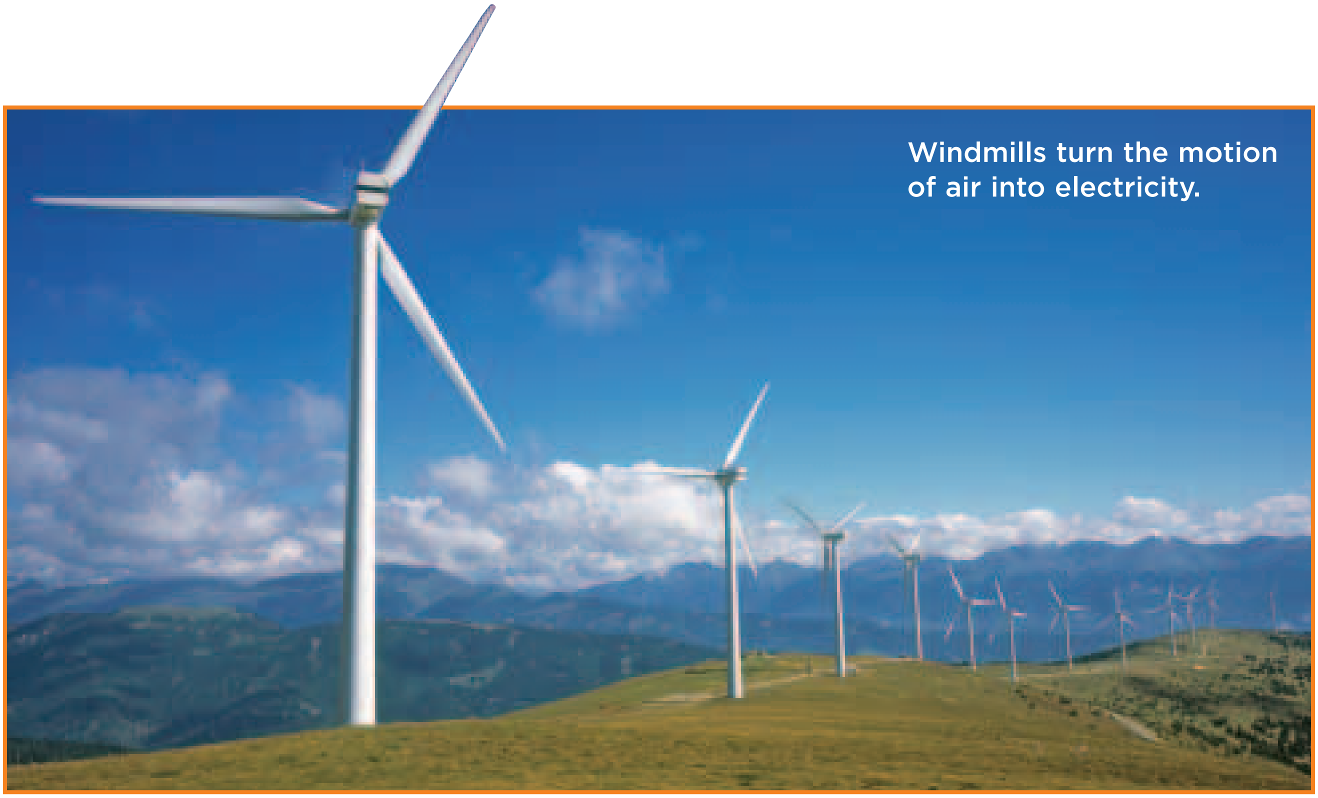
How Earth's Atmosphere Supports Life



Read a Diagram

What produces oxygen? What produces carbon dioxide?

Clue: Follow the arrows.



Windmills turn the motion of air into electricity.

Earth's Atmosphere

Earth's atmosphere is a major source of nitrogen. Plants need nitrogen to make proteins, an important class of foods. Some bacteria take nitrogen from the air and convert it to a chemical form that plants can use. When consumers eat the plants, some of the nitrogen is recycled. When consumers produce waste or die, the remaining nitrogen returns to the soil and air.

Earth's atmosphere also protects life from temperature extremes. Clouds block sunlight during the day. Clouds also stop much of the heat from escaping into space at night so that Earth does not cool off too much.

Earth's atmosphere contains a layer called the ozone layer. The **ozone layer** is a layer of Earth's atmosphere that is made of a special form of oxygen gas. This layer prevents nearly 99 percent of the Sun's powerful ultraviolet rays from reaching Earth's surface.

The atmosphere's moving air, or wind, is a source of energy. Just as blowing on a pinwheel's blades makes the pinwheel spin, so wind moves the blades of a windmill. These blades drive a *wind turbine*, a machine that generates electricity. Wind is also used in recreation. People fly kites, windsurf, and sail. All of these activities use wind as a source of energy.

Quick Check

Summarize Describe how Earth's atmosphere sustains life.

Critical Thinking What might happen to the atmosphere if the number of plants on Earth declined significantly?

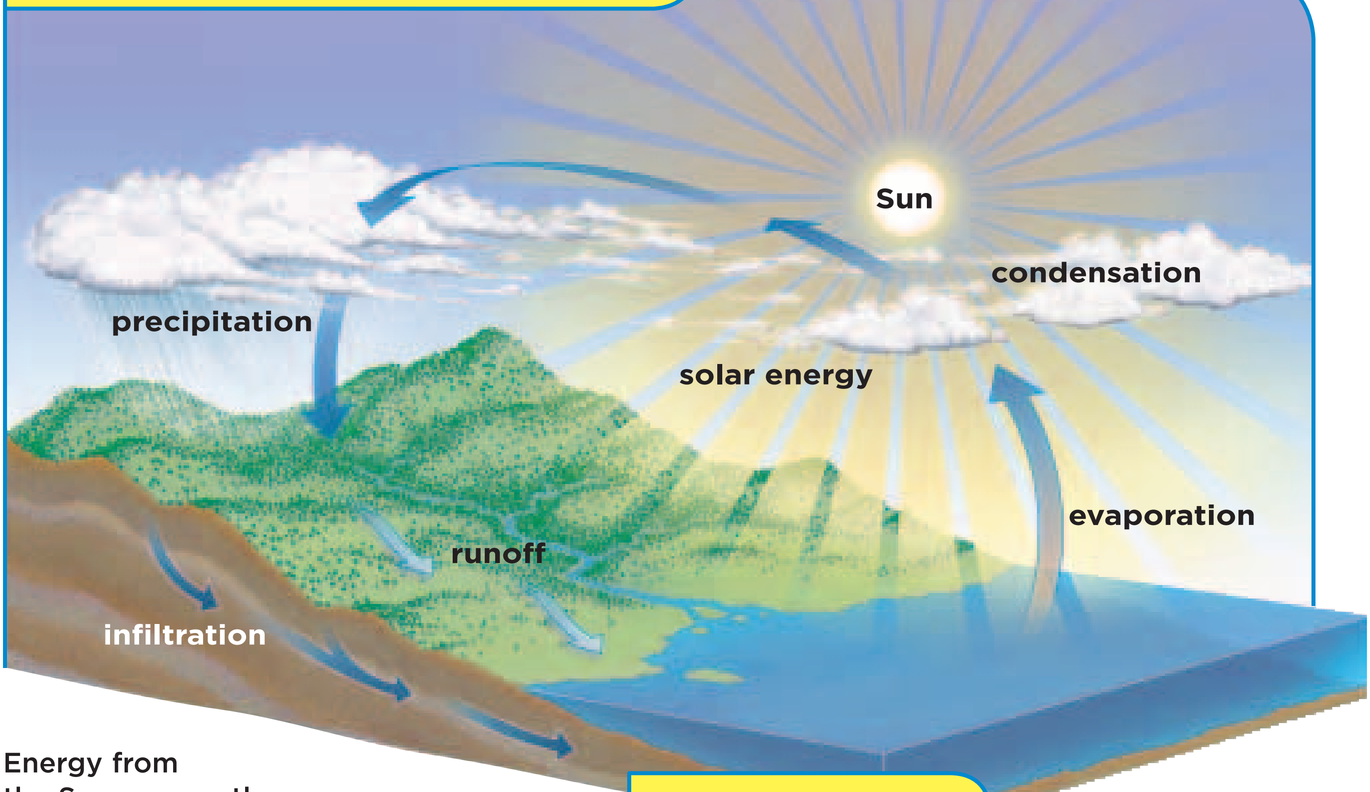
FACT Earth's atmosphere blocks most of the solar wind, or high-energy particles that come from the Sun.

Where do we find water?

Water is one of Earth's most important resources. Only a small fraction of Earth's water is usable fresh water. Fortunately, fresh water is constantly renewed by the water cycle. The **water cycle** is the continuous movement of water between Earth's surface and the air.

Water evaporates from the oceans and from bodies of water on land. The water vapor in the air rises and cools. The water then condenses into clouds of tiny droplets. When the water droplets in the clouds become heavy enough, they fall to the ground as **precipitation**. Some of the water then evaporates into the air. Some seeps into the ground, becoming *groundwater*. Some of the water moves downhill over the surface as *runoff* and enters streams and rivers. These rivers eventually reach the oceans and other large bodies of water, where the cycle continues.

Solar Energy and the Water Cycle



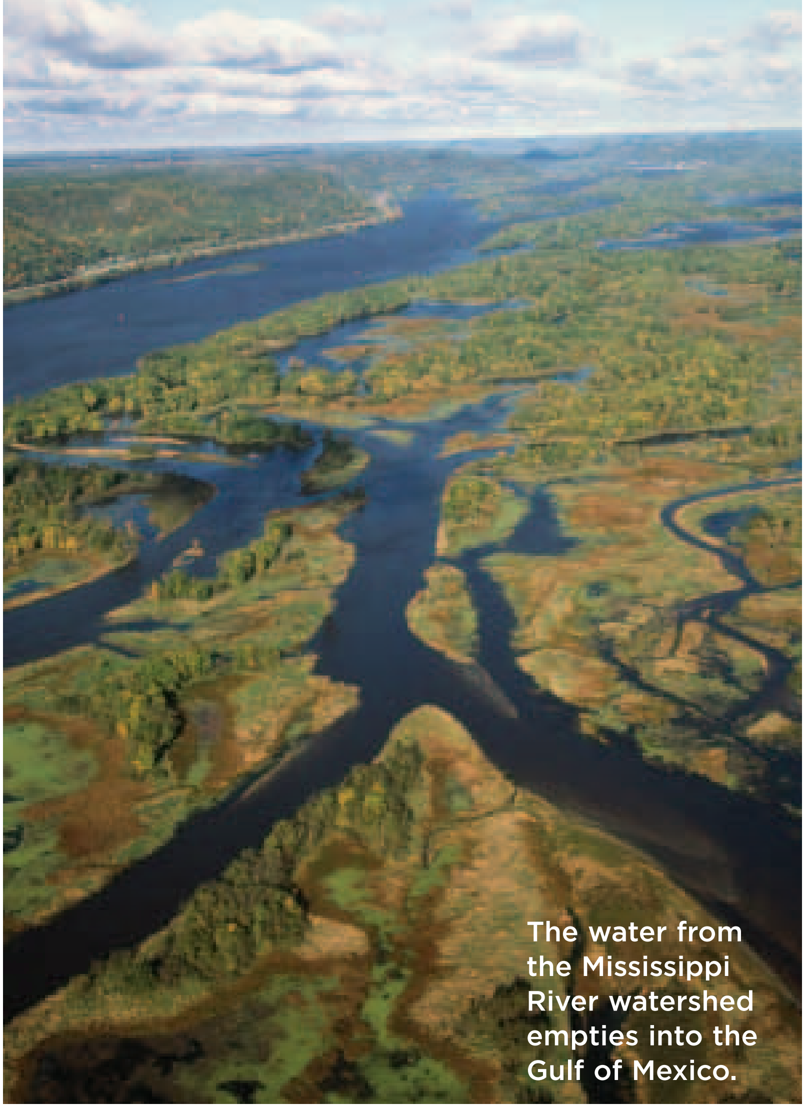
Energy from the Sun powers the water cycle. The water cycle works because water can change from a solid to a liquid to a gas and back again.

Read a Diagram

What happens after water vapor condenses?

Clue: Follow the arrows to trace the path through this cycle.

LOG ON *Science in Motion* Watch solar energy and the water cycle at www.macmillanmh.com



The water from the Mississippi River watershed empties into the Gulf of Mexico.

Watersheds

Runoff enters streams, which eventually become part of a river system. In a river system, many channels conduct the water into a main river. The region that contributes water to a river or a river system is called a **watershed**. Landforms such as mountain ridges often form the boundaries of a watershed.

Quick Check

Summarize Identify the steps in the water cycle.

Critical Thinking Why is the water cycle so important to living things?

Quick Lab

Earth's Water

1. Pour 1 L (1,000 mL) of water into a beaker. This represents all the water on Earth.
2. **Make a Model** Pour 972 mL of this water into a large graduated cylinder. Add green food coloring. This water represents Earth's ocean water.
3. Pour the remaining 28 mL into a medium-sized graduated cylinder. Add blue food coloring. This water represents Earth's fresh water.
4. Transfer 4 mL of the "fresh water" to a small graduated cylinder. This water represents Earth's groundwater.
5. Transfer 3 mL of the "fresh water" to another small graduated cylinder. This water represents the water in Earth's lakes and rivers as well as in its soil and air. The remaining fresh water represents Earth's ice caps and glaciers.
6. **Use Numbers** Divide each amount of water (in milliliters) by 1,000. Then multiply each answer by 100. Find the percent of Earth's water that each graduated cylinder represents.
7. **Use Numbers** Make a pie chart of these percents to show how Earth's water is distributed.

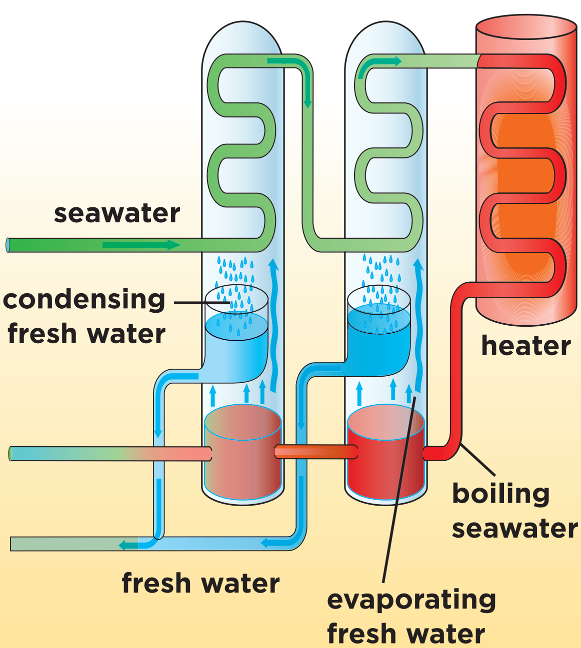
How is water useful?

If 100 pennies represented all the water on Earth, fewer than 3 cents would represent fresh water. More than 97 cents would be salt water.

The salt in salt water is mostly halite, or rock salt. As water evaporates into the air, it leaves behind the dissolved halite and other materials. The water left behind becomes more concentrated with salt. This is why the oceans are salty. As precipitation falls and streams flow into oceans, the amount of salt and the amount of water in the oceans stay about the same.

Although ocean water is too salty for people to drink, it still plays an important role in what we eat. Ocean water contains dissolved minerals and carbon dioxide. Producers use these materials and sunlight to make food.

Desalination



▲ Hydroelectric plants such as this one in Washington state produce about 10 percent of the power used in the United States.

Producers, in turn, become food for other sea life. The sea life may then become food for people. Seawater contains almost every element and mineral humans need. These elements and minerals become part of the plants and animals that people eat.

Scientists have found ways to turn salt water into fresh water. This is called *desalination*. In one such process, seawater enters a desalination plant and is heated until it is boiling. The hot seawater is then pumped to a low-pressure chamber, where it evaporates rapidly. The evaporated water is collected and condensed as fresh water. This is one of the many desalination processes used in areas where fresh water is very scarce.

The oceans have an important effect on the climates of different areas. Global ocean currents circulate warm water from the equator and cold water from the polar regions. These currents help form weather patterns on land.

Using Fresh Water

When rain or snow falls, some water seeps into the spaces among rocks and soil. This groundwater moves until it is blocked by rocks so tightly packed that there are few places for the water to flow into. As the water backs up, it fills the spaces in the rocks and soil above.

The top of this water-filled space is the **water table**. The depth of the water table varies in different places. In some areas, the water table is close to Earth's surface. In other places, the water table is deep underground. A spring is a place where groundwater comes out of the ground. Springs are located where the water table meets the surface.

Some people in suburban or rural areas use water that comes from wells. Wells are holes that are dug below the water table.

Many people use pumps to obtain water from wells. Some wells extend down into an **aquifer**, an underground area of rock and soil filled with water that is squeezed between tightly packed layers of rock. A well that extends down to an aquifer is called an *artesian well*. Artesian wells do not need pumps. Water spouts up from these wells because of pressure from the rock layers.

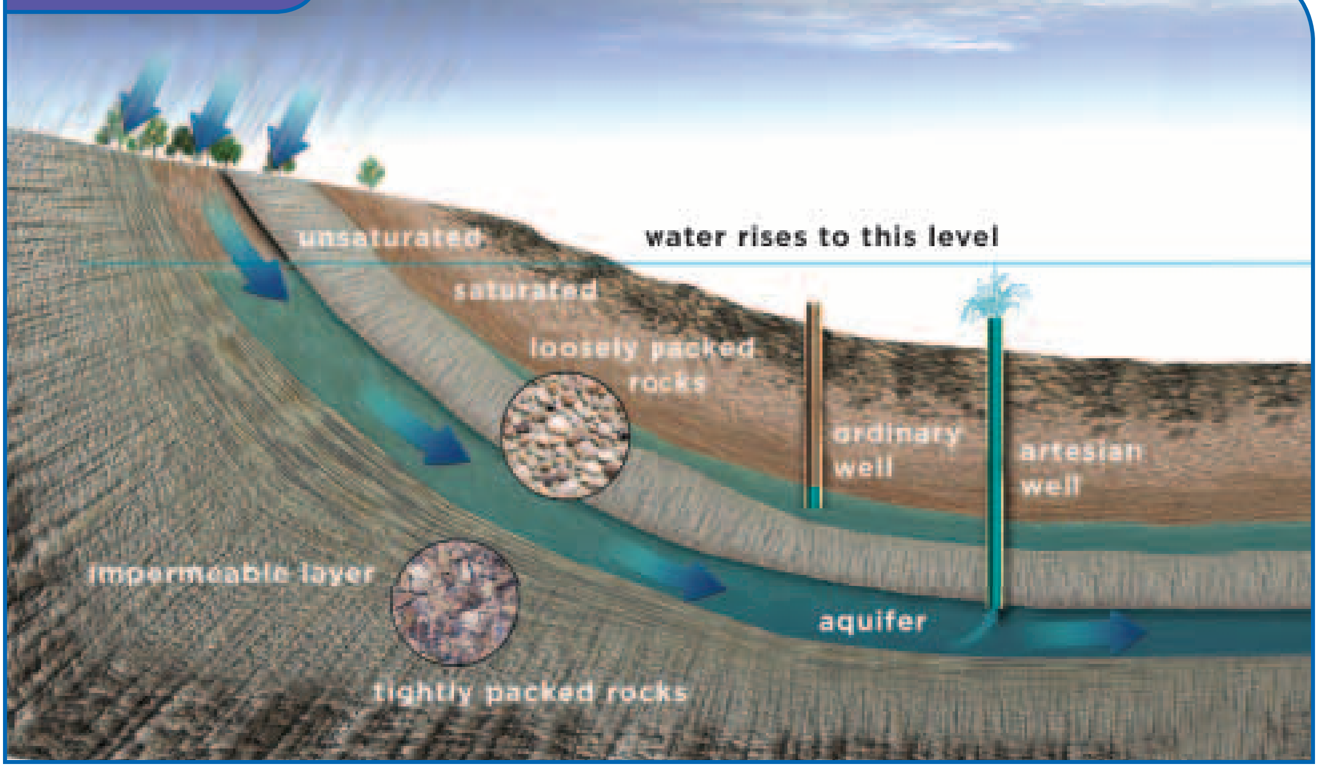
Most cities and large towns need to store supplies of fresh water in **reservoirs**. Reservoirs may be natural or built by people. Pipelines carry the water from the reservoirs into cities.

Quick Check

Summarize Describe some of the places where people find fresh water.

Critical Thinking Why is it important to conserve fresh water?

Groundwater



▲ During a drought, once-fertile land is unable to support vegetation.

▲ Hurricane Katrina flooded much of the Gulf Coast, including New Orleans.

What are droughts and floods?

When there is a lack of precipitation such as rain or snow over an extended period of time, a *drought* can occur. During the 1930s, the southern Great Plains suffered from a drought. This area became known as the "dust bowl." The drought was so severe that most crops failed. Huge dust storms blew away the dry topsoil, making large areas look like deserts.

Fortunately, people learned from this difficult experience. They found ways to help protect the land during a drought. For example, farmers used contour-plowing methods to help minimize erosion. They also planted trees as windbreaks.

Sometimes an area receives too much water. When a stream, river, or lake receives more water than its banks can hold, a *flood* results. Floods can sometimes be predicted. For example, floods often occur during wet seasons. They also can occur during the spring snowmelt. However, sudden storms can increase the amount of water in a river and produce unexpected floods.

Scientists try to predict when floods will occur. They study the amount of water in rivers or lakes, and the types of terrain that surround an area. This knowledge helps scientists make better predictions. However, there is still a lot more that scientists must learn. When Hurricane Katrina struck the Gulf Coast in 2005, the New Orleans levees—dams or banks built along a river to prevent flooding—failed. As a result, many areas were flooded.

Quick Check

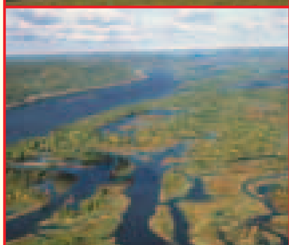
Summarize How can people protect the land from soil loss due to wind?

Critical Thinking Why is predicting when floods might occur important?

Lesson Review

Visual Summary

Air sustains and protects life on Earth. Moving air, or wind, is also a source of energy.

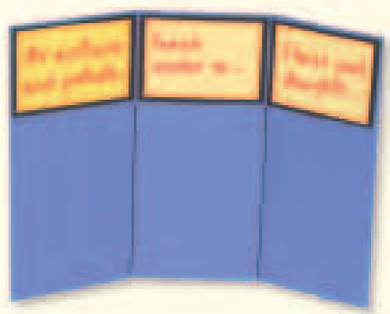


Fresh water is constantly recycled by the water cycle.

Floods and **droughts** occur when an area receives too much or too little water.

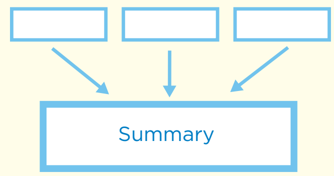
Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add other details about air and water.



Think, Talk, and Write

1. **Main Idea** Describe some life processes that require air.
2. **Vocabulary** Almost 99 percent of the Sun's ultraviolet rays are blocked by a part of Earth's atmosphere called the ________.
3. **Summarize** Explain the steps in the water cycle.



4. **Critical Thinking** How does the Sun help provide people with fresh water?
5. **Test Prep** **Which of the following is NOT a function of Earth's atmosphere?**
   A It turns carbon dioxide and oxygen into glucose.
   B It enables animals and plants on Earth's surface to survive.
   C People use it to generate electricity.
   D It protects Earth's surface from solar radiation.
6. **Test Prep** **Water falling to Earth is called**
   A condensation.
   B precipitation.
   C runoff.
   D evaporation.

Writing Link

Explanatory Writing

Compose a poem that describes what you can do to help protect your neighborhood from a flood.

Social Studies Link

Research a Drought

Research a recent drought. How did it affect people? How did it affect the land? Write a report, and present your findings to the class.

LOG ON e-Review Summaries and quizzes online at www.macmillanmh.com

Clean Up Our Watershed!

Persuasive Writing

Good persuasive writing

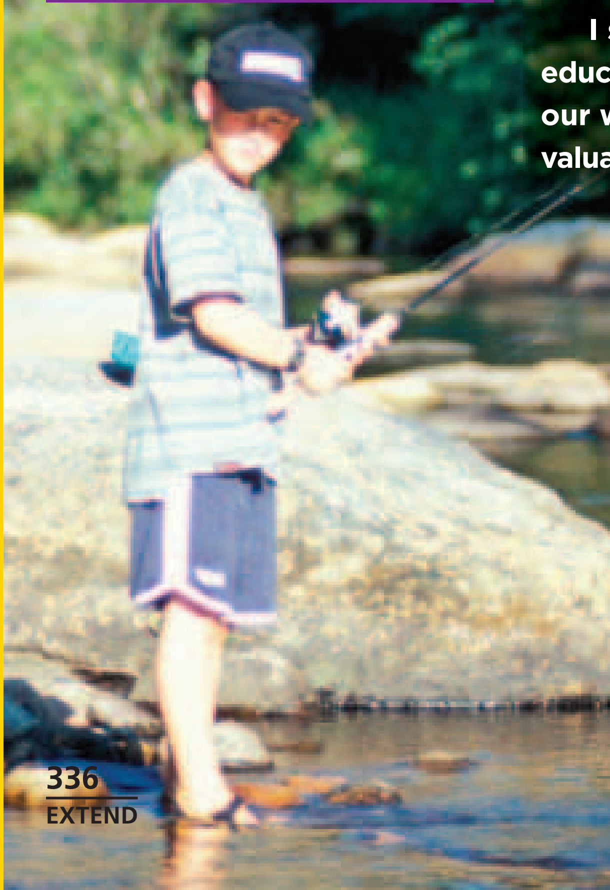
- clearly states an opinion about a specific topic
- uses convincing reasons and arguments
- organizes reasons in a logical order
- usually saves the strongest argument for last
- includes opinion words

We are lucky to live in a watershed, a land area that drains water into our many creeks and the beautiful Tappan River. Many of us enjoy picnicking near the water, watching the birds and other wildlife, and fishing in the creeks and the river. However, these bodies of water are in danger, and we are responsible for the problem.

Our creeks and river are becoming increasingly polluted. Different kinds of pollutants enter the water through storm drains on the streets of our community. Rain, melted snow, and lawn water flow into the drains. These waters carry motor oil, pet waste, litter, fertilizers, and pesticides. Water from the sewer systems in our homes can also add pollutants. The water may have been treated, but some substances cannot be removed using normal treatment methods.

If we continue to pollute the watershed, then plants, fish, and birds will die in the creeks and the river. We will not be able to fish in the river anymore, because there might be poisonous mercury levels in the fish. Other wildlife will lose a source of fresh water as well.

I strongly believe that we must work together to educate people about these problems and learn to keep our watershed clean. Unless we act now, we will lose a valuable resource for ourselves and for future generations.



Write About It

Persuasive Writing Find out what actions people can take to make watersheds less polluted. Write a persuasive essay urging people to do two of these actions.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Solar Heating: What Are the Costs?

Solar energy is a renewable source of both heat energy and light energy. Solar collectors, such as solar panels, absorb energy from the Sun and can provide hot water or heat for homes and businesses.

Solve It

1. A 60-watt (W) light bulb uses 4 kilowatt-hours (kWh) per month. (A watt is a unit of electrical power; a kilowatt is 1,000 W.) How many kilowatt-hours does it use per year?
2. A home heated by solar panels uses 2,250 kWh of electricity per year. A home heated by power plant–generated electricity uses 9,000 kWh of electricity per year. At a cost of 40 cents per kWh for solar energy and 12 cents per kWh for power plant–generated electricity, which home has lower electricity costs per year? What is the difference in electricity costs between the two homes, expressed as a percent?
3. "One family with solar heating spent $12,000 to install the solar panels. If they spend $900 per year for electricity, how many years will it take for them to use 10,000 kWh?" Do you have all the information you need to solve this problem? If not, what else would you need to know?

Finding Yearly Cost

- To determine the yearly energy cost for an item, multiply the cost per day, week, or month by the appropriate number to total a year.
- To determine the cost of using either solar or power plant–generated electricity, multiply the amount of electricity used by the cost per kWh.

Lesson 3

Other Land Resources

Look and Wonder

Crops such as the corn in this field in Nebraska need resources such as air and water to grow and are themselves an important natural resource. What are the natural resources in the world around us?

Explore

Inquiry Activity

What are objects made from?

Make a Prediction

From which natural resources are most common objects made? Do they come from plants, animals, minerals, rocks, soil, water, metals, or oil? Write your answer in the form of a prediction: “Most objects in the classroom are made from . . .”

Test Your Prediction

1. Tape the white butcher paper on the wall around the classroom. Divide the paper into four sections, labeled *Plants*, *Animals*, *Minerals*, and *Oil*.
2. **Record Data** Your teacher will assign a small group to each section of the paper. One group will identify every object in the classroom made from plant materials, another will identify objects made from animal materials, and so on.
3. **Predict** Draw each object on the mural, and identify the natural resource from which it is made. Indicate for each object whether or not the natural resource is one that will eventually be used up.

Draw Conclusions

4. **Interpret Data** Were some objects made from several natural resources? Which objects were made from natural resources that can be replaced? Which were made from resources that cannot be replaced and will eventually be used up?
5. **Infer** Consider the objects listed that are made from natural resources that will eventually be used up. Do you think there might be other things you could use instead? List some of your ideas.

Materials

- tape
- long sheet of white butcher paper
- markers or crayons of different colors

Step 3

Explore More

You have identified resources from which classroom objects are made. Additional resources are needed to manufacture these objects. Choose three different objects listed on the mural, and research the resources used to make each of them. Present your results to the class.

Read and Learn

Main Idea

Natural resources are classified as renewable or nonrenewable.

Vocabulary

renewable resource, p. 340

nonrenewable resource, p. 340

pollution, p. 344

smog, p. 345

acid rain, p. 345

landfill, p. 346

biodegradable, p. 346

toxic waste, p. 346

LOG ON e-Glossary at www.macmillanmh.com

Reading Skill

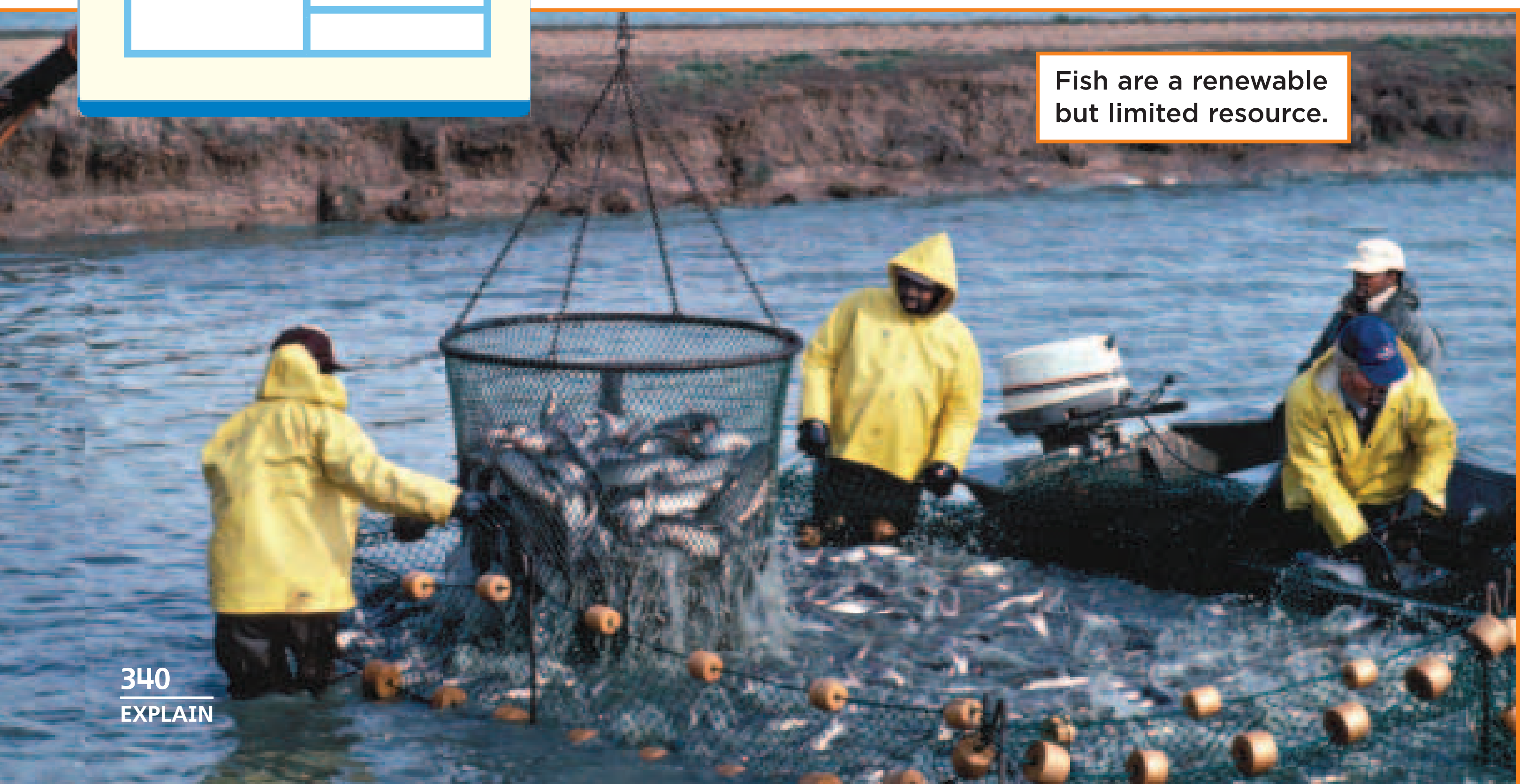
Main Idea and Details

Main Idea	Details

What are renewable resources?

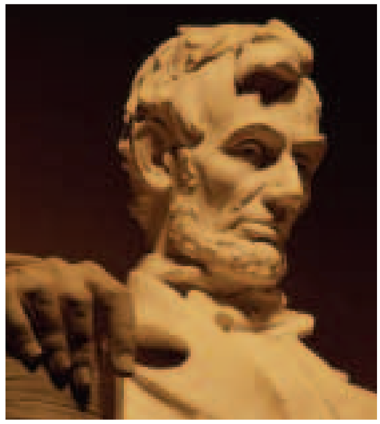
One way scientists organize Earth's natural resources is by the time needed to produce them. Nature replaces some resources relatively quickly, and some resources can be reused. Such resources are called **renewable resources**. One example is water, which is replenished through the water cycle. Solar energy, another renewable resource, is continually supplied by the Sun. Other resources, such as copper, coal, petroleum, and other minerals, are nonrenewable. **Nonrenewable resources** either cannot be replaced or take so long to replace that they are considered nonrenewable.

Availability is one factor that determines how resources are classified. Nonrenewable resources exist in limited quantities or are used up more quickly than they can be replaced. Trees, for example, are a renewable resource. However, if trees are cut down more quickly than they are replaced, trees may be regarded as a nonrenewable resource. Wildlife falls into the same category. Earth's oceans once contained seemingly endless quantities of fish. However, modern fishing fleets catch so many fish at once that many fish populations are declining rapidly.



Fish are a renewable but limited resource.

Minerals and Soil



Minerals make up the solid matter in Earth's crust. Many minerals form when magma cools and hardens into a solid beneath the surface of Earth. Some minerals, such as diamond, form deep within Earth, where the carbon that diamond is made of is under intense heat and pressure. Minerals include common table salt, gypsum, quartz, and gold. Most minerals are difficult to obtain and expensive to remove from the ground. Minerals are nonrenewable resources.

Rocks that contain useful substances, such as minerals, are known as *ores*. People mine for ores because of their value. Minerals have a wide range of uses, from construction materials to jewelry. *Gems* are minerals that are rare and beautiful. Diamonds, emeralds, sapphires, and rubies are a few well-known gems.

Quartz, which is usually found on Earth as sand, is used to make concrete and glass. Quartz contains silicon, the element used in the production of computer chips. Pieces of quartz are used in watches and clocks. Energy from a battery keeps the quartz vibrating steadily, and this makes the watch or clock keep very accurate time. Crystals of quartz, mica, and other minerals can be found in granite, a hard rock used in buildings. Minerals also make up marble, a rock that is a favorite material for statues and monuments. The minerals give the marble its rich colors and luster.

▲ Marble from Georgia was carved to form this statue of Abraham Lincoln.

Most rocks in Earth's land are covered with layers of soil, which is a mixture of weathered rock, decayed plant and animal remains, air, and water. People depend on soil to grow food. In some places, it can take hundreds or thousands of years for soil to form.

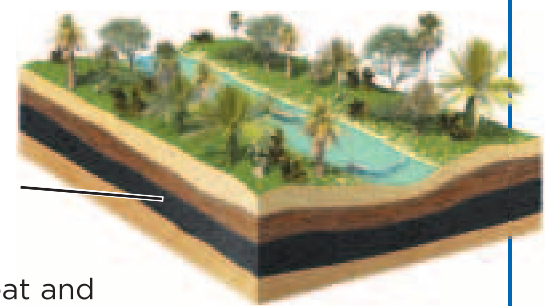
Quick Check

Main Idea and Details What is the difference between renewable and nonrenewable resources?

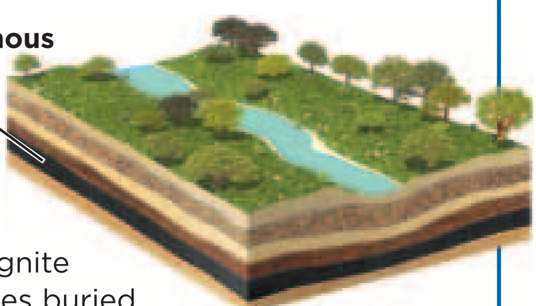
Critical Thinking Why does it take many years for soil to form?

Coal Formation

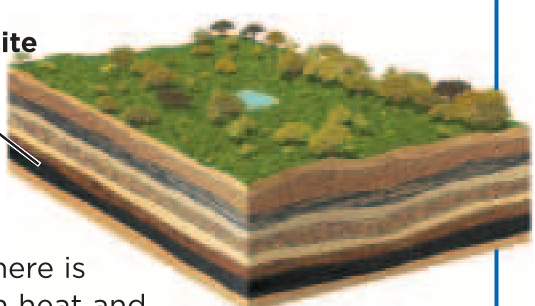
1 Dead plant material builds up in swamps and, over time, forms a layer of peat.



2 Heat and pressure change the peat layers from organic sediment into lignite, a type of coal.



3 If lignite becomes buried by more sediment, the additional heat and pressure can change it into bituminous coal.



4 If there is enough heat and pressure, bituminous coal can change into anthracite, which is also called hard coal.

How do fuels form?

Much of our energy comes from fossil fuels such as coal, oil, and natural gas. These fuels formed over millions of years from the remains of ancient organisms. Fossil fuels are nonrenewable resources, because they take so long to form and their supply is limited. In addition, once they are burned, the fuels cannot be recovered.

The formation of coal began in ancient swamps. When plants in those areas died, they sank to the bottom of the swamps. Eventually, a thick layer of peat, or partly decayed plants, built up. Over time, the layer of peat was buried by layers of sand or other sediment. After more time passed, heat and pressure turned the plant matter into either lignite (LIG•night) or bituminous (bigh•TEW•muh•nuhs) coal. Extreme heat and pressure changed some of the bituminous coal, or soft coal, into anthracite, or hard coal. When soft coal burns, it produces more energy than hard coal. However, it also produces more smoke and odor.

Coal is used to generate electrical energy. Many countries, including the United States, still use coal to supply a large portion of their energy needs.

In the United States, large deposits of coal are strip-mined along the Appalachian Mountains as well as in many western states. Underground mines tunnel below the surface to reach deep veins of coal. In parts of Maine and in the Great Dismal Swamp of Virginia and North Carolina, peat is forming. In millions of years, these areas may become coal beds.

oil field

Oil and Natural Gas

Oil and natural gas formed from the remains of organisms that once lived in the ocean. Their remains settled to the ocean floor and were buried by sand or other sediment before they could decay completely. Over millions of years, pressure and heat turned the remains of these organisms into oil and natural gas.

Petroleum products are used primarily as fuel for transportation. Limited deposits of oil and natural gas exist in North America, the Middle East, Indonesia, and Venezuela. Once these deposits are used up, they will be gone. Geologists search for places where other oil and natural gas deposits might exist. When they find a promising site, they drill test wells, hoping to find useful amounts of oil and natural gas. However, scientists believe that most of these areas have already been discovered.

Quick Lab

Fuel Supply

This table shows how quickly people are using oil and natural gas.

Fuel Use

Type of Energy Source	Proven Reserves (as of January 1, 2004)	Amount Used (in 2003)
oil	1,265 billion barrels	about 80 million barrels per day
natural gas	6,079 trillion cubic feet	about 96 trillion cubic feet per year

Source: U.S. Energy Information Administration

1. **Interpret Data** Examine the information in the table.
2. **Communicate** Based on the data in the table, calculate how long the world's supplies of oil and natural gas will last. Assume that the rates of use remain the same over time.
3. **Use Numbers** Make a line graph that displays your calculations regarding the use of oil and natural gas.

Quick Check

Main Idea and Details How are fossil fuels formed?

Critical Thinking If fossil fuels are still forming, why are they called nonrenewable resources?

FACT Some geologists predict the world's use of natural gas and oil will peak in the year 2010, then begin to decline.

How do people affect the environment?

The things people do every day affect the environment. **Pollution** is a harmful change to the natural environment. Pollution occurs because Earth's land, water, and air have a limited capacity to absorb wastes and to recycle them naturally.

When oil spills occur, they can cause great damage. Oil that leaks from a ship floats on the water's surface. This layer of oil makes feeding difficult for seabirds and coats their feathers, making it impossible for them to fly. Sea mammals can also be covered in oil. Contaminants in oil can sink to the bottom and cause damage there as well. Oil can also wash onto the shore, polluting the coastline and harming the coastal ecosystem.

Many valuable minerals are found near Earth's surface. The easiest way to remove minerals from the ground is strip-mining. This involves scraping away large areas of dirt and topsoil. When it rains, the dirt erodes, and the topsoil washes into streams and lakes.

People may also harm the soil through certain farming practices. When crops are harvested, fields may be cleared as thoroughly as possible. When this happens, there is little plant matter left to decay and restore nutrients to the soil. Planting the same crop year after year also uses up soil nutrients. In time, the soil becomes unable to support plant life. Without plant roots to anchor the soil, wind and rain can carry topsoil away. Cutting down forests without planting more trees also removes roots that prevent soil erosion.

As the populations of urban areas increase, the need for transportation also grows. People build new roads and transit systems. Urban growth brings more vehicles that emit gases and leak oil, polluting the atmosphere and the ground.

Construction will sometimes change the course of a river. This affects all the organisms that live in the area and may harm the local ecosystem.

Clear-cutting

Read a Photo

How might cutting down all the trees in an area affect the environment?

Clue: Compare the affected area of this ecosystem to the unaffected area.

smog

air pollution

How People Affect Water and Air

Many of the ordinary things people do in daily life can cause water and air pollution. Activities such as bathing, washing clothes, and flushing toilets can send harmful residues into water. Some factories that make products we use every day may also dump wastes and chemicals into lakes and rivers.

People working in agriculture usually apply fertilizers and pesticides to soil and crops. Homeowners use fertilizers and pesticides on their lawns and gardens to promote plant growth and prevent damage by insects. Some of these chemicals soak into the ground or flow into lakes and rivers, harming fish, birds, and mammals.

Fertilizer runoff can disrupt entire ecosystems. It increases algae growth so much that the water turns green. Masses of dead, decaying algae can use up vital oxygen dissolved in the water, killing fish and water plants.

When people burn fuels to power factories, heat homes, or drive vehicles, they also produce air pollution. **Smog** is a type of air pollution that can form over urban or industrial areas. *Smog* is a combination of "smoke" and "fog." Smog irritates the eyes, nose, and throat. People with respiratory conditions such as asthma often have breathing problems when levels of air pollution are high.

Acid rain occurs when air pollution mixes with moisture in the atmosphere. Nitrogen and sulfur gases produced by burning fossil fuels combine with water vapor in the air to form acids. These acids fall to Earth as acid rain or snow. Acid rain can pollute water and soil, kill plants and fish, and damage the stone and metal used in buildings and statues.

The United States has laws in effect that protect the environment. These laws help stop some of the causes of air, water, and land pollution.

Quick Check

Main Idea and Details What are some common activities that pollute air and water?

Critical Thinking What might cause an increase in the number of people who have asthma?

Daily Garbage

Read a Photo

What biodegradable materials can you identify in the photo?

Clue: Biodegradable materials are able to break down naturally over a short period of time.

How do people affect the land?

People produce large quantities of garbage every day. Most of this garbage ends up in **landfills**, specially designed places where garbage is deposited into lined pits. The areas are covered with soil. Under supervision, the garbage in landfills decomposes slowly and safely. However, in some areas, garbage is simply dumped into open pits and left to rot. In other areas, garbage is burned in incinerators that give off large amounts of smoke.

Household garbage may contain harmful substances, such as motor oil and weed killers. Some garbage is **biodegradable**, or able to break down naturally over a short period of time. For example, banana peels and paper are biodegradable. Other materials, such as foam cups and many plastic containers, are nonbiodegradable. Since these materials do not break down easily, they add to the amount of trash that needs to be stored.

Industrial materials and waste may contain poisonous chemicals and metals. **Toxic waste**, a collection of poisonous materials, must be disposed of carefully so it does not pollute soil, groundwater, rivers, and lakes. Toxic waste is poisonous to plants, people, and other organisms. Common household items such as paints, cleaners, oils, and batteries can contain hazardous components. These products, if mishandled, can be dangerous to the environment. It is important to follow directions on the proper way to dispose of all toxic materials.

Some recycling systems break down garbage into useful compounds and elements or convert garbage into energy. These are good ways of dealing with the garbage that people produce.

Quick Check

Main Idea and Details How do people pollute the land?

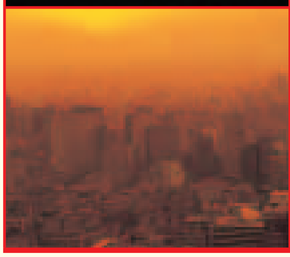
Critical Thinking What are some possible problems with burning garbage to dispose of it?

Lesson Review

Visual Summary

Renewable resources can be replaced over a short period of time. **Nonrenewable resources** cannot.

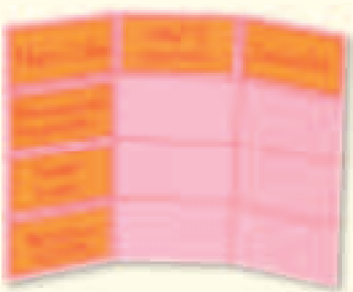
Fossil fuels include coal, oil, and natural gas.



Pollution occurs when people burn fossil fuels, produce garbage, or use fertilizers and toxic materials that enter the environment.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the phrases, and include supporting details about other land resources.



Think, Talk, and Write

1. **Main Idea** Explain the difference between renewable resources and nonrenewable resources.
2. **Vocabulary** When sulfur and nitrogen gases in the air mix with moisture, the result is ________.
3. **Main Idea and Details** How does the burning of fossil fuels pollute the environment?

Main Idea	Details

4. **Critical Thinking** How can using disposable products damage the environment?
5. **Test Prep** **Which of the following is NOT a fossil fuel?**
   A oil
   B natural gas
   C wood
   D coal
5. **Test Prep** **Which of the following is known as hard coal?**
   A anthracite
   B bituminous coal
   C peat
   D granite

Math Link

Calculate Garbage Use

The United States has a population of more than 290 million people. If each person in the country throws away about 2 kg of garbage per day, how much garbage is thrown away in 1 day?

Social Studies Link

Research Coal Mining

Coal is a very important fuel in the history of the United States. Research the impact of coal on the Industrial Revolution. Prepare a presentation that summarizes your findings.

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Clean Steam

We live in a technologically advanced society. We work on computers, heat our food in microwave ovens, and cool our homes with air conditioners. All of these appliances use a lot of electricity. Can you imagine going through one day without using any electricity?

As the use of electricity has grown, scientists have looked for new ways to turn different types of energy into electricity. Some energy sources can have negative effects. When we burn fossil fuels such as coal and oil, we are using up resources that will not be replaced for millions of years and creating air pollution and carbon-dioxide emissions.

Geothermal energy, or heat energy that comes from inside Earth, has none of these negative effects. Geothermal energy can come from steam, from hot water, or directly from hot rocks that may be found close to the surface or several kilometers below.

For example, the people of Santa Rosa, California, benefit from geothermal energy. Hot steam from geysers in the area is used by a power plant to generate electricity. When most people think of a geyser, they imagine a fountain of hot water shooting up out of the ground. The geysers near Santa Rosa are nothing like that. They produce a lot of steam but very little water. They make up the largest dry-steam field in the world.

If geothermal energy is so great, why isn't everyone using it? One reason is that it is not available everywhere. The inside of Earth is very hot, but only in certain areas does some of this heat make its way close enough to the surface. This is typically where there has been recent volcanic activity. Santa Rosa is one of only two locations in the world where dry steam is used to turn turbines to generate electricity.

▶ The Santa Rosa geothermal plant produces enough electricity for 1.1 million people.

Write About It

Summarize

1. In general, how does the use of fossil fuels affect the environment?
2. How is geothermal energy used to generate electricity?

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Summarize

- ▶ Identify the most important points.
- ▶ Briefly describe the main idea and significant details.

American Museum of Natural History

Lesson 4

Saving Resources

Look and Wonder

These solar panels in Daggit, California, gather sunlight to use as a source of energy. People use energy from many sources, including fossil fuels, water, and wind. How do these different energy sources compare? How can we use Earth's resources more efficiently?

Do some light bulbs waste less energy than others?

Make a Prediction

Light bulbs give off both light and heat. Do some types of light bulbs give off more heat and waste more energy than other types of light bulbs do? Write your answer in the form "If one type of light bulb gives off less heat than another, then . . ."

Be Careful. Let bulbs cool before touching them.

Test Your Prediction

Measure Lay the towel on a table. Place the lamp at one end of the towel. Put the thermometer at the other end of the towel. Record the starting temperature. Put the incandescent light bulb in the lamp. Angle the lamp so that it will shine on the thermometer. Plug in the lamp, and turn it on.

Experiment Shine the lamp on the thermometer for 5 minutes. Record the temperature. Turn the lamp off and unplug it. Allow the lamp and the table to cool back to your starting temperature. Repeat steps the process, using the fluorescent light bulb.

Draw Conclusions

Infer Which type of bulb appears to waste less energy as heat?

Communicate Which type of bulb would you recommend to others who want to save energy?

Explore More

Which would be better to use in an air-conditioned home: incandescent lights or fluorescent lights? Make a prediction, and design a way to test it.

Materials

- white towel
- gooseneck lamp
- extension cord
- thermometer
- incandescent light bulb
- meterstick
- stopwatch
- compact fluorescent light bulb

Read and Learn

Main Idea

Conservation helps preserve Earth's resources and our environment.

Vocabulary

geothermal energy, p. 354
biomass, p. 354
hydroelectricity, p. 355
solar cell, p. 355

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Reading Skill

Problem and Solution

Problem
↓
Steps to Solution
↓
Solution

How can we save Earth's land, water, and air?

Earth's resources are precious. People must protect the land, water, and air from waste and pollution. Fortunately, many people have researched and tested ways in which we can help protect the planet.

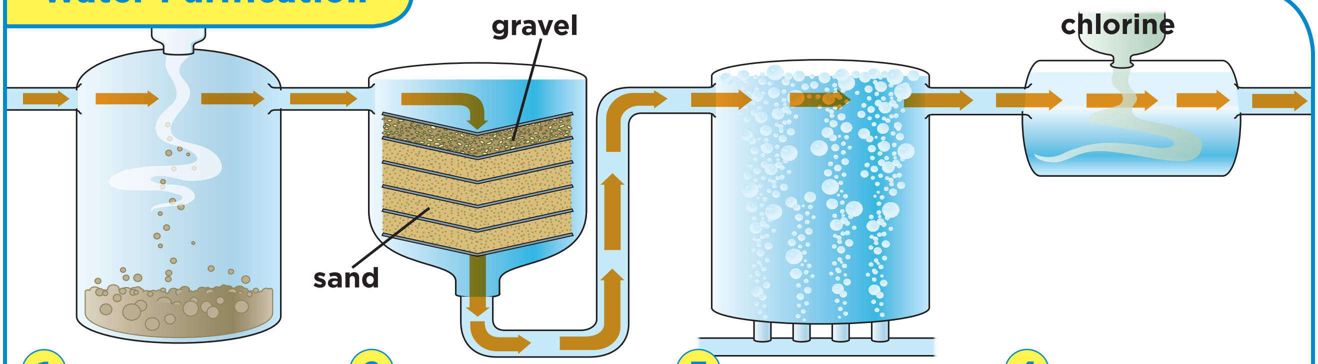
People have developed many ways to protect the soil. After harvesting crops, farmers add humus, or decomposed organic material, to the soil. This replaces minerals removed by the crops as they grow. Many farmers spread manure on fields where they grow their crops. The manure adds organic matter to the soil to help crops grow.

Farmers can also rotate their crops, growing a different crop each year in a given field. This way, the same substances and nutrients are not removed from the soil year after year. Some crops add substances to the soil that other crops remove.

Some farmers plant grass between rows of crops. Others plant crops in "steps" known as terraces. Still other farmers plant trees in a row across the top of a hill. All these methods help trap runoff and prevent the soil from being washed or blown away.

Terraced farming helps conserve soil.

Water Purification



1 Chemical treatments cause particles in the water to form clumps. The larger particles then sink to the bottom.

2 The water flows through layers of gravel and fine sand. The gravel and sand filter out smaller particles from the water.

3 Air may be bubbled through the water to improve the taste.

4 Chlorine is added to kill bacteria. Many cities also add fluoride, which helps prevent cavities in teeth.

Read a Diagram

How do water-purification plants use sand and gravel to help make water drinkable?

Clue: What does the sand seem to do?

Recycling

People should be aware of where garbage goes after they throw it away. Trash placed in wastebaskets is more likely to wind up in landfills than on streets or in waterways. Recycling trash reduces the amount that goes into landfills. Many communities have recycling centers to collect materials, such as paper, glass, metals, and plastic, that can be used again. Using objects made of recycled materials helps reduce waste even more.

Conserving Water

The first Earth Day took place in 1970. Ever since, people have used that day to share their ideas about protecting the planet. One thing that has been discussed is how to purify water after it has been polluted. Water can be purified in water-treatment or water-purification plants. In these plants, polluted water is treated with chemicals. The water is then filtered to remove impurities. Finally, the water is treated with chemicals such as chlorine to kill bacteria and make the water fit to drink once again.

Some countries have passed laws to keep sewage, chemicals, and other wastes out of the oceans. Some countries also limit the catches of commercial fishing fleets. Some nations have set aside areas where marine animals can live undisturbed.

Quick Check

Problem and Solution What are some ways in which farmers try to protect and conserve soil?

Critical Thinking How do wastes put into the oceans affect people?

How can we reduce the burning of fossil fuels?

Fossil fuels such as coal, oil, and natural gas form from the remains of living things. Supplies of fossil fuels are limited because they are nonrenewable. People burn fossil fuels to power their cars, heat their homes, and generate electricity. As our population increases, so does our use of fossil fuels. It is important to conserve current supplies of fossil fuels so that they will last longer. However, the solution is to search for other sources of energy.

Alternative Energy Sources

Alternative energy sources are sources of energy other than fossil fuels. There are many alternative energy sources, and there are many scientists who study ways in which these sources can be used.

Some energy can be found within Earth. Earth's interior is very hot. In some places this heat rises to the surface in the form of steam or hot water. The steam or hot water provides **geothermal energy**, heat from below Earth's surface. Geothermal energy can be used in some areas to heat homes and produce electricity.

Wind is now a major alternative energy source. Windmills use moving air to spin wind turbines that generate electricity. Many windmills can be placed in a given area to generate electricity that is then used in homes, businesses, and industries.

Biomass, or plant and animal wastes that might be thrown away, can also be processed to make fuel. This process, known as *biomass conversion*, takes place in a waste-treatment plant called a biorefinery. These plants produce alcohol-based fuels and generate electricity and heat. Corn and other grains, as well as sugarcane, can also be turned into fuel in this way.

Geothermal steam pours from a power plant in Iceland.


Solar panels provide energy for the International Space Station.

Running water has always provided energy in the United States. The use of running water to generate electricity is called **hydroelectricity**. Many dams have hydroelectric plants at their bases.

The Sun provides the largest amount of energy for Earth. The Sun heats the atmosphere, causes the winds to blow, and drives the water cycle. Plants use energy from the Sun to produce food. People harness the power of sunlight by using **solar cells**, devices that use sunlight to produce electricity. The energy stored in a series of solar cells is enough to light a house and keep it warm all night.

Quick Check

Problem and Solution How can people reduce their dependence on fossil fuels?

Critical Thinking Which alternative energy source do you think people would be most willing to use? Explain the reason for your choice.

The Power of Water

Make a list of factors you think affect how well a waterwheel works. How can you design the blades on a waterwheel so that they turn as fast as possible?

Make a Model Cut eight equally spaced slits from the rim to the base of a plastic cup. **Be Careful.**

Fan out the sections of the cup to form eight "blades." Poke a hole through the bottom of the cup, and insert a pencil as an axle.

Observe Hold the pencil loosely at both ends, and place it in a horizontal position. Hold the fanned-out blades under running water. What happens?

Predict Will your waterwheel turn faster with more blades? With fewer blades? Design an experiment to find out.

What We Throw Away

Source: Environmental Protection Agency

Read a Diagram

Do people discard more paper and cardboard or more plastics?

Clue: Compare the sizes of the wedges.

What are the 3 *R*s?

We can help protect Earth's land, water, and air by following the 3 *R*s of conservation: reduce, reuse, and recycle. We can reduce the amount of natural resources we use. We can reduce the fuel used for heating and air conditioning by adjusting indoor temperatures to use less heat in cold weather and less air conditioning in hot weather. We can also design cars that are more fuel efficient and can encourage people to use them.

Reusing materials saves resources. We can reuse many products. We can use washable tableware instead of disposable cups, dishes, and plates. Making products uses energy, and this energy is saved when we reuse things.

We can also save resources by recycling materials that can be reused in new ways. Separate trash for recycling pickup, or bring paper products, plastic, glass, and metal cans to recycling centers. Recycling reduces the amount of energy needed to make things and also reduces the amount of garbage we produce.

It is also important to recycle electronic equipment. Experts estimate that about 100 million computers become old and outdated in the United States each year. Millions of these computers, as well as televisions, cellular phones, and other products, are thrown away. Since many of these items contain hazardous materials, they can harm the environment if they are not reprocessed properly.

Quick Check

Problem and Solution How does recycling help solve the problem of pollution in the environment?

Critical Thinking How do you think solar cells might be used to help air-condition a home?

Visual Summary

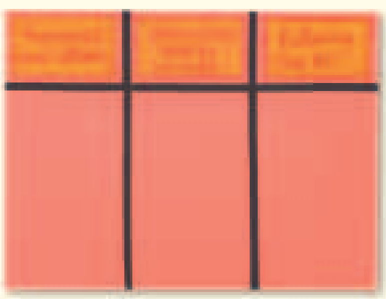
Farmers and others use practices that **conserve** the land, water, and air.

Alternative energy sources can help reduce the use of fossil fuels.

Follow the 3 *R*s—**reduce, reuse, recycle**—to help protect and preserve resources.

Make a Study Guide

Make a Trifold Book. Complete the phrases shown. Add other details about how to save resources.



Think, Talk, and Write

Main Idea What helps preserve Earth's resources and our environment?

Vocabulary Energy from running water is used to generate ________.

Problem and Solution How could you prevent fossil fuels from polluting the environment?

Critical Thinking How do you think solar cells might be used to provide energy at night?

Test Prep **Which type of energy could BEST be used in a geyser-filled area?**

A hydroelectricity
B solar energy
C wind energy
D geothermal energy

Test Prep **Biomass conversion generates energy from**

A plant and animal wastes.
B running water.
C sunlight.
D moving air.

Writing Link

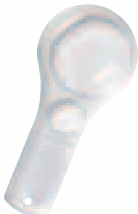
Writing That Compares
Make a brochure about two alternative sources of energy. Describe the two energy sources, and compare their similarities and differences. Share your brochure with your class.

Math Link

Calculate Garbage Production
A family generates about 64 kg of garbage per week. If the family recycled 25 percent of these materials, how much less garbage would they generate each week?

Be a Scientist

Materials



hand lens

igneous rock samples

cup of water

Structured Inquiry

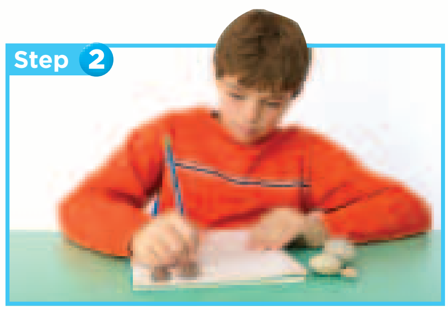
What are some of the characteristics of volcanic rocks?

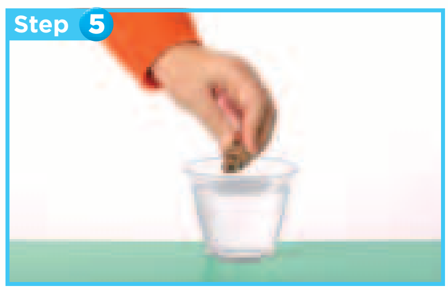
Form a Hypothesis

The cooling of lava from volcanoes is one way igneous rocks are formed. The cooling rate determines the crystal structure and the appearance of the rocks. When lava cools immediately, there are no visible crystals, and the rocks look glassy. When lava takes a few days to cool, the crystals appear very small and look like grains of sand. When the lava cools over the span of a few years, the crystals become very large and form large rocks. What are some characteristics of volcanic rocks? Write your answer in the form of a hypothesis: "If a rock is igneous, then . . ."

Test Your Hypothesis

1. **Observe** Use a hand lens to look at each rock sample.
2. Sketch the crystals, or grains.
3. **Record Data** Feel each rock. Record the texture of each.
4. **Classify** Record the color and coarseness of the grains in each sample.
5. **Experiment** Place each rock in a cup of water. Record your observations.





Draw Conclusions

6. **Compare** Are any of the characteristics the same in all of your samples? Why do you think this happens?
7. **Infer** What factors influenced the colors of the rocks that you observed?

Guided Inquiry

What happens when the pressure changes inside a volcano?

Form a Hypothesis

Can changes in the amount of pressure inside a volcano change the force of the eruption? Write your answer in the form of a hypothesis: "If the pressure increases inside a volcano, then . . ."

Test Your Hypothesis

Design an experiment to investigate what happens inside a volcano when there is an increase in magma or gas pressure. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

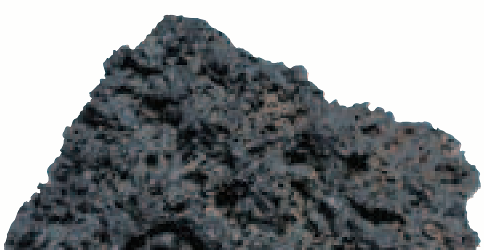
What changes increase the internal pressure of a volcano? Did your experiment support your hypothesis? Why or why not? Present your results to your classmates.

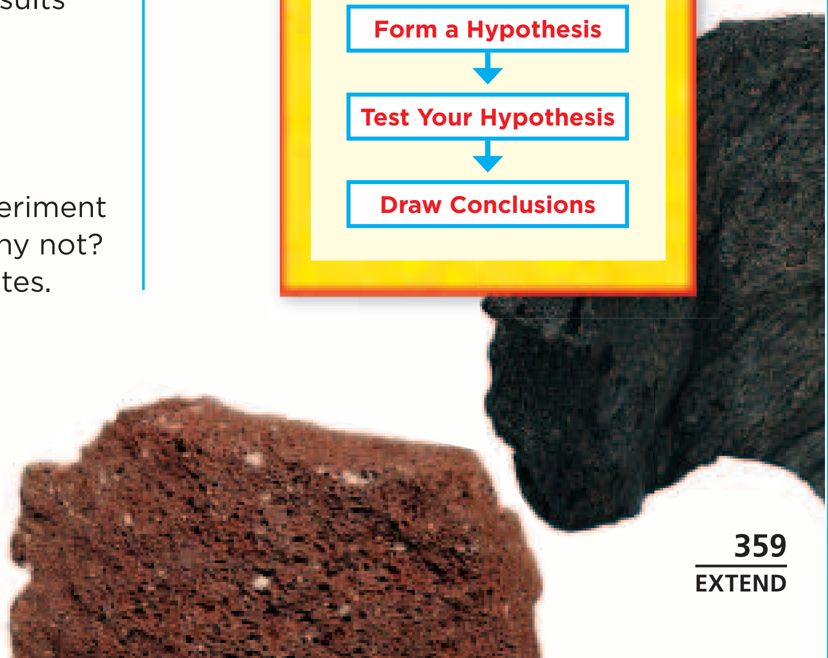
Open Inquiry

What else would you like to learn about volcanoes? Would you like to know about the different types of volcanoes? Design an experiment to answer your question. Organize your experiment to test only one variable, or one item being changed. Record the research materials you used for your experiment.

Remember to follow the steps of the scientific process.

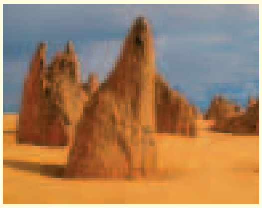
Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions





CHAPTER 6 Review

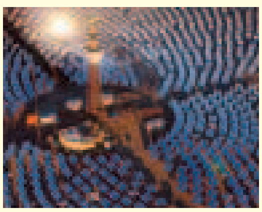
Visual Summary



Lesson 1 Earth's crust is made of minerals that have different properties.

Lesson 2 Living things use air and water to carry out their life processes.

Lesson 3 Natural resources are classified as renewable or nonrenewable.



Lesson 4 Conservation helps preserve Earth's resources and our environment.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.

Vocabulary

Fill each blank with the best term from the list.

aquifer, p. 333

biomass, p. 354

landfill, p. 346

mineral, p. 314

renewable resource, p. 340

rock cycle, p. 322

solar cell, p. 355

watershed, p. 331

1. A naturally occurring solid material found in Earth's crust is called a(n) ________.

2. Wastes that come from plants, animals, and other organisms form ________.

3. Because it can be replaced by nature, water is a(n) ________.

4. Rocks change from one kind of rock into another over long periods of time in a process called the ________.

5. Most garbage is placed in a specially designed, lined pit called a(n) ________.

6. An underground area of rock and soil filled with water is called a(n) ________.

7. Mountains often form the boundaries of a(n) ________, which contributes water to a river.

8. A device that produces electricity from sunlight is a(n) ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. **Compare and Contrast** In what ways are the rock cycle and the water cycle similar? In what ways are they different?

10. **Persuasive Writing** Many people think that there should be more development of energy sources other than fossil fuels. Do you agree or disagree? Write a letter to a government official to persuade him or her to take action based on your position.

11. **Use Variables** You are doing an experiment to determine and compare the hardnesses of talc, fluorite, and calcite by scratching them with your fingernail. Which variable could you change in this experiment? How could changing this variable affect the results?

12. **Critical Thinking** Suppose you are designing a new car. Describe possible ways that you could use the 3 *R*s to design a car that uses lesser amounts of Earth's nonrenewable resources.

13. **Interpret Data** Describe the appearance of the igneous rock below. Is this intrusive rock or extrusive rock?

obsidian

The Big Idea

14. Where do the materials and sources of energy that people use come from?

Performance Assessment

Flood-Control Inspector

Your goal is to investigate how your community is protected from flooding.

What to Do

1. Research local dams, ditches, storm drains, levees, embankments, or culverts that direct water flow. Find photographs or draw pictures of these structures.
2. What happened after heavy rainfall in these areas before and after the structures were built? Prepare a report to summarize your findings.

Analyze Your Results

- How have the water-directing structures in your state helped prevent flooding?

Test Prep

1. The graph below shows the different kinds of materials that people throw away.

Reducing the use of which materials might save the MOST room in landfills?

A plastics and glass

B food and yard waste

C metals and other waste

D paper and cardboard

Farmer

People around the world depend on farmers for food. To be successful at farming, you should enjoy working outdoors for long hours. In addition, farmers need to know about genetics, botany, animal science, soil, weather, chemistry, and business. Some farmers obtain this knowledge from other farmers in their families, through courses at school, or through youth organizations. Today, many aspiring farmers pursue bachelor's degrees in agricultural science. Farmers also closely follow changing technology in order to take advantage of new equipment and techniques for raising plants and animals.

▲ Modern farming requires knowledge of many scientific fields.

▼ Archaeologists apply science skills when studying the past.

Archaeologist

Do you "dig" the past? If so, you should explore a career in the field of archaeology. This is the study of the material remains of human activities. Archaeologists locate and study fossils and artifacts from the past. Working as an archaeologist can take you to faraway places to discover ancient mysteries. It can also keep you close to home, identifying and protecting local historic sites. If you would like to build a career unearthing the past, you can get started with a bachelor's degree and even go on to receive advanced degrees in archaeology. There are many sites left to explore!

LOG ON e-Careers at www.macmillanmh.com

UNIT D

Weather and Space

Begun in 1986, the Russian space station Mir changed the course of space exploration for more than a decade.

Monarch Butterflies at Risk

by Jill Egan

Severe weather conditions and other dangers are harming the population of monarch butterflies.

Monarch butterflies are some of the largest butterflies in North America. Each year, millions of the colorful butterflies flock back north to the United States after spending the winter in Mexico.

The monarch is one of the most well-known butterfly species. However, severe weather conditions and habitat destruction are putting the delicate butterfly population in jeopardy. Some butterfly experts say that the number of monarch butterflies has been cut by 25 percent.

Life Cycle in Danger

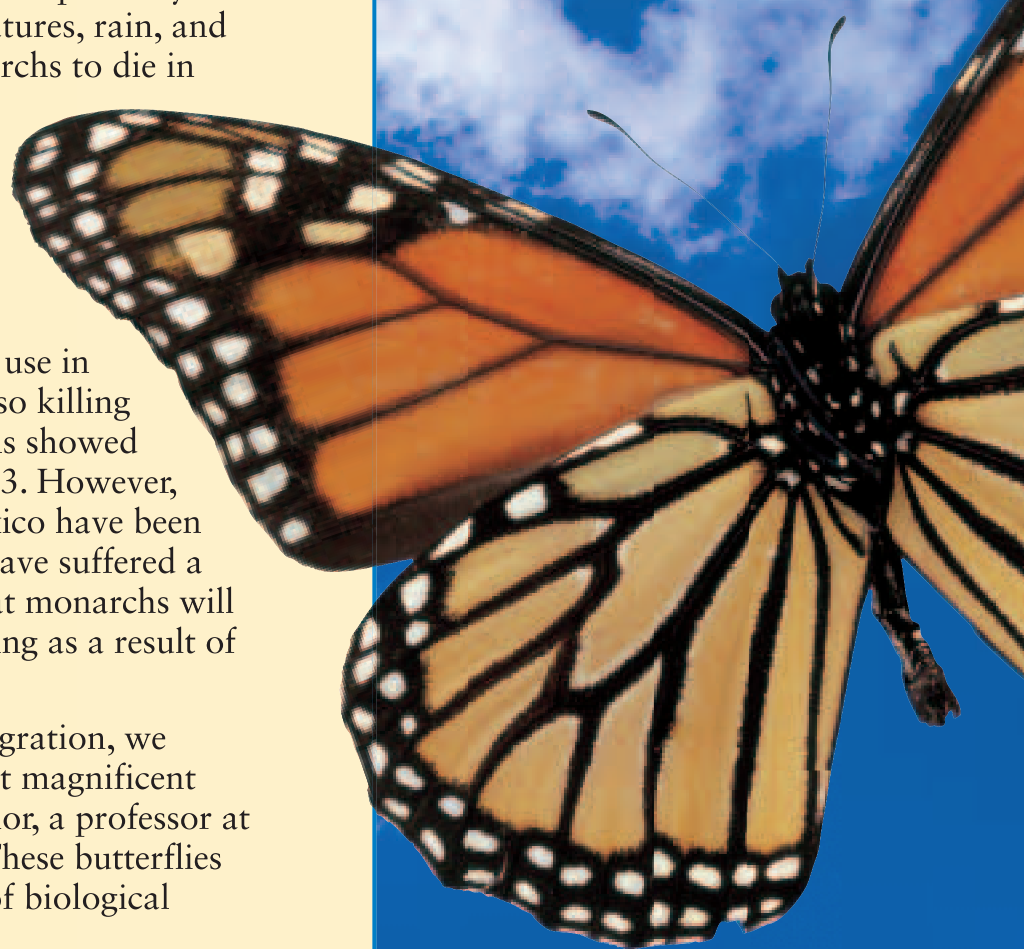
Monarch butterflies are creatures of habit. Each November, the orange-and-black butterflies fly to the mountains of central Mexico. They return to the United States in April. During the journey north, the butterflies lay eggs on milkweed plants and then die. That is when the life cycle begins again.

from *Time for Kids*

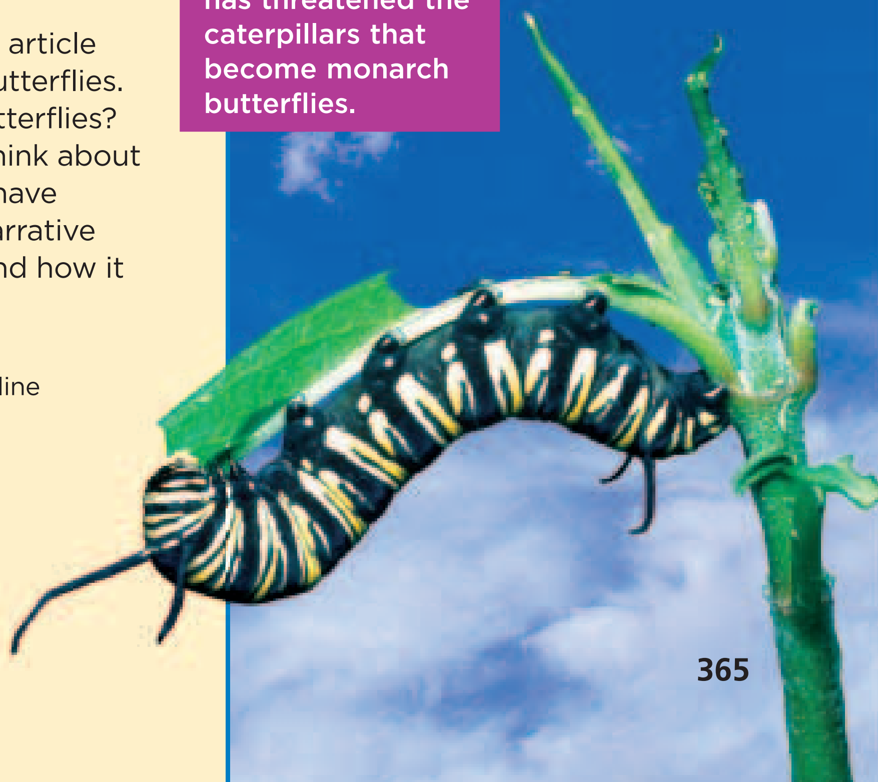
In recent years, the weather has been hard on these fragile insects. Experts say that unusually cold temperatures, rain, and droughts have caused monarchs to die in large numbers. These severe conditions have also prevented new butterflies from hatching.

Weather is not the butterflies' only problem. Illegal logging and pesticide use in the forests of Mexico are also killing the butterflies. The monarchs showed signs of coming back in 2003. However, the past two winters in Mexico have been so cold that the butterflies have suffered a setback. Scientists worry that monarchs will not produce as many offspring as a result of these problems.

"If we lose the whole migration, we lose one of the nation's most magnificent phenomena," said Chip Taylor, a professor at the University of Kansas. "These butterflies are the symbol of richness of biological diversity."



Climate change has threatened the caterpillars that become monarch butterflies.



Write About It

Response to Literature In this article the author discusses monarch butterflies. What conditions affect these butterflies? What role does weather play? Think about a severe weather condition you have experienced. Write a personal narrative describing the severe weather and how it affected you and other people.

LOG ON e–Journal Write about it online at www.macmillanmh.com

CHAPTER 7

Weather and Climate

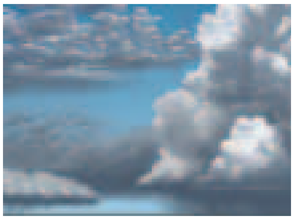
The Big Idea

What factors determine Earth's weather and climates?

dangerous ice storm in Oklahoma

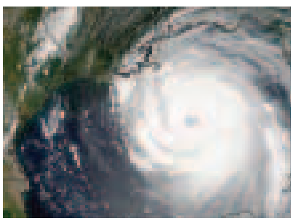
Key Vocabulary

condensation
The changing of a gas into a liquid as heat is removed. (p. 382)

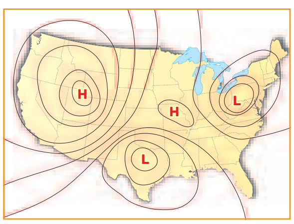


cirrus clouds
Clouds that have a wispy, featherlike shape. (p. 384)

tornado
A violent, whirling wind that moves across the ground in a narrow path. (p. 389)



hurricane
A large, swirling storm with low pressure at the center. (p. 390)



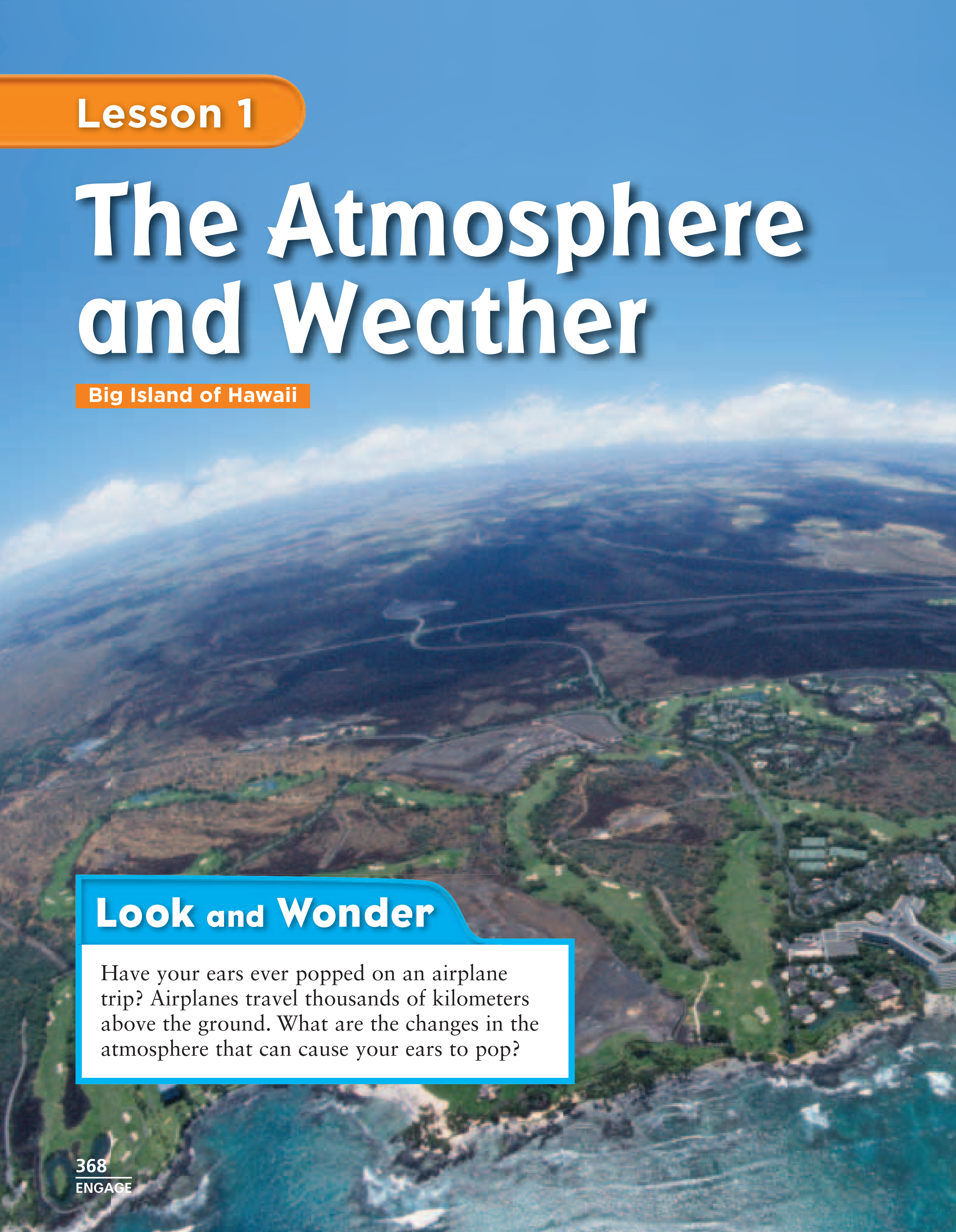
isobar
A line on a weather map that connects places with equal air pressure. (p. 398)

rain shadow
A region on the side of a mountain where air becomes dry and descends. (p. 411)

More Vocabulary

atmosphere, p. 370
troposphere, p. 370
insolation, p. 372
air pressure, p. 374
convection cell, p. 374
sea breeze, p. 375
land breeze, p. 375
Coriolis effect, p. 376
evaporation, p. 382
humidity, p. 383
stratus cloud, p. 384
cumulus cloud, p. 384
air mass, p. 400
front, p. 400
cold front, p. 400
warm front, p. 400
occluded front, p. 400
sunspot, p. 412

The Atmosphere and Weather



Big Island of Hawaii

Look and Wonder

Have your ears ever popped on an airplane trip? Airplanes travel thousands of kilometers above the ground. What are the changes in the atmosphere that can cause your ears to pop?

Explore

Inquiry Activity

How can you observe air pressure?

Form a Hypothesis

When you push inward on an inflated balloon, you see the effect of your pushing. Can air do the same thing as your hand? Write your answer in the form of a hypothesis: "If the air outside a bottle pushes harder than the air inside a bottle, then the bottle will . . ."

Test Your Hypothesis

1. **Experiment** Open an empty 2 L bottle. Place the bottle in a basin or container of very warm tap water. Hold the bottle partly submerged in the water for a few minutes. Put the cap on the bottle, and twist it tightly. Remove the empty bottle from the water, and stand it on a flat surface.
2. **Observe** Watch the bottle carefully for about a minute. Record your observations. Move in close, so that your ear is near the top of the bottle. Unscrew the cap, and record what you observe.
3. **Interpret Data** Before you put the cap on, how was the air pressure inside the bottle in relation to the pressure outside the bottle? What happened after you tightened the cap?

Draw Conclusions

4. Was your hypothesis correct? Describe the evidence that supports your explanation.
5. **Infer** What do you think caused any changes to the sides of the bottle? How would you explain what happened when you removed the cap?

Explore More

What would happen if you placed the empty bottle in a freezer instead of in very warm water? Form a hypothesis, and test it. Does your evidence support your hypothesis? Explain.

Materials

- 2 L plastic bottle with twist cap
- large basin or container
- warm water

Dark clouds are a sign that rain is on the way.

Read and Learn

Main Idea

Many factors affect a region's weather.

Vocabulary

atmosphere, p. 370
troposphere, p. 370
insolation, p. 372
air pressure, p. 374
convection cell, p. 374
sea breeze, p. 375
land breeze, p. 375
Coriolis effect, p. 376

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Reading Skill

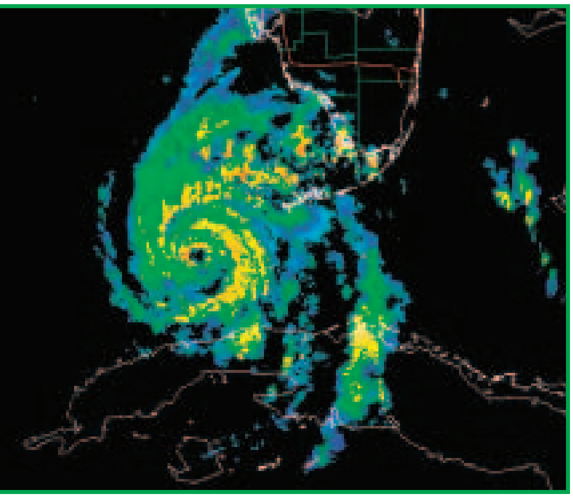
Fact and Opinion

Fact	Opinion

Technology

SCIENCE QUEST

Explore weather patterns with a meteorologist.



Doppler radar sends out radio waves and records their echoes. This informs scientists about how clouds are moving.

Where is the weather?

If you climbed a high mountain, you might notice that the air felt colder. This change in temperature would occur because you were traveling upward through the **atmosphere**, the layers of gases that surround Earth. The atmosphere extends out about 700 kilometers (435 miles) above Earth's surface.

The layer of the atmosphere closest to Earth's surface is the **troposphere** (TROP•uh•sfeer). This layer is about 11 kilometers (7 miles) thick and contains about 80 percent of the total amount of air in the atmosphere. Air is mainly a mixture of gases, dust, and water vapor. In fact, the troposphere contains 99 percent of all the water vapor in the atmosphere. Most weather takes place in the troposphere.

Jet airplanes normally fly within the stratosphere (STRAT•uh•sfeer), just above the troposphere, because it is very stable. The stratosphere contains the ozone layer. The ozone layer absorbs harmful rays from the Sun. Rock fragments from space often burn up in the next layer, the mesosphere (MEZ•uh•sfeer). The coldest temperatures in Earth's atmosphere are found at the top of the mesosphere. The outermost layer, the thermosphere (THUR•muh•sfeer), is where space shuttles orbit. The atmosphere becomes gradually thinner until it reaches the near-vacuum of space.

Weather Conditions

Weather is the state of Earth's troposphere at a given place and time. The conditions that make up weather are called *weather variables*, conditions that change periodically. Weather variables include factors such as temperature, wind, moisture, cloud cover, and precipitation.

People have always looked for signs that might help them predict upcoming weather. Some signs were obvious, such as the presence of very dark clouds just before a storm. Others became known over many years of observation. The ancient Egyptians studied the stars. They figured out that the Nile River would flood at about the same time of year that they saw the star Sirius rise in the sky before dawn.

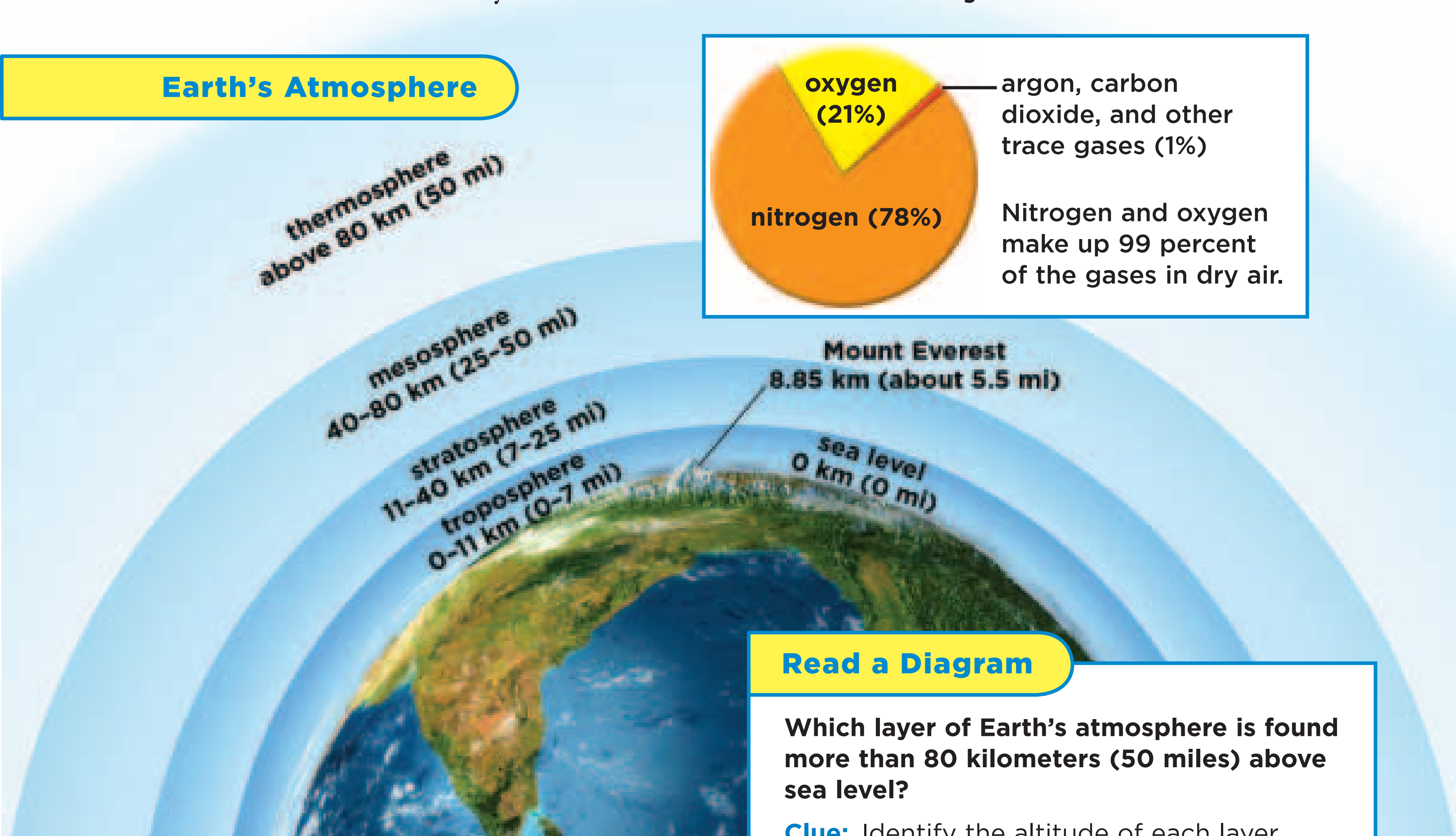
Today, scientists have many ways to obtain data about the atmosphere and weather. Weather balloons take readings as they rise through the atmosphere. Weather satellites provide information from space. Doppler radar can show a local area's current weather, including precipitation, wind direction, and wind speed.

Quick Check

Fact and Opinion "Oxygen is the most important gas in the troposphere, because people need it to breathe." Is this a fact or an opinion? Explain.

Critical Thinking Why is it important to be able to predict the weather accurately?

Earth's Atmosphere



Nitrogen and oxygen make up 99 percent of the gases in dry air.

Read a Diagram

Which layer of Earth's atmosphere is found more than 80 kilometers (50 miles) above sea level?

Clue: Identify the altitude of each layer.

What affects air temperature?

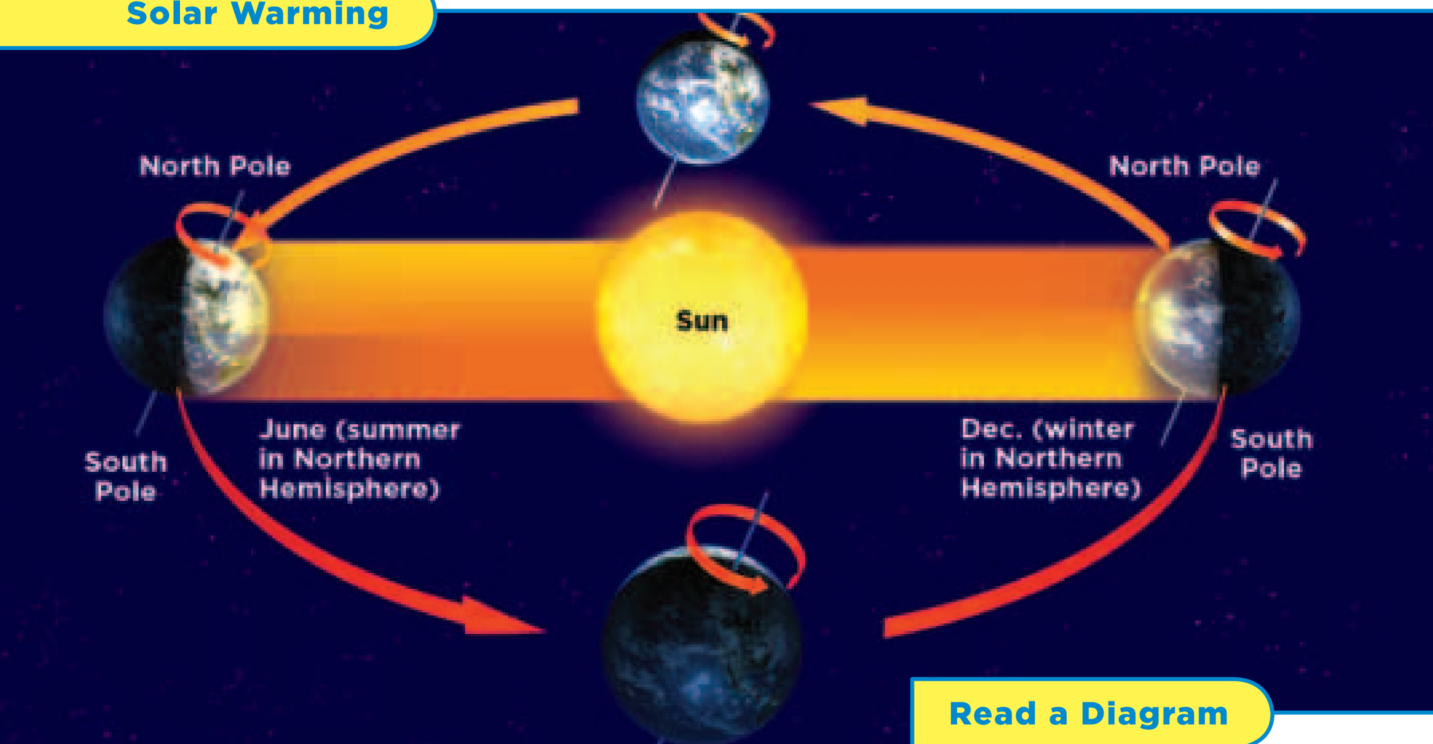
On any day in February at the same time, it might be hot in Argentina and cold in Michigan. How can two places have such different temperatures? As sunlight reaches Earth, the Sun's energy penetrates the atmosphere and warms Earth's surface. As the surface is warmed, it also warms the air above it.

Insolation (in•soh•LAY•shuhn) is the amount of the Sun's energy that reaches Earth at a given time and place. The angle of insolation is the angle at which sunlight hits Earth's surface. The greater the angle, the more intense the Sun's rays. The rays are most intense when the Sun is directly overhead. As the angle of insolation increases, the air becomes warmer.

The angle of insolation depends on several factors. These factors include latitude, time of year, and time of day. The angle is greater near the equator and smaller near the poles. The Sun's rays are less concentrated and more spread out near the poles, so they do not warm the surface there as much.

Because Earth is on a tilted axis, seasonal differences affect insolation. When the Northern Hemisphere has summer, the Sun's rays hit Earth's surface there at steeper angles than they do during winter. It may surprise you to learn that Earth is closer to the Sun in January than it is in July. Even so, the Northern Hemisphere is much warmer in July than in January.

Solar Warming



The Sun's rays strike Earth's surface at different angles as Earth travels around the Sun.

Read a Diagram

When are the Sun's rays strongest in the Southern Hemisphere?

Clue: Look at where and when the Sun's light is more concentrated.

Insolation also varies during the course of a day, because Earth rotates on its axis once every 24 hours. At dawn, the Sun appears close to the horizon, and the angle of insolation is small. By midday, the Sun appears much higher in the sky, and the angle of insolation is at its greatest. After midday, the Sun appears to move lower in the sky again. At dusk, the angle of insolation is small once again. This is why, in temperate climates, temperatures are higher at midday than at dawn or dusk. You can measure the angle of insolation by looking at the shadows cast by objects struck by the Sun's rays. The shorter the shadow is, the steeper the angle of insolation.

Measuring Temperature

Thermometers use three different temperature scales. The Fahrenheit scale is indicated by the letter *F*. The metric Celsius scale is indicated by the letter *C*. The Kelvin scale, which is also metric, is indicated by the letter *K*. The Kelvin scale has no negative numbers. Water freezes at 32°F, 0°C, or 273 K. Water boils at 212°F, 100°C, or 373 K. An average room temperature measures about 72°F, 22°C, or 295 K.

Quick Check

Fact and Opinion "Solar energy enters the atmosphere and warms Earth's surface and the air above it." Is this a fact or an opinion?

Critical Thinking Why does the angle of insolation change between midday and evening, and how does this affect the air temperature?

Quick Lab

Analyze Temperature Differences

1. **Record Data** Stand in an area of paved concrete. Hold a thermometer at about the height of your ankle. After 3 minutes, measure and record the air temperature. Then hold the thermometer even with your waist. Wait 3 minutes more, and record the new air temperature.

2. Repeat step 1 over grass, a patch of soil, and a puddle of water.
3. **Interpret Data** Over which surface was the difference in temperature greatest between the ankle-height and waist-height readings?
4. **Classify** Over which surface was the ankle-height temperature the highest? The lowest?
5. **Infer** Which surface seems to absorb the most heat? Which surface absorbs the least heat?

What is air pressure?

Have you ever wondered why leaves scatter in the wind? This occurs because air particles are colliding with the leaves. The force of these impacts is what pushes the leaves forward. Even on windless days, air particles continue to move. Air particles have mass, and so Earth's gravity attracts them. **Air pressure** is the force exerted on a given area by the impacts of gas particles in constant motion. Standard air pressure, or the air pressure at sea level, is about 1 kilogram per square centimeter (14.7 pounds per square inch).

Picture a balloon filled and pinched closed. The balloon has expanded until the air pressure inside is greater than the air pressure outside. When the pinch is released, the higher pressure air inside the balloon can escape, reducing the pressure inside. Air flows out of the balloon, moving from an area of higher pressure to an area of lower pressure. This movement of air is called *wind*.

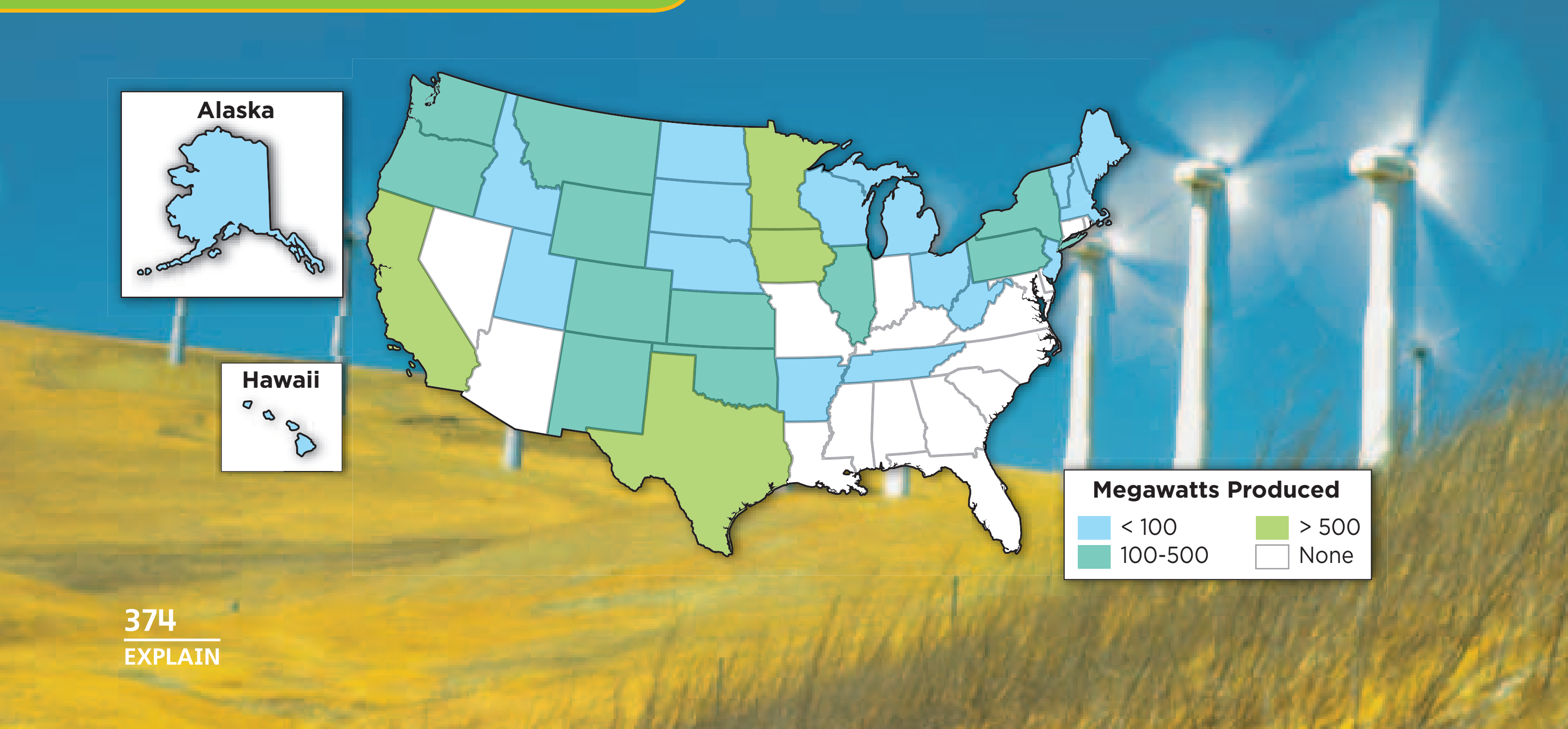
Earth's air pressure varies. As you move higher in the atmosphere, there is less air above you. Because there are fewer air particles above you that are being pulled toward Earth by gravity, there is less air pressure. Air pressure is an important weather variable. Air pressure variations help produce wind.

Temperature also causes air to move. As air warms, it spreads out and takes up a larger area, resulting in less air in a given volume. The air is then less dense, and its pressure decreases. Warmer air, with lower density and pressure, rises above cooler air, which has a higher density and pressure.

Convection Cells

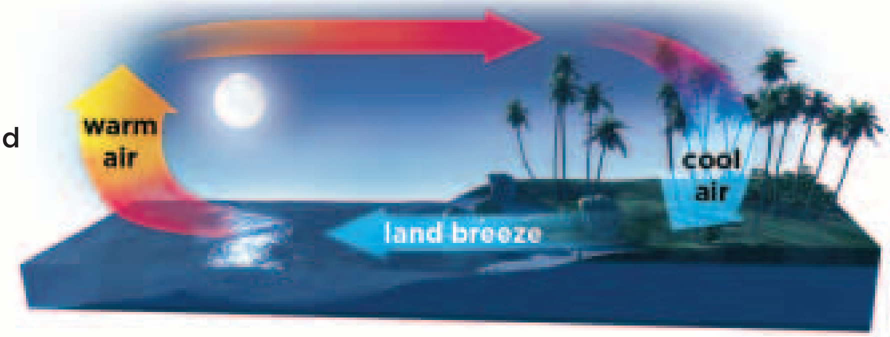
Suppose air in an area is cool and under high pressure. If a nearby place is warmer and at a lower pressure, air will move from the high-pressure area to the low-pressure area. This is called a *surface wind*. Unequal heating and cooling of a region's air forms a **convection cell**, a circular pattern of rising air, sinking air, and wind.

Wind-Farm Energy Production



Sea and Land Breezes

During the day, winds usually blow from the water toward the land.



At night, the winds change direction and blow from the land toward the water.

Sea and Land Breezes

If you were at the beach on a summer day, you might notice that the wind regularly blows from the ocean toward land. At night, the wind normally reverses. Why? During the day, air over land warms faster than air over water. The warm air expands and rises, and cooler air over the sea blows toward the land. Wind that blows from the sea to the land is a **sea breeze**. At night, air over land cools faster than air over water. A **land breeze** then blows from the land to the water.

Measuring Wind and Air Pressure

Weather maps often use drawings to display wind speed and direction. This drawing is called a *station model*. Wind speed is measured with an *anemometer* (an•uh•MOM•i•tuhr), a device with a set of cups that are attached around a central pole. The cups spin quicker as the wind blows faster.

A *weather vane* is used to measure the wind's direction. A weather vane is a movable arrow which points in the direction that the wind is blowing.

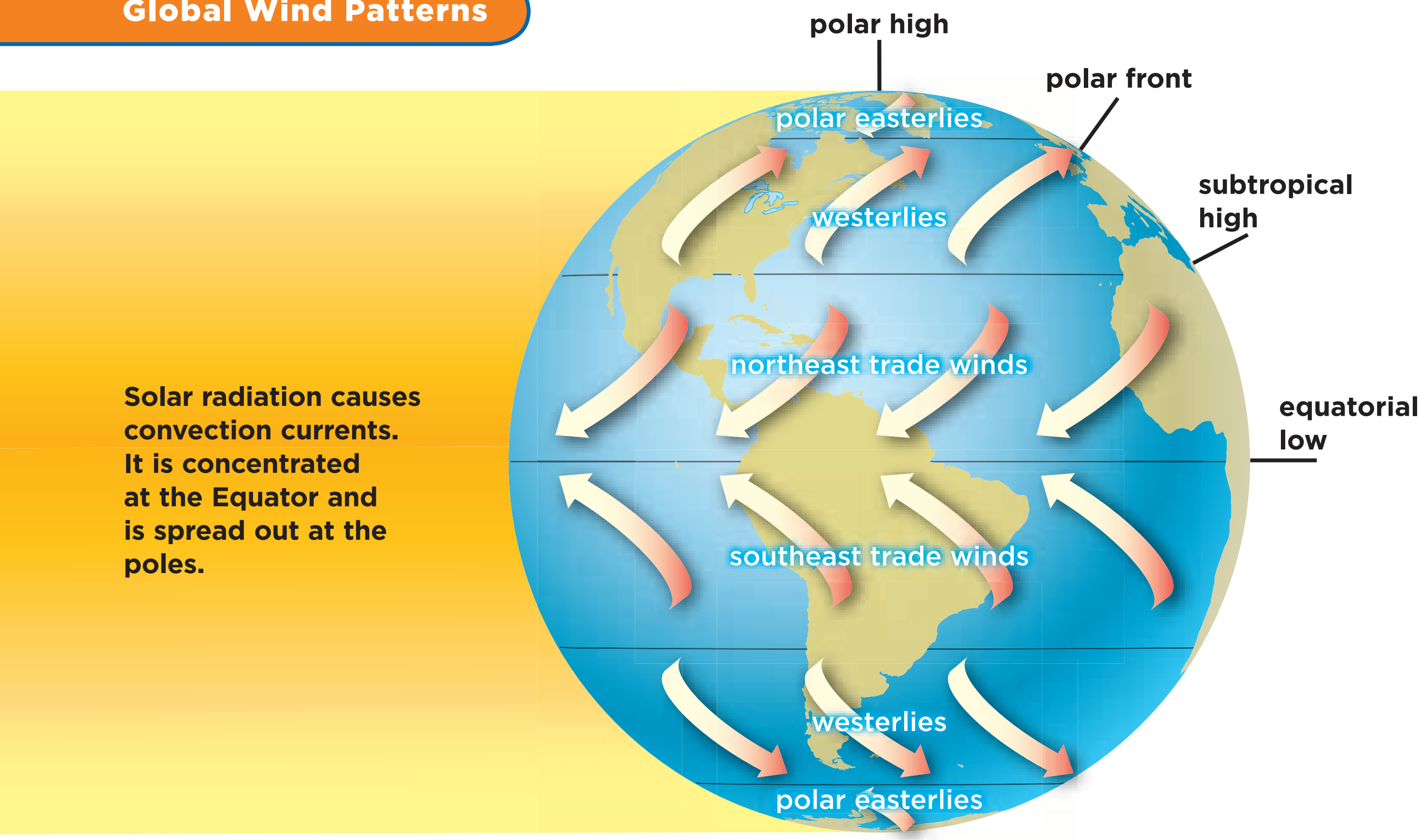
A *barometer* (buh•ROM•i•tuhr) measures surrounding air pressure against standard air pressure. Older-style barometers worked by measuring in millibars the air's ability to maintain the height of a column of mercury. Modern barometers are all electronic, but the *millibar* is still the common unit of measurement for air pressure.

Quick Check

Fact and Opinion "Land breezes are more refreshing than sea breezes." Is this statement a fact or an opinion? Explain your answer.

Critical Thinking What role do changing air temperatures play in a convection cell?

Global Wind Patterns



What are global winds?

Winds blow from areas of higher pressure to areas of lower pressure. However, Earth's rotation pushes the winds to either the right or the left. This shift is called the **Coriolis effect** (kawr•ee•OH•luhs). The Coriolis effect causes winds in the Northern Hemisphere to curve to the right, or clockwise. In the Southern Hemisphere, the Coriolis effect causes winds to curve to the left, or counterclockwise.

Global Wind Patterns

Convection currents set air into constant motion, producing global winds that are sometimes generalized and called prevailing winds. The Coriolis effect causes these winds to curve. *Trade winds*, the winds that blow toward the equator, are curved to the west by the Coriolis effect. These winds are referred to by the direction from which they come—northeast or southeast. The winds that blow toward the poles are curved to the east. Because they seem to come from the west, these winds are called *westerlies*.

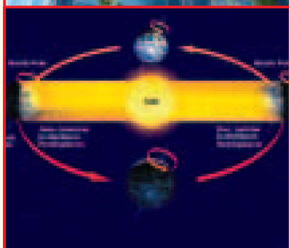
Quick Check

Fact and Opinion "The Coriolis effect causes winds to curve to the right or the left." Is this statement a fact or an opinion? Explain your answer.

Critical Thinking What causes global wind patterns?

Lesson Review

Visual Summary

	The **troposphere** is the layer of Earth's atmosphere in which weather occurs.
	**Air temperature** is affected by factors such as the angle of solar insolation, the time of day, and the time of year.
	**Air pressure**, **convection cells**, and the **Coriolis effect** are responsible for wind patterns around the world.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the phrase and provide supporting details.

Think, Talk, and Write

1. **Main Idea** What are three factors that can affect the weather?

2. **Vocabulary** Winds follow a curved path over Earth's surface because of the _________.

3. **Fact and Opinion** "An anemometer is easier to use than a barometer." Is this statement a fact or an opinion? Explain your answer.

Fact	Opinion

4. **Critical Thinking** Why is the air at the equator so much warmer than the air at the poles?

5. **Test Prep** **The instrument used to measure wind speed is called**
   A a barometer.
   B a weather vane.
   C a thermometer.
   D an anemometer.

6. **Test Prep** **A breeze that blows from the land to the sea is a**
   A sea breeze.
   B land breeze.
   C trade wind.
   D westerly.

Writing Link

Explanatory Writing

Write a minilesson that explains the difference between a sea breeze and a land breeze. Write your lesson as if your students were a class of fifth-graders.

Social Studies Link

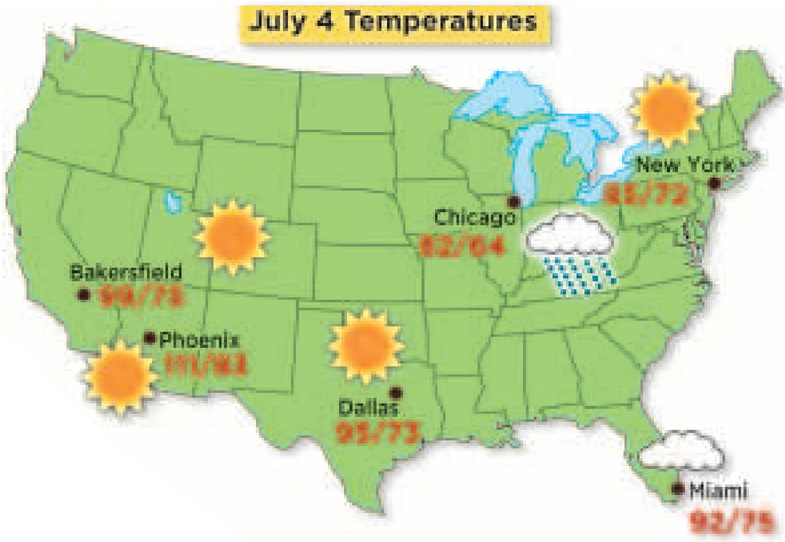
Write a Report

Long before modern ships were built, explorers traded goods with faraway countries. Research the origin of the term *trade winds*, and write a report on your findings.

Focus on Skills

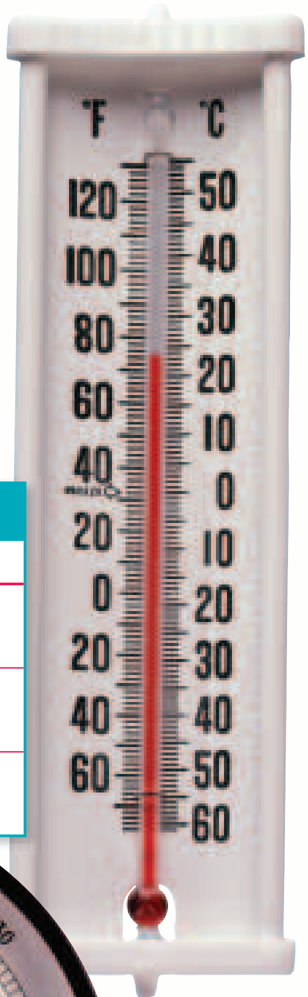
Inquiry Skill: Interpret Data

Scientists study weather maps and **interpret data** from them. They look at temperature patterns, especially any extreme changes from past years, in order to predict future weather in an area. They also look for fronts, where cold and warm air push against each other. Then they interpret all the data to draw conclusions and explain why things happen.



Learn It

When you **interpret data**, you use information that has been gathered to answer questions or solve problems. It is usually easier to analyze and interpret data if it has been organized and placed on a chart or a graph. Then you can see at a glance any extreme changes or patterns in the data.



Try It

1. Look at the map above. It shows high and low temperatures in six cities on one day in July. Then look at the chart below. The chart lists average high and low temperatures and the rainfall for some U.S. cities during July in past years. **Interpret data** from both the map and the chart to answer all the questions.

Average July Temperatures and Precipitation by City

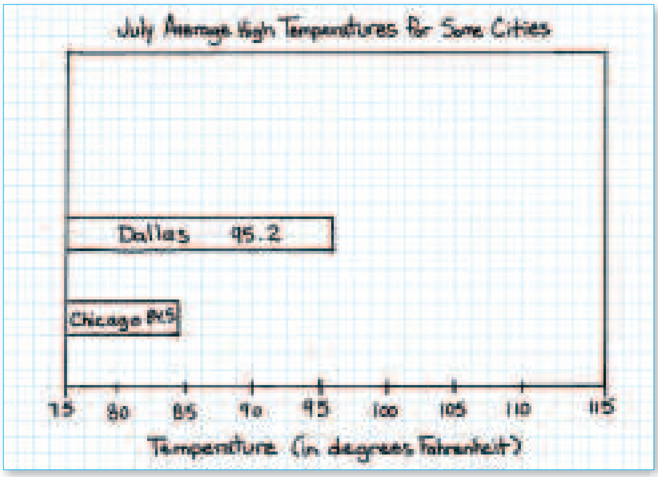
	Bakersfield	Chicago	Dallas	Miami	New York	Phoenix
High Temperature	98.4°F	84.4°F	95.2°F	88.5°F	80.8°F	109.0°F
Low Temperature	69.4°F	65.7°F	72.0°F	74.1°F	65.7°F	75.9°F
Precipitation	0.0 in.	4.0 in.	2.4 in.	8.1 in.	3.3 in.	0.6 in.

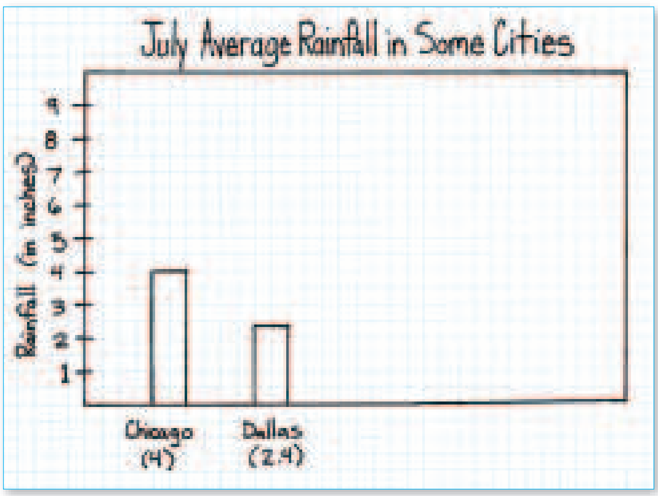
2. According to the map and chart, how did the one-day high and low temperatures for Bakersfield differ from its average high and low temperatures?

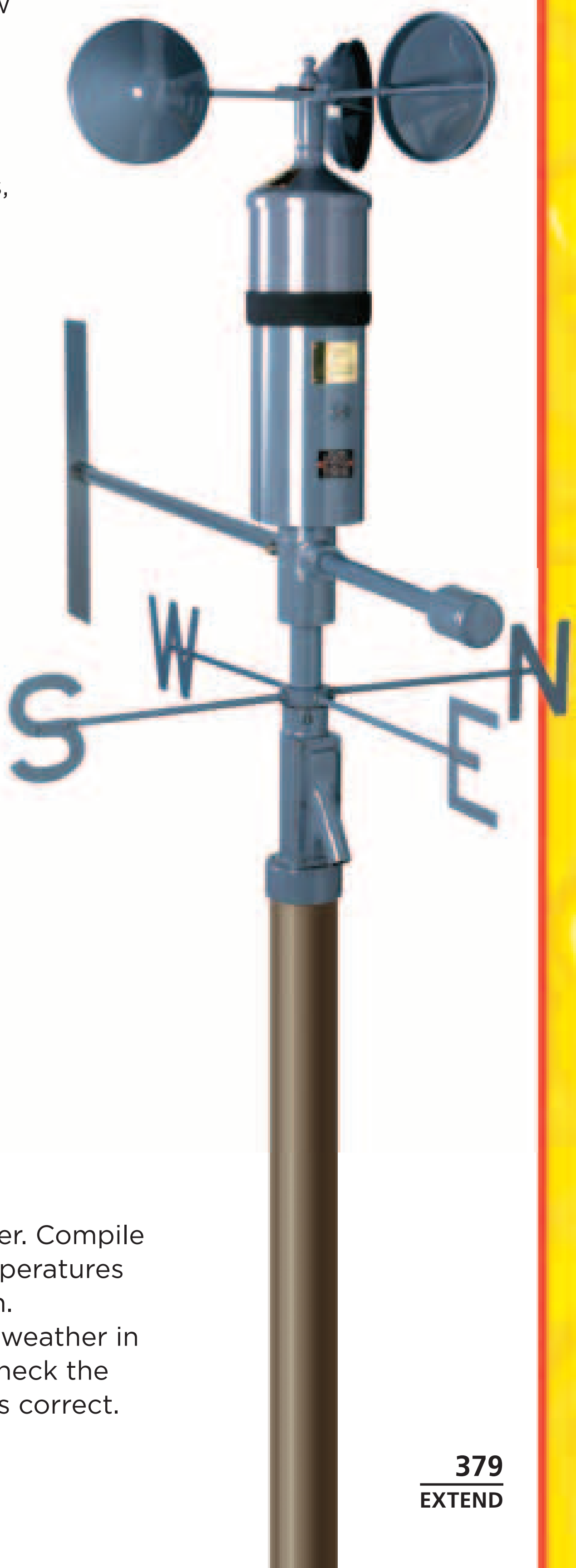
3. Which city had one-day high and low temperatures closest to its average high and low temperatures?
4. Which city had cooler-than-average high and low temperatures for the day?

▶ Apply It

1. Now use data from the chart to make bar graphs, like the ones started here, to compare the high temperatures or the amounts of precipitation.



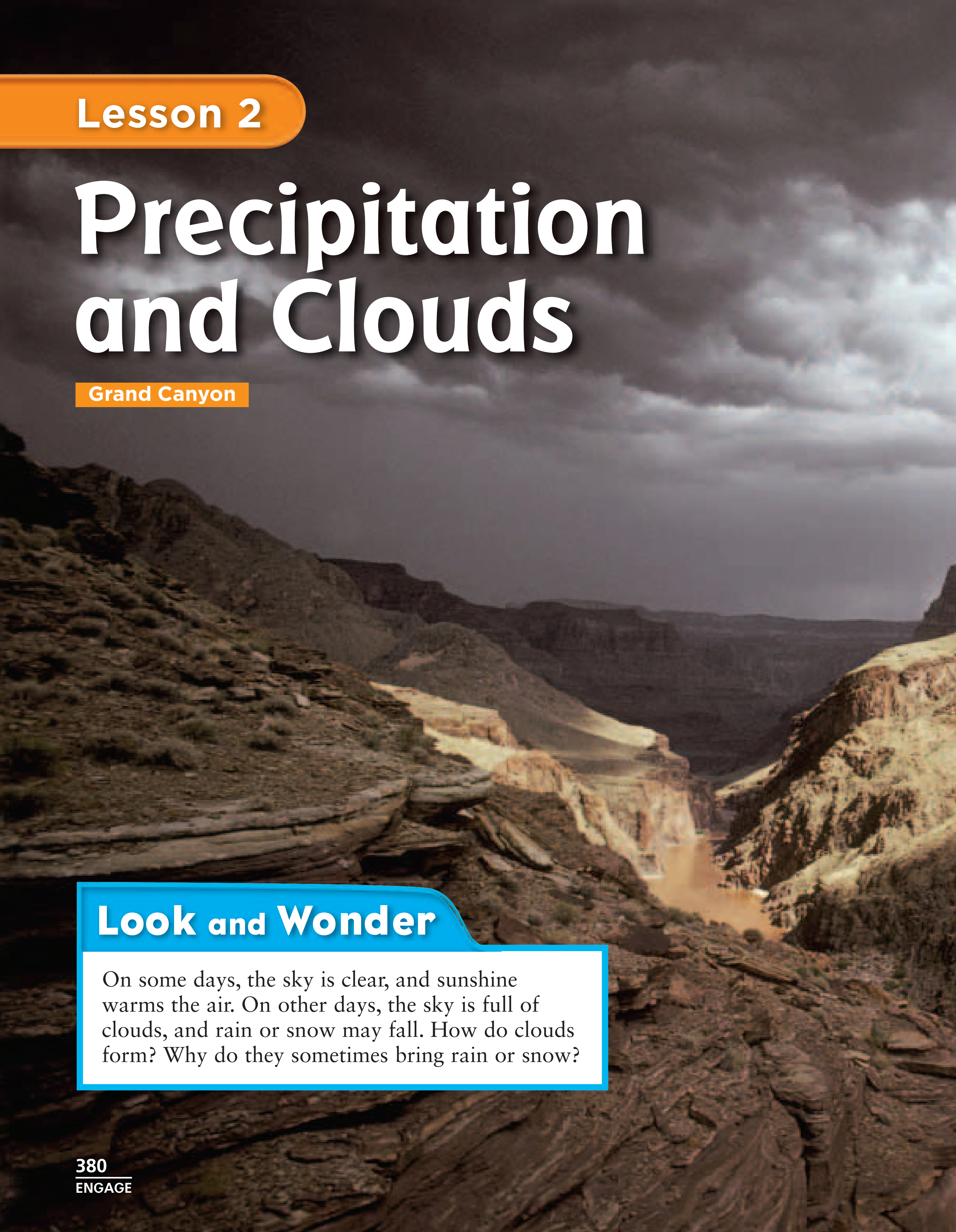




2. Look at a weather map from your local newspaper. Compile data from the map to make a graph. Include temperatures and precipitation for cities in your state or region. **Interpret data** in your graph to predict what the weather in your area may be like tomorrow. Remember to check the following day to see whether your prediction was correct.

Lesson 2

Precipitation and Clouds



Grand Canyon

Look and Wonder

On some days, the sky is clear, and sunshine warms the air. On other days, the sky is full of clouds, and rain or snow may fall. How do clouds form? Why do they sometimes bring rain or snow?

Explore

Inquiry Activity

How can you make a model of fog?

Form a Hypothesis

If pressure increases on a volume of air, the air's temperature increases. When pressure decreases, the air expands and cools. How do you think temperature and humidity affect the formation of fog? Write your answer in the form of a hypothesis: "If moist air in a bottle is cooled, then . . ."

Test Your Hypothesis

1. **Experiment** Pour a small amount of warm water into a plastic water bottle. Twist the cap on, shake the bottle, and remove the cap. Your teacher will then add smoke by lighting a match, blowing it out, and then immediately holding the smoking match inside the bottle.
2. After a few seconds, your teacher will take the match out of the bottle. Quickly twist the cap onto the bottle, closing it tightly.
3. **Experiment** Squeeze the bottle firmly. Then release this force on the outside of the bottle, and observe what happens inside the bottle.

Draw Conclusions

4. **Interpret Data** Do you think the force you placed on the bottle affected the air inside the bottle during this experiment? Explain.
5. **Infer** How does the temperature of moist air cause a change from water vapor to water droplets?

Explore More

What might you see if you did this experiment using very cold water? Form a hypothesis, and test it with your teacher or another adult. Analyze your results, and then present them to the class.

Materials

- warm water
- plastic water bottle with twist-on cap
- long, wooden safety matches

Step 1

Step 3

Read and Learn

Main Idea
Water vapor and changes in temperature are important factors in cloud formation and in precipitation.

Vocabulary
evaporation, p. 382
condensation, p. 382
humidity, p. 383
stratus cloud, p. 384
cumulus cloud, p. 384
cirrus cloud, p. 384
tornado, p. 389
hurricane, p. 390

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Reading Skill
Classify

Technology
SCIENCE QUEST
Explore weather patterns with a meteorologist.

How does the water cycle affect weather?

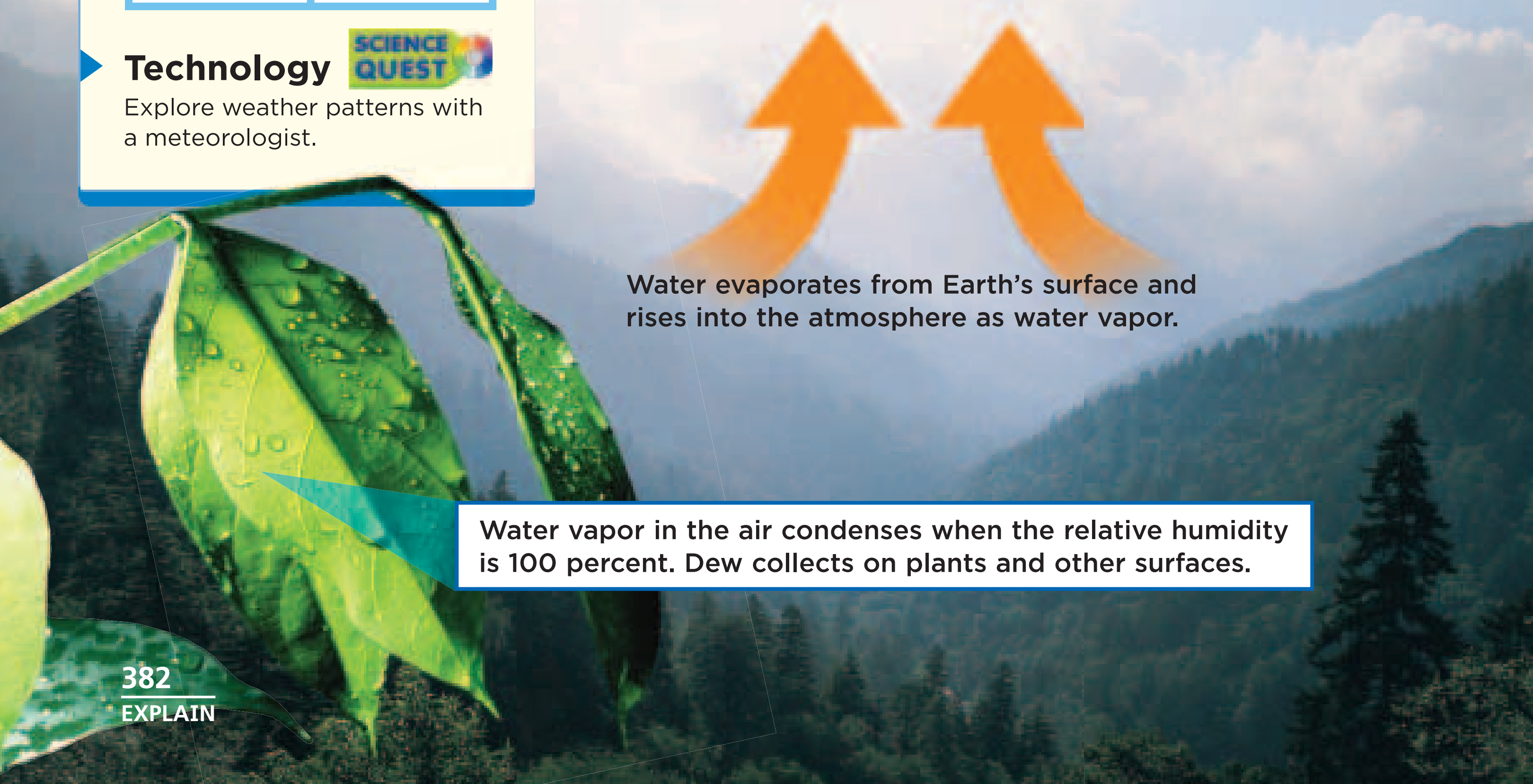
If you hold a glass of ice-cold lemonade on a hot day, you will see drops of water form on the outside of the glass. The drops of water did not come from inside your glass. Where did the water come from?

The water came from the air around the glass. Air contains *water vapor*, or water in the form of a gas. As the air around the glass cooled, water vapor in the air condensed onto the glass.

When the Sun heats Earth's water, solar energy causes evaporation to occur at a faster rate. **Evaporation** is the changing of a liquid to a gas. During evaporation, tiny water particles leave lakes, oceans, and puddles and enter the atmosphere.

When air cools, the tiny particles of water vapor in it lose energy and slow down. If they slow enough, condensation occurs. **Condensation** is the changing of a gas to a liquid as heat is removed. The water on your ice-cold glass of lemonade is condensation.

When water vapor suddenly condenses near the ground, fog can form. Fog can sometimes be dense enough to make it difficult to see the ground below.



Water evaporates from Earth's surface and rises into the atmosphere as water vapor.

Water vapor in the air condenses when the relative humidity is 100 percent. Dew collects on plants and other surfaces.

Water vapor may be measured as **humidity**, the actual amount of water vapor in the air. The higher the temperature of the air, the more water vapor it can hold. In other words, warm air can absorb much more water vapor than cold air can. *Relative humidity* measures the amount of water vapor in the air compared to the total amount the air could hold at that temperature. A relative humidity of 50 percent means that the air contains half the water vapor it could possibly hold at that particular temperature.

When the air cannot hold any more water vapor, the relative humidity is 100 percent. The air is saturated, or filled, with water vapor. Any additional water vapor condenses into a liquid. The temperature at which this occurs is called the *dew point*.

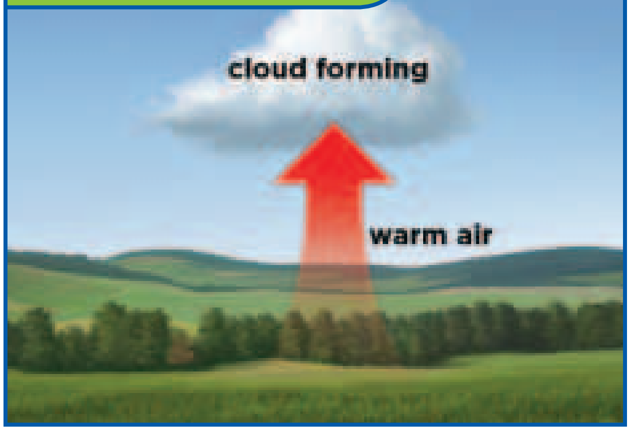
When warm, moist air rises, it cools. As the air cools, its relative humidity increases. When the temperature reaches the dew point, the air is saturated. Additional water vapor in the air then condenses into tiny water droplets and forms clouds. If the air temperature is below the freezing point of water, the water vapor forms clouds of tiny water droplets and ice crystals. The diagram on this page shows three ways in which clouds form as air cools.

Quick Check

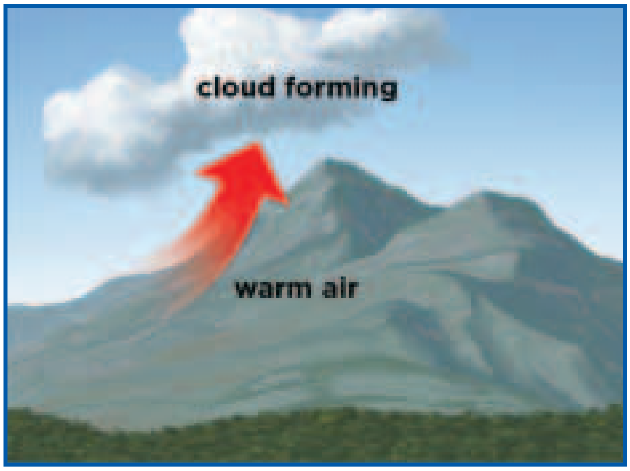
Classify Which parts of the water cycle contribute to the formation of clouds? Which parts do not?

Critical Thinking How are humidity and relative humidity alike? How are they different?

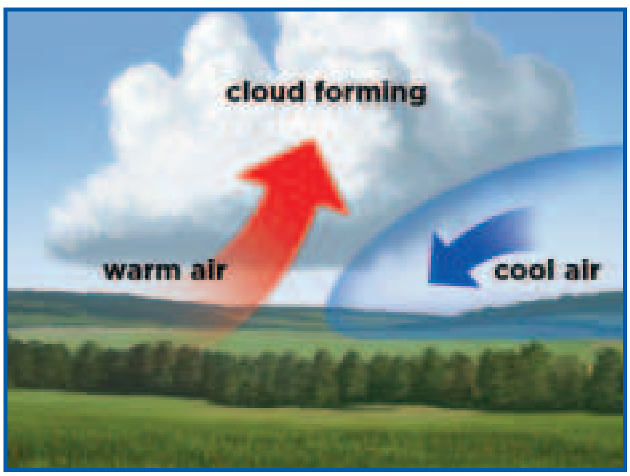
How Clouds Form



▲ The Sun heats the ground, warming the air and making it rise. Air expands and cools as it rises.



▲ Air cools when it is pushed upward over mountains by winds.



▲ Cold air meets warm air. The lighter warm air is pushed up over the heavier cold air. As it rises it cools.

What are the types of clouds?

There are three basic cloud shapes. **Stratus clouds** (STRAY•tuhs) appear in blanketlike layers. **Cumulus clouds** (KYEW•myuh•luhs) are billowy, puffy clouds that seem to rise from flat bottoms. **Cirrus clouds** (SEER•uhs) have wispy, featherlike shapes.

Clouds are described as high, middle, or low clouds, depending on the altitudes at which they form. Clouds that form at high altitudes have the prefix *cirro-* attached to their names. Clouds that form at middle altitudes have names that start with the prefix *alto-*. The suffix *-nimbus* or the prefix *nimbo-* is added to the names of clouds that produce precipitation. For example, cumulonimbus clouds often bring thunderstorms.

Cloud Cover

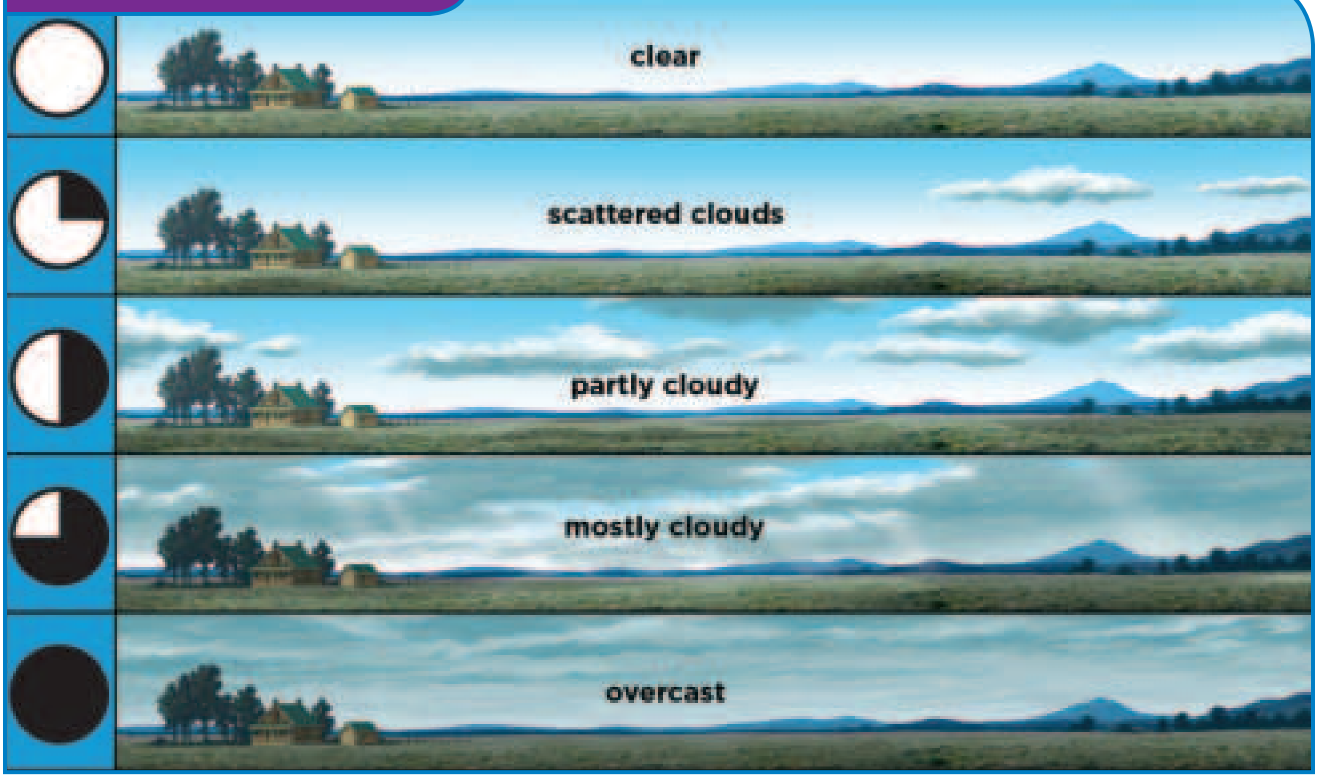
How much of the sky is covered by clouds? Terms such as *clear*, *scattered clouds*, *partly cloudy*, *mostly cloudy*, and *overcast* are all used to describe the amount of cloud cover. You can record cloud cover using symbols such as those shown below. An empty circle indicates clear skies. Circles with different shaded portions indicate varied amounts of cloud cover. These symbols are used in weather forecasts.

Quick Check

Classify Describe the three main cloud shapes.

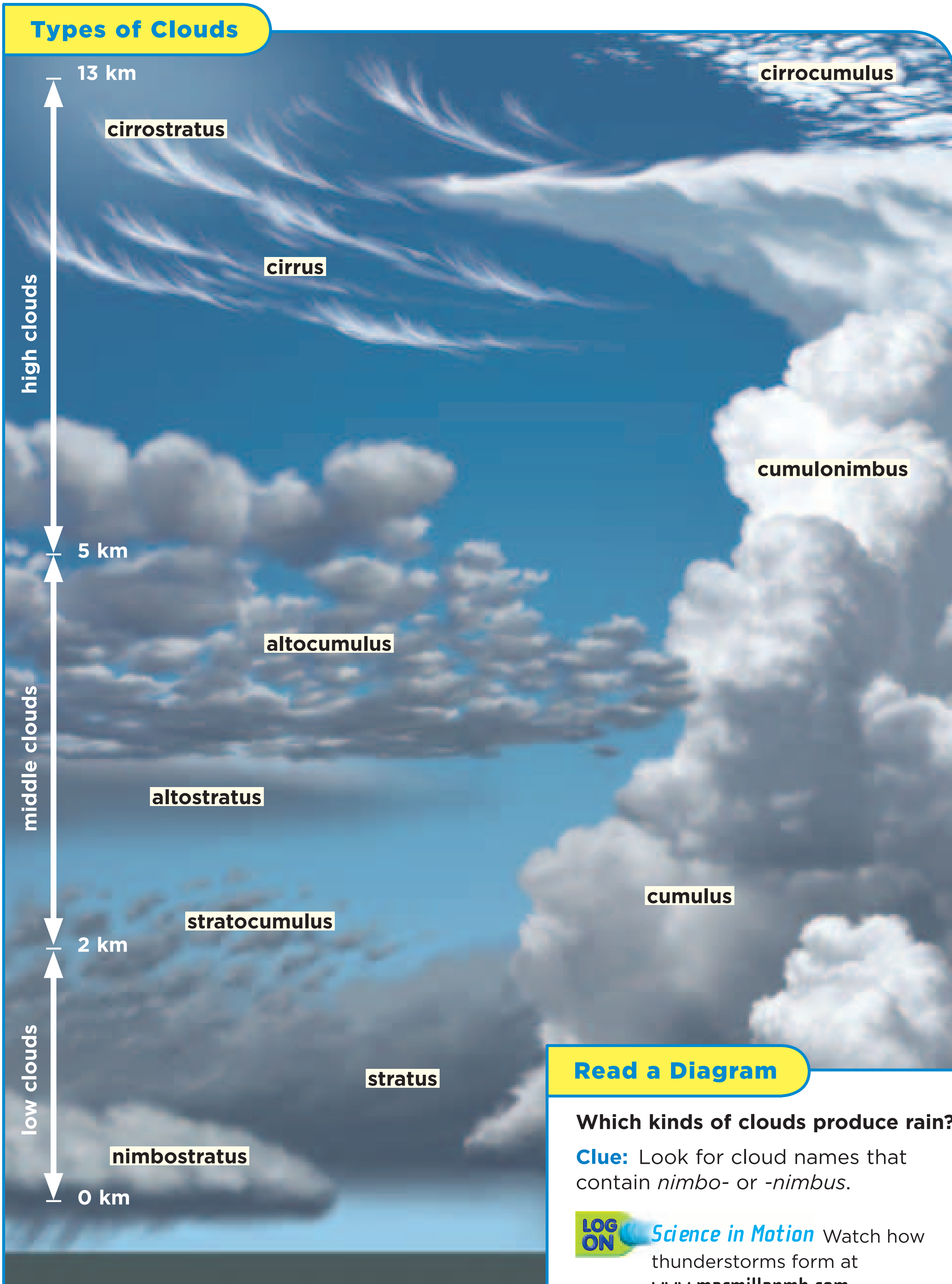
Critical Thinking Compare altocumulus and altostratus clouds.

Cloud-Cover Symbols



▲ Shaded circles are used to show the amount of cloud cover on a weather-station model.

Types of Clouds

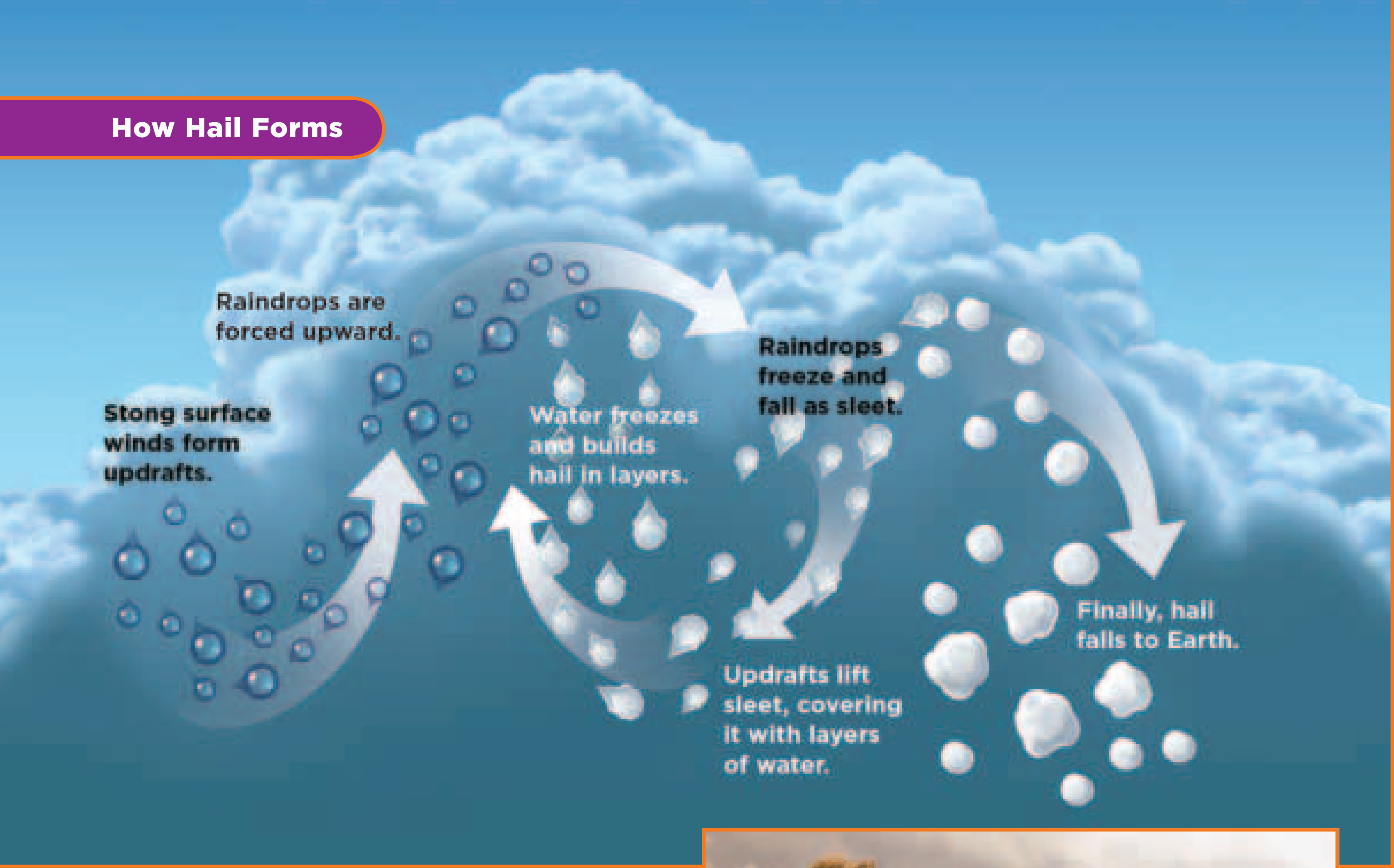


Read a Diagram

Which kinds of clouds produce rain?

Clue: Look for cloud names that contain *nimbo-* or *-nimbus*.

LOG ON *Science in Motion* Watch how thunderstorms form at www.macmillanmh.com



What are the different types of precipitation?

All forms of precipitation begin as water droplets or ice crystals in clouds. Temperature differences determine the type of precipitation that forms. The four main types are rain, sleet, snow, and hail. As precipitation falls, it passes through the lower atmosphere, where the temperature determines which form the precipitation will take as it nears the ground.

▲ Hail is produced in tall clouds. The hailstones can be very large.

Clouds and Weather

Clouds give clues about the type of weather you can expect. Not only do clouds help us predict weather, but they also provide a hint of the kind of precipitation that may be forming.

How Precipitation Forms

Puffy cumulus clouds often appear in fair weather. Wispy cirrus clouds indicate changes in the weather. Darker stratus and cumulonimbus clouds forecast precipitation.

Large cumulus clouds can bring heavy rain or snow showers. These showers often end quickly. Stratus clouds usually cause long-lasting precipitation with smaller raindrops or snowflakes. Taller clouds are likely to produce larger drops.

Very tall clouds hold a great deal of water and may bring heavy downpours. The temperatures at the tops of these clouds are often below freezing. Strong up-and-down air drafts within these clouds can hurl ice crystals upward again and again. When this happens, water can freeze into ice in layer after layer. The layered lumps or pellets of ice are hailstones.

Measuring Rainfall

People have measured rainfall for thousands of years. It is especially important for farmers to know how much rain or snow will fall each year and when it will come. Today, the instrument used to measure rainfall is a rain gauge, a funnel-shaped or straight-sided container with a flat bottom.

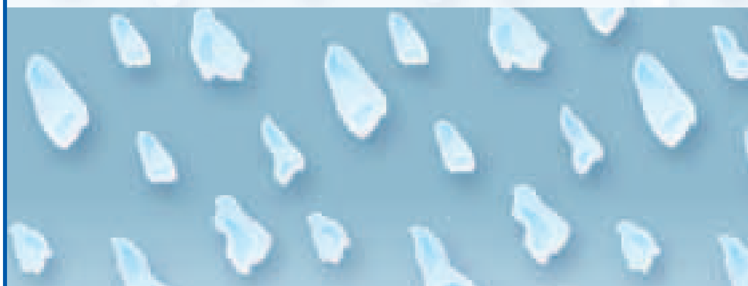
Quick Check

Classify Which types of precipitation are associated with cumulus and stratus clouds?

Critical Thinking Why do you think hail forms in tall clouds?

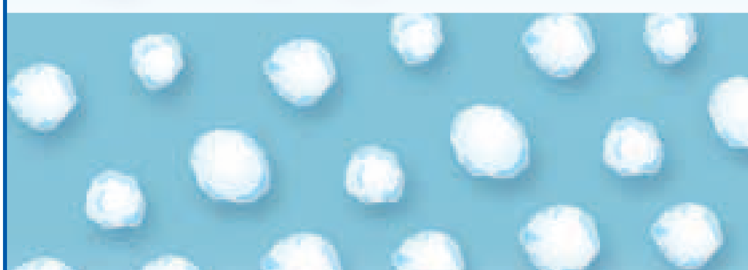
Precipitation

Rain falls when the temperature is warm enough to melt ice; water droplets then condense.



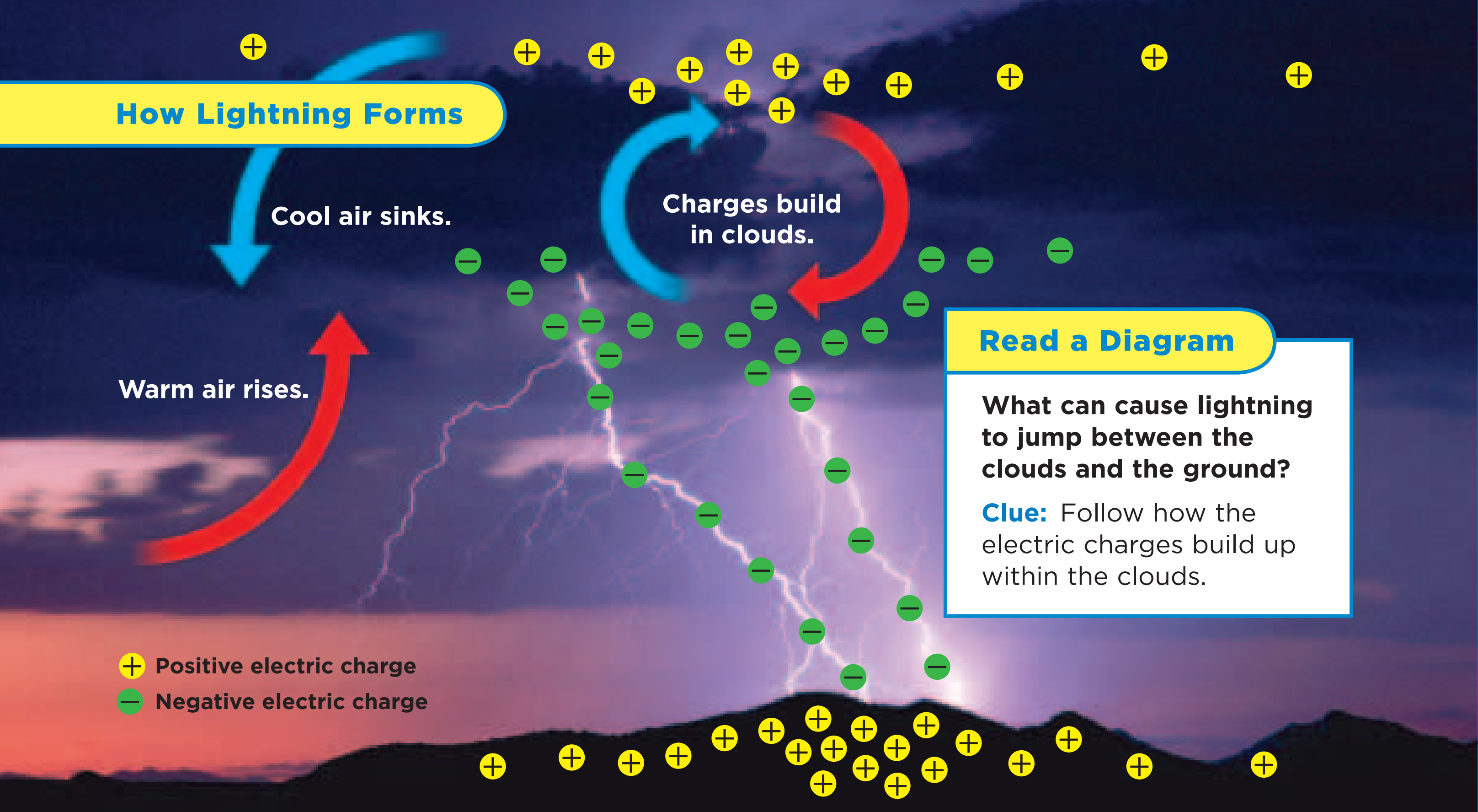
Sleet forms when raindrops freeze and turn into pellets of ice before falling to Earth's surface.

Snow falls when the air is so cold that water vapor becomes solid rather than condensing into droplets.



Hail forms as wind pushes raindrops high into the atmosphere, where they turn into ice. The process repeats as water freezes in layers, and the hailstones grow. In time, the hail falls.

How Lightning Forms



The attraction between positive and negative charges produces a conductive path. The surge of electricity heats the air, and we see a flash of lightning.

Read a Diagram

What can cause lightning to jump between the clouds and the ground?

Clue: Follow how the electric charges build up within the clouds.

Thunderstorm-Safety Tips

Thunderstorms can be very dangerous. Watch for storm warnings, and follow these tips:

- Stay away from trees and other tall structures that stand alone. Avoid touching metal.
- If possible, take shelter in a car or building. Close windows and doors.
- If you are in an open area, get as close to the ground as possible.
- Stay away from water.

What is a thunderstorm?

Rain sometimes comes with a *thunderstorm*, the most common kind of severe storm. Thunderstorms form in cumulonimbus clouds. They usually produce strong winds and heavy rain.

Thunderstorms begin when intense heat causes air to rise quickly. This heated air, or updraft, cools and forms clouds. Updrafts hold water droplets and ice crystals in the clouds. When they grow too heavy for the updrafts to support, they fall as rain or hail.

As the precipitation falls, many collisions occur among the raindrops and ice crystals. Downdrafts in the cloud also cause falling air to brush against rising air. This results in an electric charge. When enough of a charge builds up, it produces a huge spark, which is called lightning. Lightning may jump from ground to cloud, from cloud to ground, or from cloud to cloud. Lightning superheats the air around it. The air expands suddenly and then contracts as it cools. This rapid movement of air produces sound waves that are heard as thunder.

Tornadoes

The most violent thunderstorms can produce tornadoes. A **tornado** is a violent, whirling wind that moves across the ground in a narrow path. Tornadoes form when cold, dry air mixes with warm, moist air.

On very hot days, rising air causes powerful updrafts. The air begins to spin. If the updraft is very strong, air rushes in at a high speed, and the air pressure in the center drops. As more air rushes in, the pressure drops even more, and the spinning increases. Soon, a funnel forms that may touch the ground. Winds in the funnel can reach speeds of 500 kilometers (300 miles) per hour or more.

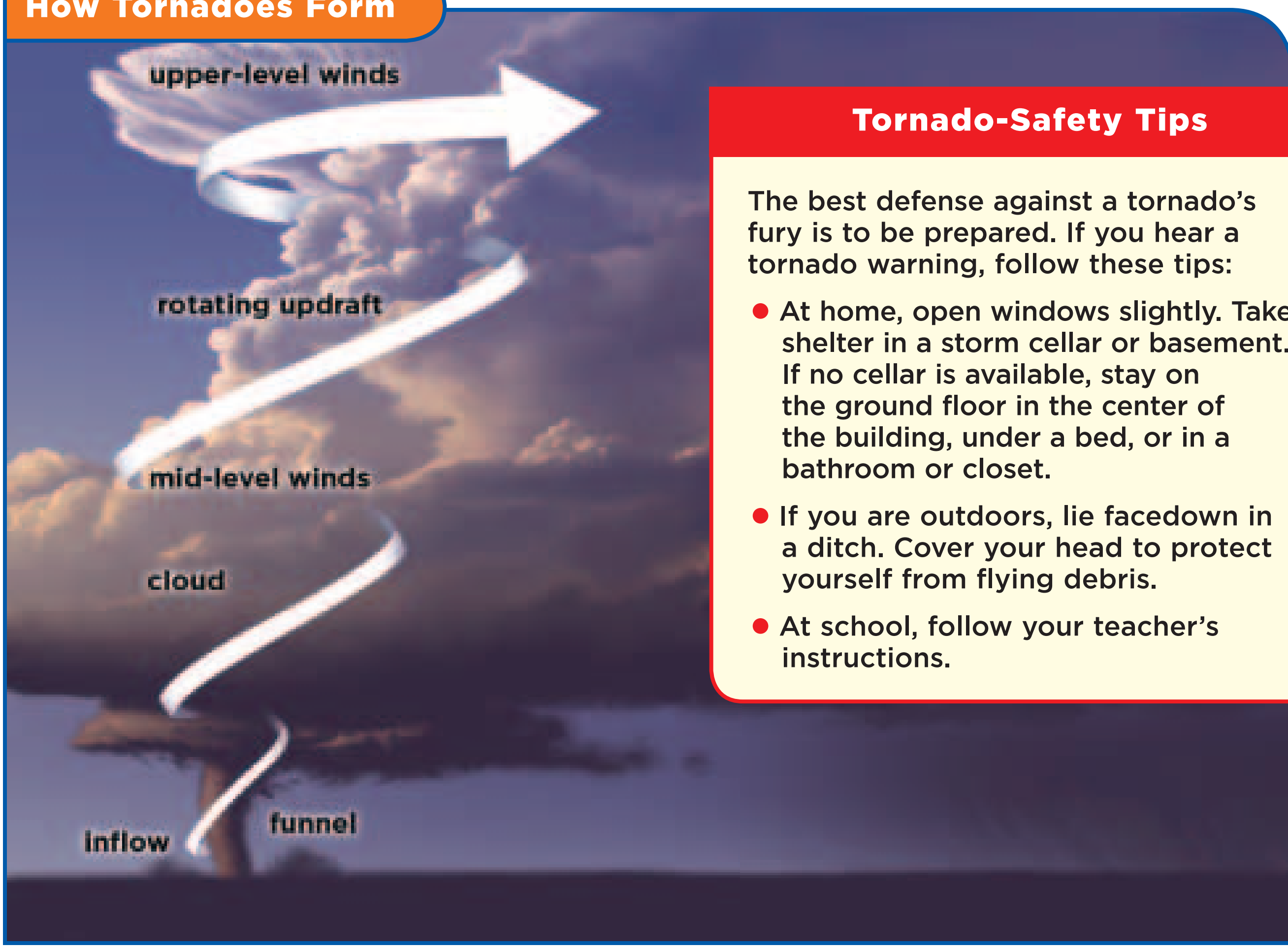
The wind speed of a tornado is not the speed at which the tornado moves along the ground. Tornadoes can move either quickly or slowly. They can also change direction abruptly, moving first in one direction and then in another. Tornadoes can cause terrible damage, breaking up buildings, uprooting trees, and lifting cars into the air.

Quick Check

Classify Categorize these storms according to degree of danger: tornado, rainstorm, thunderstorm. Explain your ranking.

Critical Thinking Why should people stay alert during a severe storm, even if they are indoors?

How Tornadoes Form



Tornado-Safety Tips

The best defense against a tornado's fury is to be prepared. If you hear a tornado warning, follow these tips:

- At home, open windows slightly. Take shelter in a storm cellar or basement. If no cellar is available, stay on the ground floor in the center of the building, under a bed, or in a bathroom or closet.
- If you are outdoors, lie facedown in a ditch. Cover your head to protect yourself from flying debris.
- At school, follow your teacher's instructions.

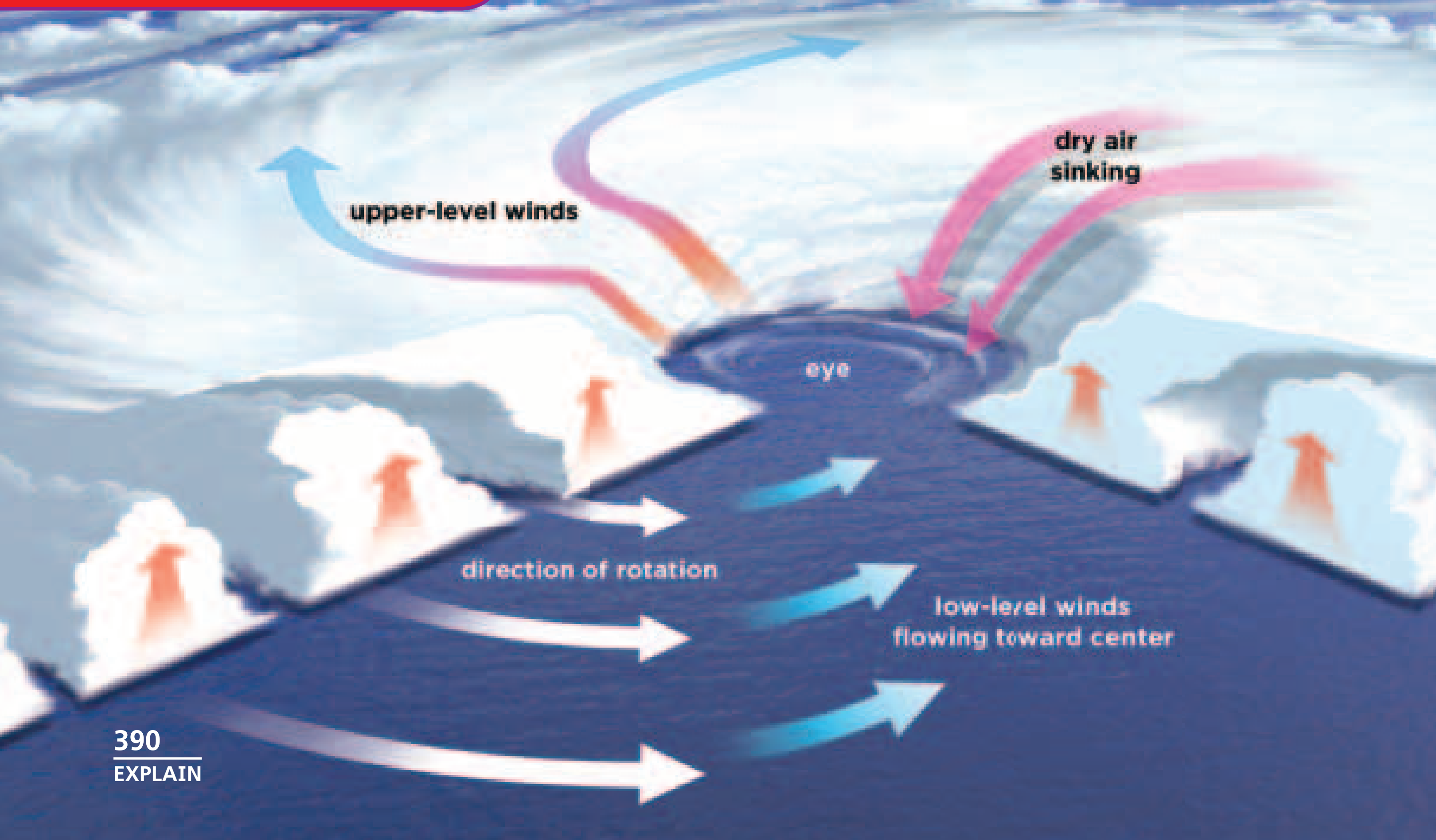
What are hurricanes?

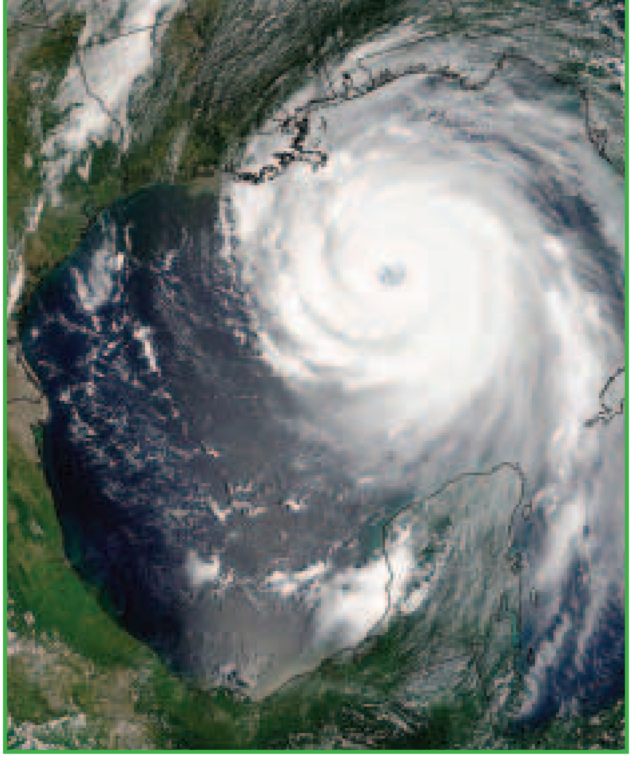
Hurricanes are large, swirling storms with low pressure at the center. They begin as thunderstorms over tropical oceans near the equator. Global winds push the thunderstorms west. Heat and evaporation produce a large region of low pressure in the center of these storms. Winds blow in toward the center and spiral upward. In the Northern Hemisphere, the Coriolis effect causes the winds to flow counterclockwise. The thunderstorms merge into one large storm that gathers strength as it travels over warm waters.

Water vapor in the storm condenses and releases heat. The warming of the air causes the density and pressure of the air to drop even more. As the air pressure falls, the winds grow stronger. When winds at the storm's center reach 120 kilometers (75 miles) per hour, the storm is considered a hurricane. Hurricanes produce tremendous amounts of rain. The center of the hurricane, an area of light winds and nearly clear skies, is called the *eye*.

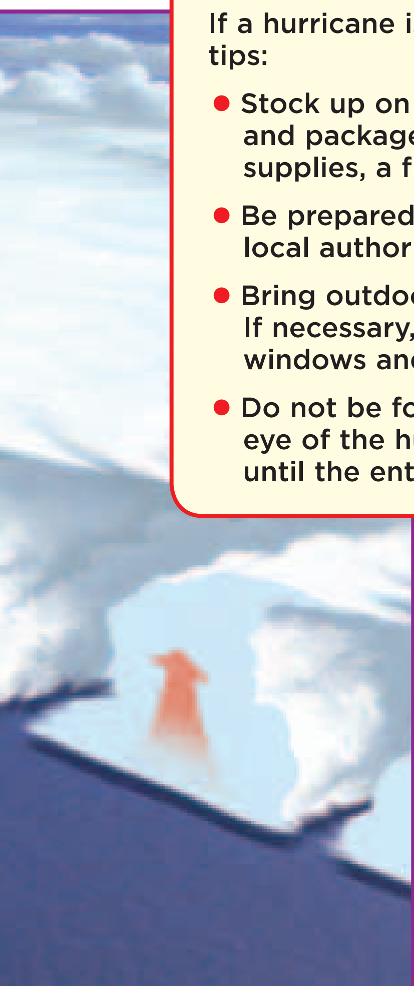
Air pressure always presses down on the surface of the ocean. Because the air pressure in a hurricane is low, the greater pressure surrounding the hurricane causes the level of the sea beneath the hurricane to rise. This forms a bulge that travels along below the hurricane. When the hurricane reaches land, this bulge causes the sea level near the shore to rise suddenly, often by 6 meters (20 feet) or more. This is called the *storm surge*. Usually, a great deal of hurricane damage is caused by water from the storm surge.

How Hurricanes Form





▲ In August 2005, Hurricane Katrina struck the southern United States. This is a satellite image of the hurricane just before it made landfall.



Hurricane-Safety Tips

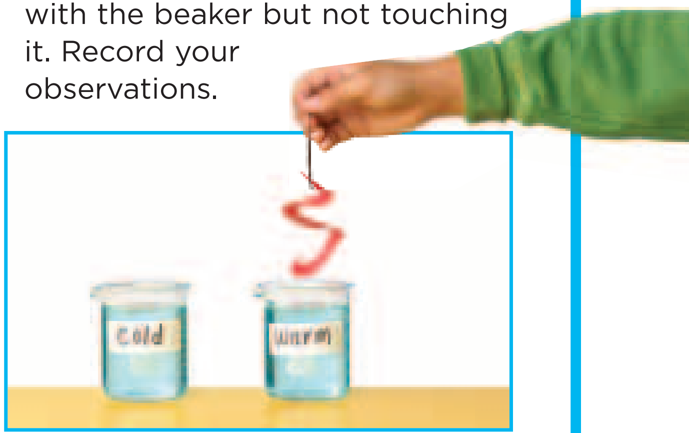
If a hurricane is expected, follow these tips:

- Stock up on bottled water, canned and packaged foods, first-aid supplies, a flashlight, and batteries.
- Be prepared to leave the area if local authorities advise you to do so.
- Bring outdoor objects inside. If necessary, board or tape up windows and glass doors.
- Do not be fooled by the calm at the eye of the hurricane. Stay indoors until the entire hurricane has passed.

Quick Lab

Comparing Currents

1. **Use Variables** Place two identical beakers about 50 cm apart on a table. Pour cold water from the refrigerator into one beaker. Pour very warm water into the other beaker.
2. **Experiment** Hold a paper spiral by a thread over the very warm water for about 20 seconds. The bottom of the paper spiral should be level with the beaker but not touching it. Record your observations.



3. Repeat step 2, using the cold water instead of the very warm water.
4. **Communicate** How would you explain your observations? (Hint: Think of what happens when water is very warm.)
5. **Infer** Why do hurricanes form in the tropics but not in the northern Atlantic or Pacific oceans?

Quick Check

Classify What makes hurricanes so dangerous?

Critical Thinking Why do you think hurricanes often lose some of their force after moving over land?

How can we predict severe storms?

Storms are often difficult to predict because they can form quickly. To find and track developing storms, scientists use weather satellites, radar, and planes fitted with special equipment. They look for weather conditions such as the formation of severe low-pressure areas. When such conditions arise, scientists closely monitor how they develop.

In August 2005, Hurricane Katrina headed toward the Gulf Coast. To find out more about the storm, weather forecasters sent a specially-equipped plane into the eye of the hurricane. The crew members measured wind speed, temperature, and air pressure. This information helped scientists make predictions about the size of the storm and the speed of its winds.

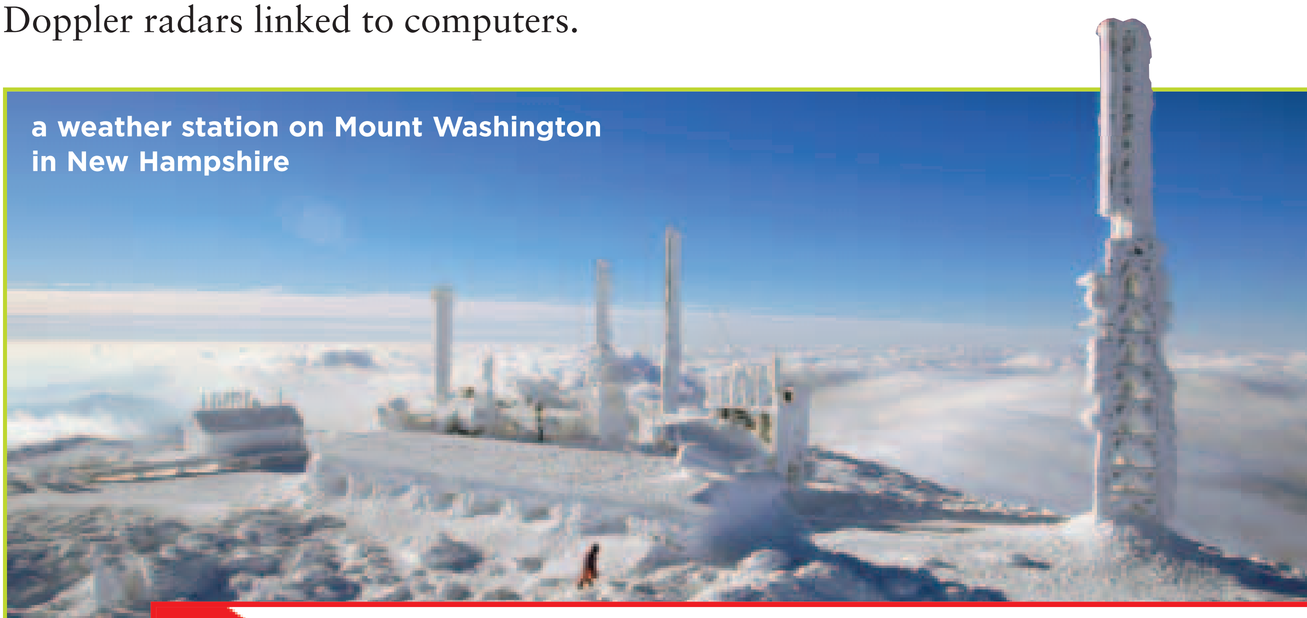
Images from satellites also provide important information. Scientists use Doppler radar to learn more about global weather patterns. NEXRAD, a more advanced version, uses a series of Doppler radars linked to computers. This setup increases scientific accuracy and produces three-dimensional images of storms. NEXRAD tracks both the direction and speed of a storm, as well as the type of precipitation produced.

Mobile Doppler radar helps provide an early warning of severe weather.

Quick Check

Classify What kind of weather information do satellite images provide?

Critical Thinking How is information about air pressure used in predicting storms?

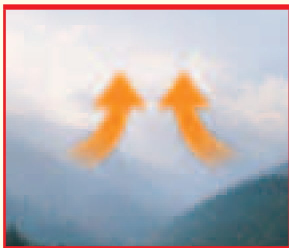


a weather station on Mount Washington in New Hampshire

FACT The highest wind speed ever recorded on Earth, 372 kilometers (231 miles) per hour, occurred in 1934 on Mount Washington in New Hampshire.

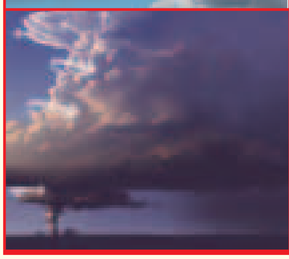
Lesson Review

Visual Summary



Earth's weather is directly affected by the **water cycle**.

Clouds have different shapes, form at different altitudes, and can produce different types of precipitation.



Thunderstorms, **tornadoes**, and **hurricanes** are three kinds of storms that can develop quickly and cause destruction.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add details for each weather-related topic.

Think, Talk, and Write

1. **Main Idea** Two factors in the formation of clouds and precipitation are ________ and ________.
2. **Vocabulary** When a gas changes into a liquid as heat is removed, the process is called ________.
3. **Classify** What kinds of clouds are most often found in hurricanes?

4. **Critical Thinking** Explain why hurricanes form over tropical seas but not over the seas in polar regions.
5. **Test Prep** **What kind of cloud forms in blanketlike layers?**
   A stratus
   B cumulus
   C cirrus
   D cumulonimbus
6. **Test Prep** **Much of the damage connected with a hurricane is caused by the**
   A humidity.
   B storm surge.
   C runoff.
   D dew point.

Math Link

Calculate Weather Averages
Collect the weather pages of a local newspaper for one week. Calculate the average temperature, humidity, and air pressure of your area, using data from each day of that week.

Social Studies Link

Compare Weather Around the World
Compare and contrast the weather in one Northern Hemisphere city and one Southern Hemisphere city. Choose cities that are about the same distance from the equator.

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Be a Scientist

Materials


potting soil


aluminum pan


plastic cup


water


sand


gravel

Structured Inquiry

What can change a river?

Form a Hypothesis

All across the United States, people have changed the flow of rivers to accomplish different tasks, such as irrigating fields and powering turbines for electricity.

The flow of water in a river is influenced by various factors. Rain and snowfall can increase the amount of water in a river. Drought and human-made structures can also slow or stop the flow. Even the type of material that a river moves through will affect a river's shape and flow.

What materials affect the shape and flow of a river the most? Write your answer in the form of a hypothesis: "If a mountain is made of soil, sand, gravel, or a combination of all three, then the river's shape and flow will change the most if the mountain is made of ________."

Be Careful. Wash your hands with soap and water after this activity.

Test Your Hypothesis

1. Use potting soil to make a mound at one end of the aluminum pan. This will represent a mountain.
2. Use a plastic cup to pour a small amount of water onto the top of your soil mountain. Draw and record what happens to the mountain as a result.
3. Repeat steps 1 and 2 with sand and then with gravel.
4. Repeat steps 1 and 2 using a mixture of all three materials.

Draw Conclusions

5 **Compare** What similarities and differences did you notice among the soil, sand, and gravel mountains?

6 **Interpret Data** Compare your data from the mountains made of soil, of sand, of gravel, and of all three materials. Which of the four mountains do you think was most like a real mountain? Why?

7 **Infer** What type of mountains or land would cause the deepest rivers to form? Why?

Guided Inquiry

What affects the speed of flowing water?

Form a Hypothesis

What can you do to change the speed at which water flows in a river? Write your answer in the form of a hypothesis: "If a streambed is narrowed, then the speed of the water will . . ."

Test Your Hypothesis

Design an experiment to investigate how narrowing the streambed affects the speed of the flowing water. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

Did your results support your hypothesis? Why or why not? What factors contributed most to the speed of the flowing water?

Open Inquiry

What else can you learn about rivers? For example, what effect do dams have on a river's speed and flow? Design and carry out an experiment to answer your question. Organize your experiment to test only one variable, or one item being changed. Write the experiment with enough detail that another group could repeat your experiment by following your instructions.

Remember to follow the steps of the scientific process.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions

Lesson 3

Predicting Weather

Look and Wonder

These scientists are using a weather balloon to learn more about an approaching storm. Thunderstorms often occur when there are sudden changes in temperature. How can temperature variations cause the weather to change?

Explore

Inquiry Activity

Does temperature affect the movement of air?

Form a Hypothesis

What happens when the temperature of air changes? Does air that is cooler rise or sink? Write your answer in the form of a hypothesis: "If the temperature of air is lowered, then the air will . . ."

Test Your Hypothesis

1. Place a tray of ice cubes on a table. Put pencils underneath each end to raise the tray slightly.
2. Slide a liquid-crystal thermometer strip underneath the ice-cube tray.
3. Rest two pencils on top of the ice-cube tray. Put a second liquid-crystal thermometer strip on top of the pencils.
4. **Observe** Record the temperature of each strip every minute for 5 minutes.

Draw Conclusions

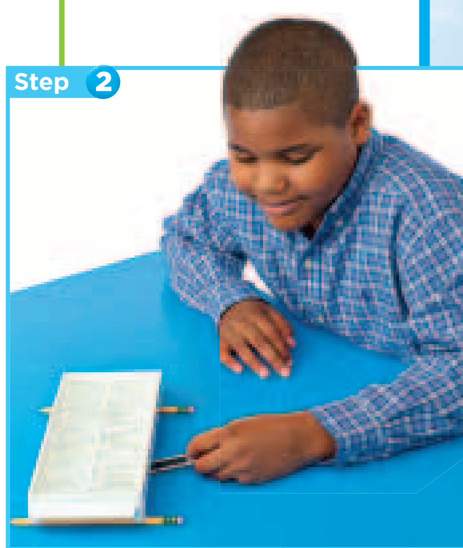
5. **Use Numbers** Make a line graph showing the temperature changes for each strip. Place time along the *x*-axis and temperature along the *y*-axis.
6. **Interpret Data** Which cooled faster: the air above the tray or the air beneath it? Did your observations support your hypothesis?

Explore More

Design an experiment to test the movement of warm air. Check with your teacher, and then carry out your experiment. Interpret your data, and then present your results to the class.

Materials

- ice-cube tray filled with ice
- 4 pencils
- 2 liquid-crystal thermometer strips
- stopwatch



Read and Learn

Main Idea

To predict weather, scientists study air's properties and movement.

Vocabulary

isobar, p. 398
air mass, p. 400
front, p. 400
cold front, p. 400
warm front, p. 400
occluded front, p. 400

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Reading Skill

Cause and Effect

Cause → Effect
→
→
→
→

Technology SCIENCE QUEST

Explore weather patterns with a meteorologist.

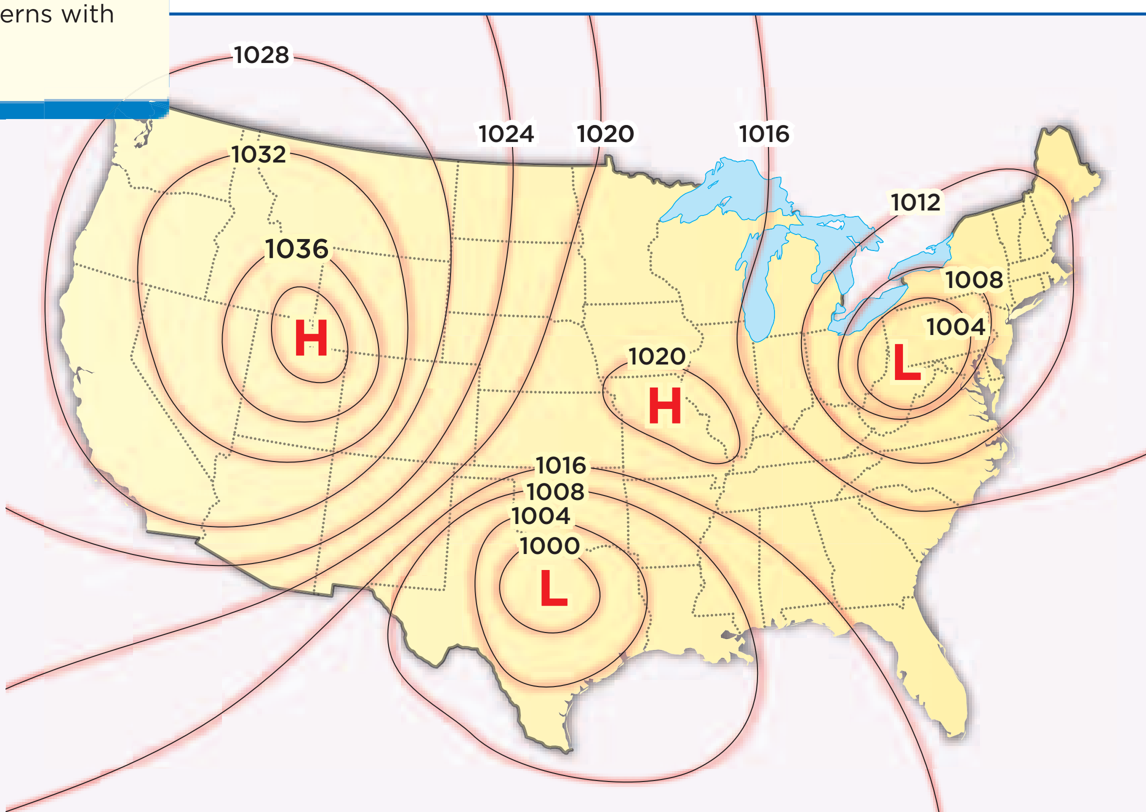
What are highs and lows?

In order to predict weather, scientists study how air moves. Recall that air moves from areas of high pressure to areas of low pressure. This movement is wind.

Weather maps show a region's air pressure. They include **isobars**, which are lines that connect places with equal air pressure. Isobars help make air-pressure patterns easier to see. Air pressure is commonly measured in millibars.

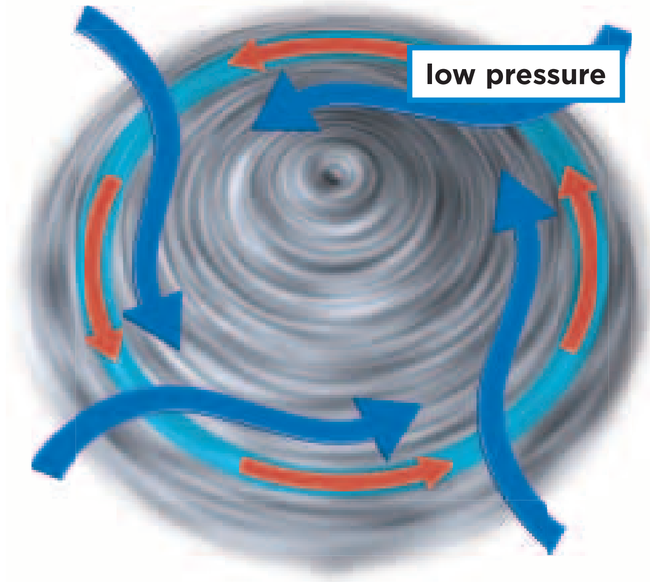
Look at the map on this page. Notice the series of circles within circles in the east. This pattern is a low-pressure system (L), or low. Isobar readings decrease toward the center of a low-pressure system. The map shows another set of isobars in the west. This pattern is a high-pressure system (H), or high. The center of this system has higher air pressure than the surrounding area.

Isobars give scientists an idea of wind speed. Air moves fastest where pressure differences are greatest. Isobars spaced closely together show a large change of pressure over a small area. They indicate that wind speeds will be high. Widely spaced isobars indicate gentle winds.



This map shows a sample of air-pressure readings across the continental United States. The air pressure is measured in millibars

Air-Pressure Systems: Northern Hemisphere



Read a Diagram

In which direction does air move around a high-pressure system?

Clue: Compare the direction of the movement to a clock's hands.

Air Movement Around Highs and Lows

In areas of high pressure, air flows outward from the center of the system. In the Northern Hemisphere, the air leaving a high-pressure system rotates clockwise because of the Coriolis effect. The opposite pattern occurs around a low-pressure system. Air flows in toward the area of low pressure and rotates counterclockwise.

In the Southern Hemisphere, the Coriolis effect bends moving air to the left. The patterns of movement around high-pressure and low-pressure systems are the reverse of those in the Northern Hemisphere.

Air Pressure and Weather

Different types of weather develop in highs than in lows. In general, areas of high pressure have fair weather. Cumulus clouds might be present, but there would generally be little or no rain. A low-pressure area usually has clouds and precipitation. Storms and rain often follow a drop in air pressure. When the barometer reading drops suddenly, there is a good chance that precipitation will occur.

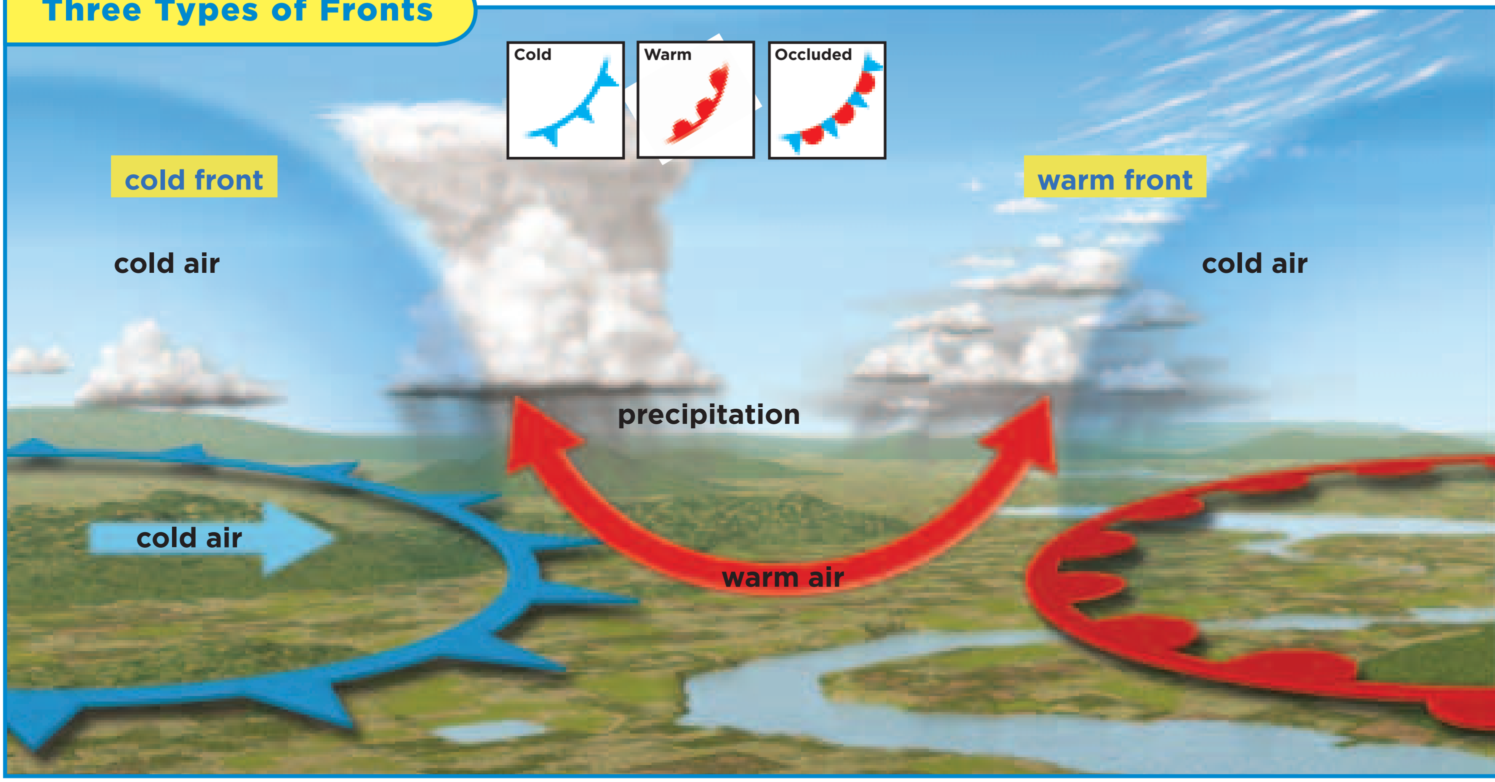
Quick Check

Cause and Effect What kind of weather would be caused by a drop in air pressure?

Critical Thinking In what direction would air move around a low in the Southern Hemisphere? Explain.

FACT The Coriolis effect is not strong enough to affect the motion of draining water in bathtubs or sinks.

Three Types of Fronts



What are weather fronts?

Why do weather conditions vary from one part of a country to another part? This is because the two locations have different air masses. An **air mass** is a large region of the atmosphere in which the air has similar properties throughout. Several air masses may be over a country at any given time.

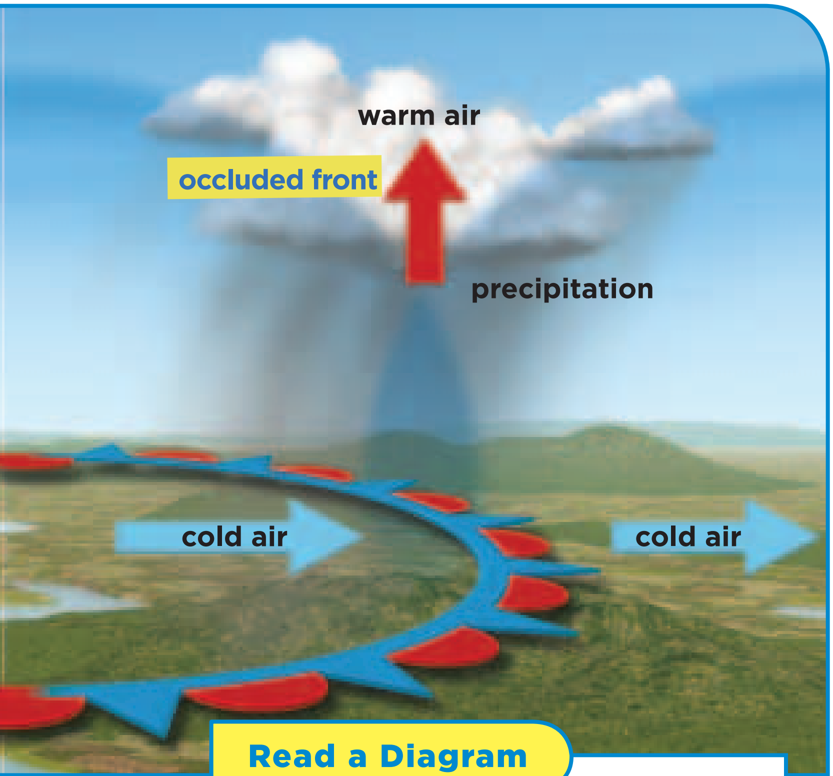
The properties of an air mass depend on the region in which it forms. Air masses that form over water tend to be humid. Air masses that form over land tend to be dry. An air mass that forms in the tropics is hot. If it forms near the poles, it is cold.

After an air mass forms, global winds may move it. For example, westerlies move air masses from west to east. Air masses meet at a **front**, the boundary between two air masses.

There are three basic types of moving fronts. Along fronts, weather can change rapidly. At a **cold front**, cold air moves in under a warm air mass. Cold fronts often bring brief, heavy storms. After these storms, the skies become clear, and the weather is usually cooler and drier.

At a **warm front**, warm air moves in over a cold air mass. Warm fronts often bring light, steady rain or snow. Afterward, the weather is usually warmer and more humid.

When a cold front catches up with a warm front, an **occluded front** (uh•KLEW•did) forms. Cool air moves underneath the warm front. This produces a wedge of warm air between two masses of cold air. The formation of an occluded front often indicates that a storm will not last a long time.



Read a Diagram

Describe the conditions that cause a warm front to form.

Clue: Observe the way the cold-air and warm-air arrows are pointing.

Quick Lab

Weather Prediction

1. Find a weather map that shows the weather across the United States.
2. **Communicate** Describe the weather in each region: the Northwest, Southwest, Midwest, Southeast, and Northeast.
3. **Predict** Weather patterns generally move from west to east across the United States. How do you think the weather just east of the fronts will change in the next day or so? Explain.

Interpreting Weather Maps

Many factors combine to influence weather. These factors include air pressure, humidity, and temperature. To predict the weather, information about these and many other factors must be compiled from points of research all over the world. Scientists use computers to analyze all this information. This information is then summarized on weather maps.

Weather maps usually show different fronts and areas of high and low air pressure. To interpret a weather map, look first at the highs and lows. Recognize that a high usually means fair weather and a low usually means rain or snow. Then look at the fronts.

Fronts always come out of lows. In the Northern Hemisphere, fronts rotate counterclockwise around a low. Front locations can explain the wind direction in your city. For example, if you are northeast of an approaching front, winds will blow from the southeast.

Quick Check

Cause and Effect Suppose the temperature dropped and a storm brought heavy rains. Which type of front might have caused this?

Critical Thinking Why does weather change along a front?

Weather satellites provide data about temperature, winds, moisture, and cloud cover.

How is technology used to study weather?

The information on weather maps comes from a variety of sources. On the ground, weather stations record temperature, wind direction, wind speed, and humidity.

Scientists also use weather balloons to take measurements from high up in Earth's atmosphere. Weather balloons rise to 35 kilometers (22 miles) above the ground, recording data up into the stratosphere. Eventually, the balloons burst. The data recorders then return to the ground by parachute.

Weather balloons are expensive, because the balloons must be replaced constantly. In some cases, satellites can perform similar functions. The satellites orbit Earth, taking photographs and relaying them to computers. Satellite images show large weather patterns, such as the development of low-pressure systems and fronts.

Another important tool for weather scientists is radar. Radar uses radio signals to detect precipitation. The equipment fires pulses of energy at the area under investigation. Radar measures the time it takes for echoes of the signal to return and records any changes to the signal. The signals provide data about precipitation in the atmosphere. Doppler radar also gives an indication of wind speed.

By combining information from ground measurements, weather balloons, satellites, and radar, scientists can form detailed pictures of weather conditions.

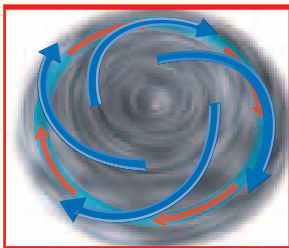
Quick Check

Cause and Effect What effect has technology had on weather prediction?

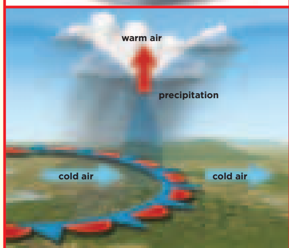
Critical Thinking Why is it better to obtain weather information from more than one source?

Lesson Review

Visual Summary



High-pressure and **low-pressure systems** cause changes in the weather.

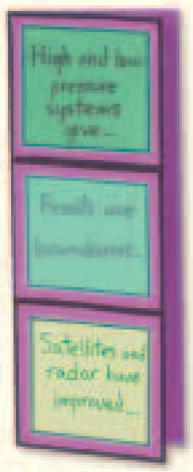


Fronts are boundaries where air masses meet. The properties of a front depend on the properties of the air masses.

Satellites and **radar** have improved the accuracy of weather forecasts.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the phrase and provide supporting details.



Think, Talk, and Write

1. **Main Idea** Scientists study the properties and movement of air so that they can ________.

2. **Vocabulary** When a warm air mass moves over a cold air mass, a(n) ________ forms.

3. **Cause and Effect** What type of weather often happens at a cold front?

Cause	→	Effect
	→	
	→	
	→	
	→	

4. **Critical Thinking** If you owned an almanac, a book that predicts weather years in advance, why would you still watch weather forecasts?

5. **Test Prep** **An air mass that forms over the ocean is always**
   A humid.
   B dry.
   C warm.
   D cold.

6. **Test Prep** **Lines that connect places with equal air pressure on a weather map are called**
   A fronts.
   B air masses.
   C station models.
   D isobars.

Writing Link

Expository Writing

Research the kinds of air masses that affect weather in the United States. Write a report about these air masses, including what they are named, where they form, and how they affect weather.

Social Studies Link

Make a Time Line

Research the history of weather forecasting. Make a time line that shows when new technology and advances in weather forecasting were invented and put into use.

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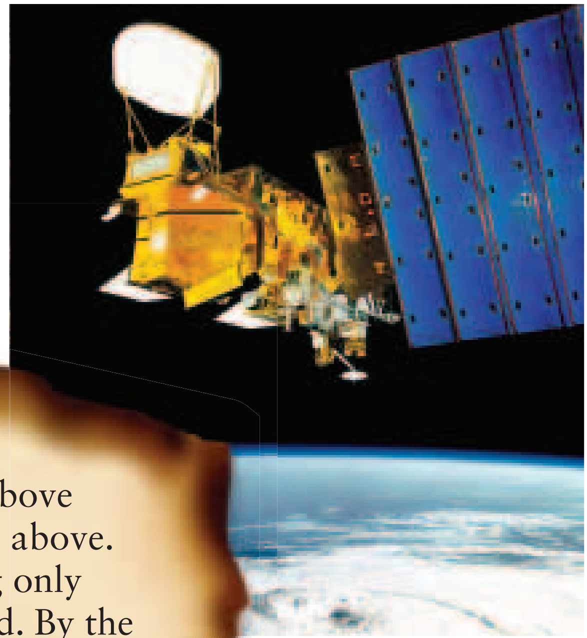
WILDFIRE ALERT

Every year, wildfires blaze throughout Southern California. The wildfires are fueled by the Santa Ana winds. These warm, dry winds blow out of the desert when it is cold, from October through March each year. They can gust up to 50–60 knots (93–111 kilometers or 58–69 miles per hour), through canyons and passes, moving as fast as a car on the freeway. The winds occur when high atmospheric pressure builds to the north and east of Southern California. Cold air then begins to sink and flow downhill from the mountains, where it compresses and warms. As the temperature rises, this air starts to dry up, producing the fast, hot, dry Santa Ana winds.

These winds can bring disaster to the residential areas of Southern California that have been built on the grasslands. The extremely low humidity helps dry out vegetation, making it better fuel for a fire. In addition, the winds can cause a fire to change direction in ways that are complex and difficult to predict. The USDA Forest Service monitors the speed and direction of the Santa Ana winds to predict what impact they may have on a fire.

A Forest Service air tanker spreads fire retardant to protect homes in California.

Scientists also use data from satellites above Earth that help the scientists see fires from above. Picture having to battle a wildfire by using only information you could get from the ground. By the time you got people out to the perimeter of the fire, the fire might have spread in new directions. You would need an incredible number of people and a lot of time just to be able to survey the fire area. NASA's *Terra* and *Aqua* satellites fly 644 kilometers (400 miles) above Earth. Data collected from these satellites is transmitted rapidly to the USDA Forest Service. The information helps the Forest Service know the whereabouts of a fire almost immediately. By working as a team, scientists and firefighters are able to control wildfires better than before.



The *Aqua* satellite monitors Earth's water cycle and global temperature changes.

Write About It

Sequence

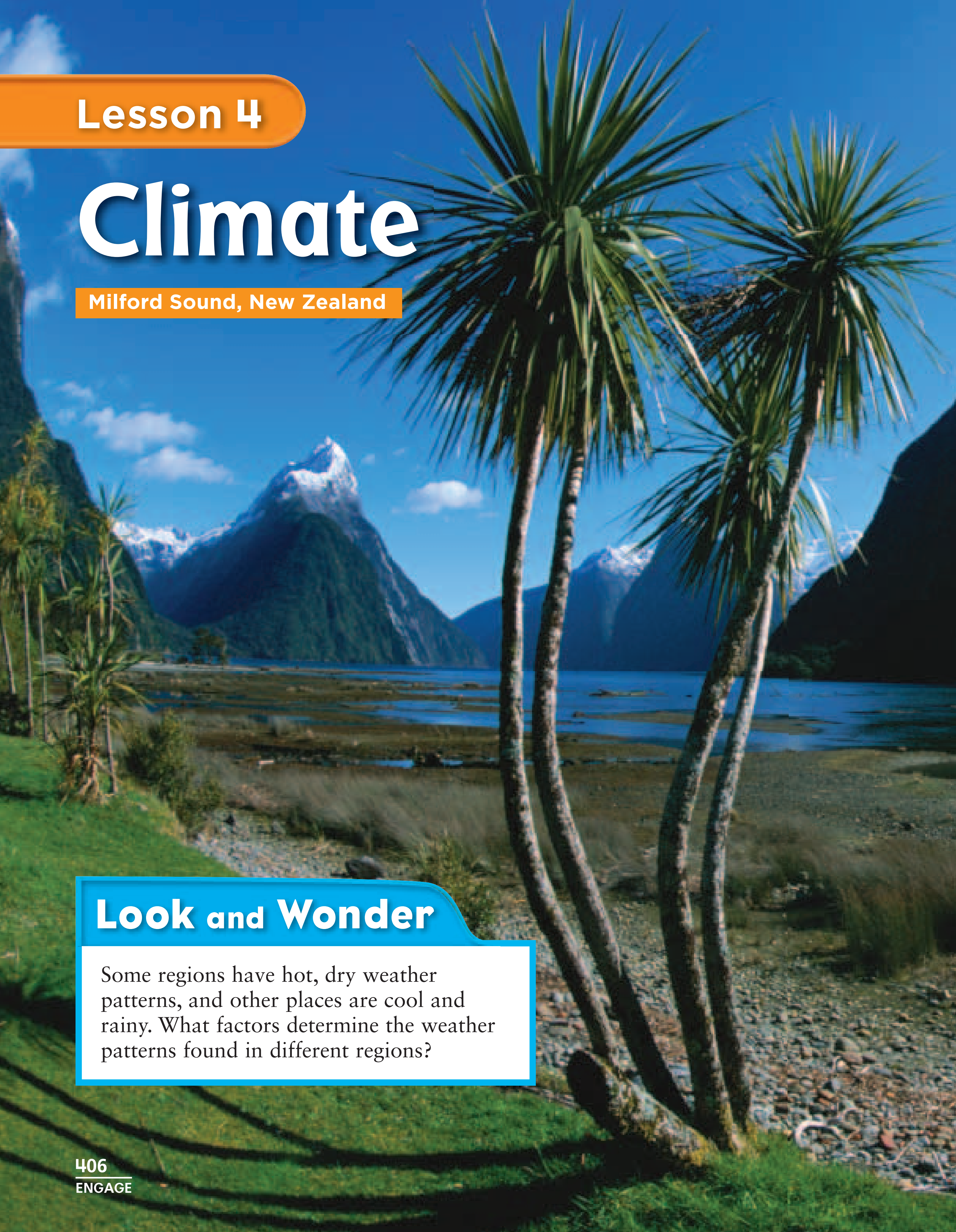
1. How do the Santa Ana winds affect vegetation before the outbreak of a wildfire?
2. What happens if the Santa Ana winds blow during a wildfire?

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Sequence

- Look for steps that happen first and last.
- Think about how steps relate to one another.

American Museum of Natural History



Lesson 4

Climate

Milford Sound, New Zealand

Look and Wonder

Some regions have hot, dry weather patterns, and other places are cool and rainy. What factors determine the weather patterns found in different regions?

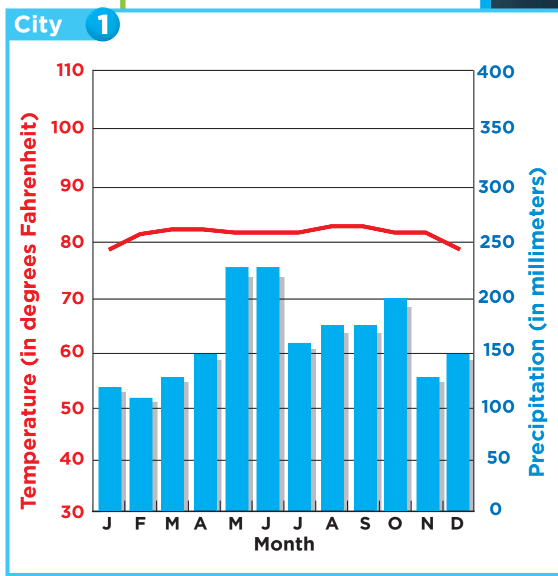
Explore

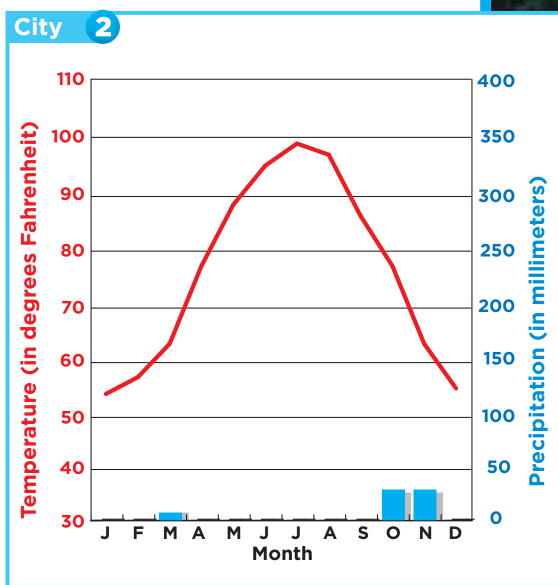
Inquiry Activity

What can weather patterns tell us?

Materials

- graphs (shown)





Purpose

What can you learn by studying weather patterns of a region? Could you use this information to compare two regions? Use the data on these graphs to compare the weather patterns of two cities.

Procedure

1. **Use Numbers** Look at the graphs for city 1 and city 2. The bottom of each graph is labeled with the months of the year. The left side of each graph is labeled with average temperature in degrees Fahrenheit. What is the average temperature in city 1 during July? In city 2? (Hint: Temperature is indicated in red.)
2. **Use Numbers** The right side of each graph is labeled with average precipitation in millimeters. What is the average precipitation in city 1 during July? In city 2? (Hint: Precipitation is indicated in blue.)

Draw Conclusions

3. **Interpret Data** How do the monthly temperatures throughout the year compare for the two cities?
4. **Interpret Data** How do the monthly amounts of precipitation compare for the two cities?
5. **Infer** Describe the average annual weather pattern of each city. Be sure to include information about temperature and precipitation as well as their relationship to the seasons.

Explore More

Research the weather patterns of your town, and make a graph similar to the ones shown. Present your results to the class.

Read and Learn

Main Idea

A region's average weather pattern, which can change over time, determines its climate.

Vocabulary

rain shadow, p. 411

sunspot, p. 412

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Reading Skill

Draw Conclusions

Text Clues	Conclusions

What is climate?

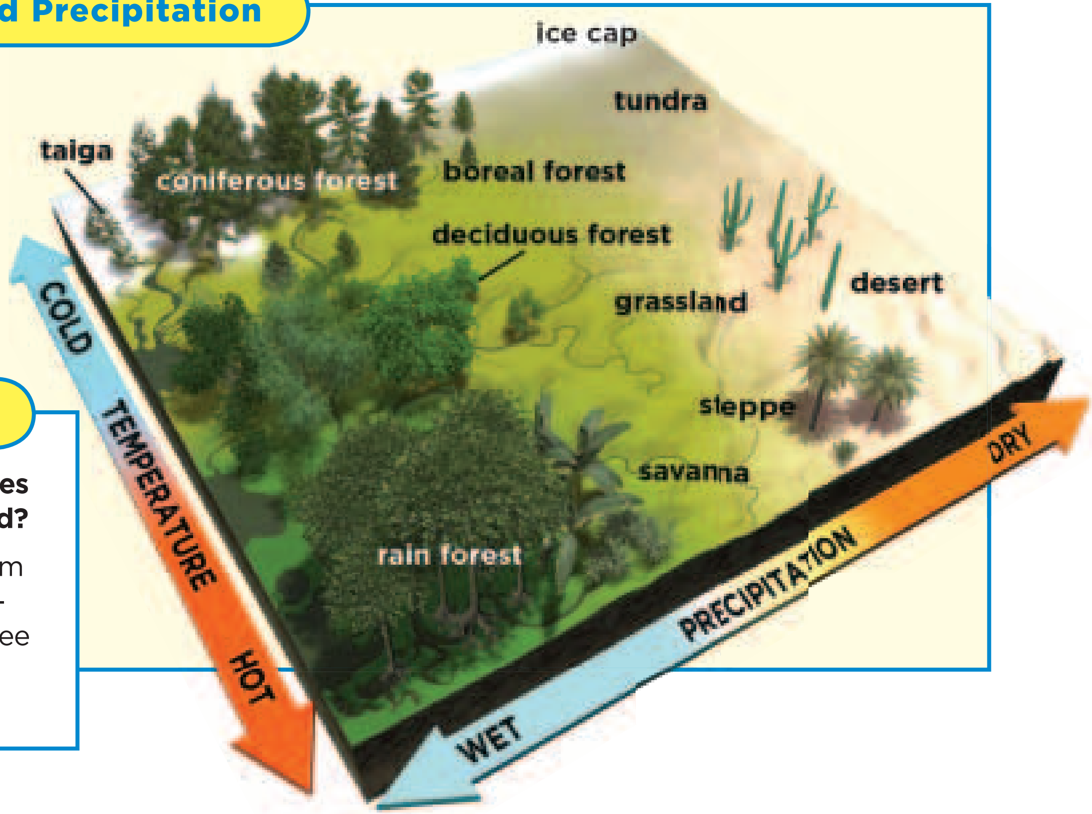
Weather changes often, but it follows a pattern over long periods of time. In your own town, summer may be hot and humid, winter may be cold and snowy, and spring and fall may be cool and dry.

Climate, the average weather pattern of a region, varies considerably. Many areas of the United States have climates with warm summers and cold winters. Climate differs from weather. Even though the climate in a region may include hot summers, the weather there on any single summer day could be cool.

Latitude

Climate is closely related to latitude, or distance north or south of the equator. Areas closer to the equator receive more of the Sun's energy than areas that are farther from the equator. As a result, areas near the equator have warmer climates. For example, the southern United States has a warmer climate than the northern area. In Southern California and in Florida, winter temperatures do not tend to dip below freezing, and snow rarely falls.

Temperature and Precipitation

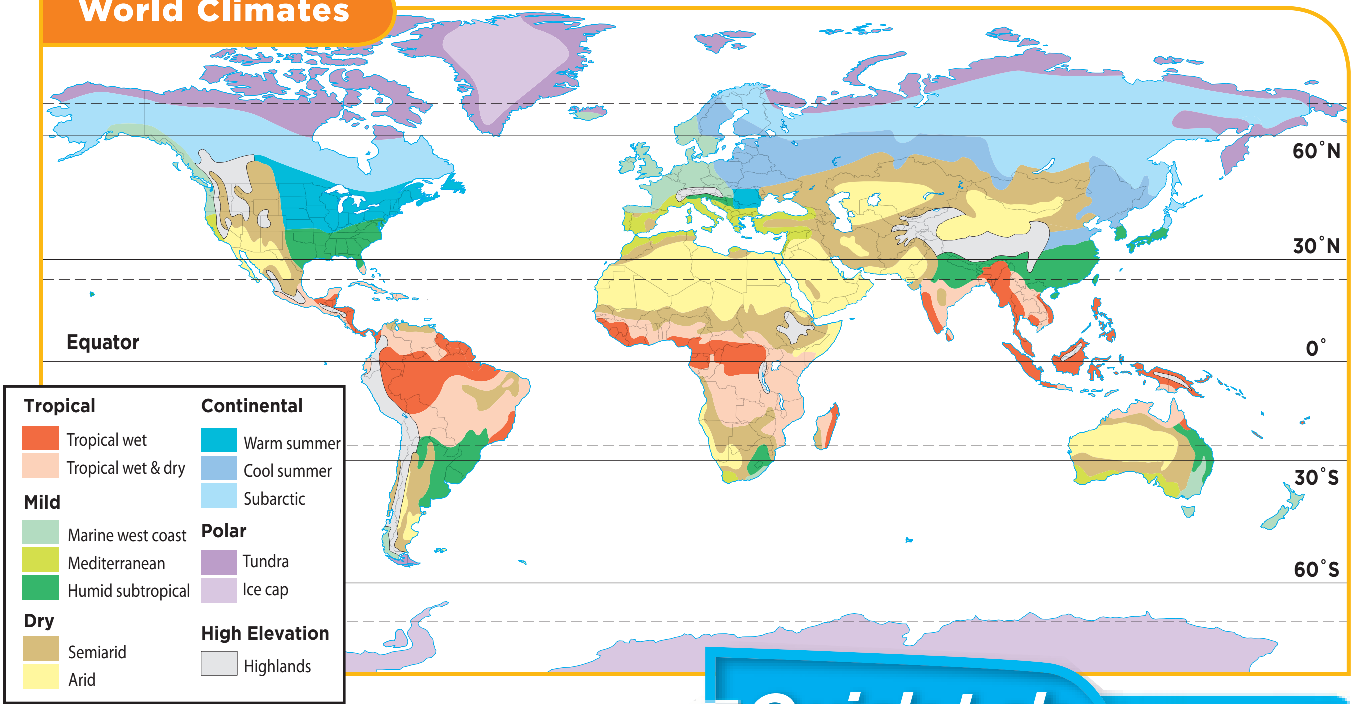


Read a Diagram

What types of climates are both wet and cold?

Clue: Use the diagram sides like a graph's *x*-axis and *y*-axis, and see where wet and cold conditions meet.

World Climates



In North Dakota and Montana, on the other hand, winter temperatures are often below freezing, and heavy snowfalls are common. Latitude plays a large part in these climate differences.

Tropical zones near the equator tend to have a hot and wet climate. At latitudes of about 30°N and 30°S, the climate is often hot and dry. Many deserts are found at these latitudes.

At latitudes between 30°N and 60°N or between 30°S and 60°S, summers are warm, and winters are cool or cold. At latitudes near the poles, winters are long and frigid, and summers are short and cool.

Quick Check

Draw Conclusions What types of plants might live in areas of low precipitation?

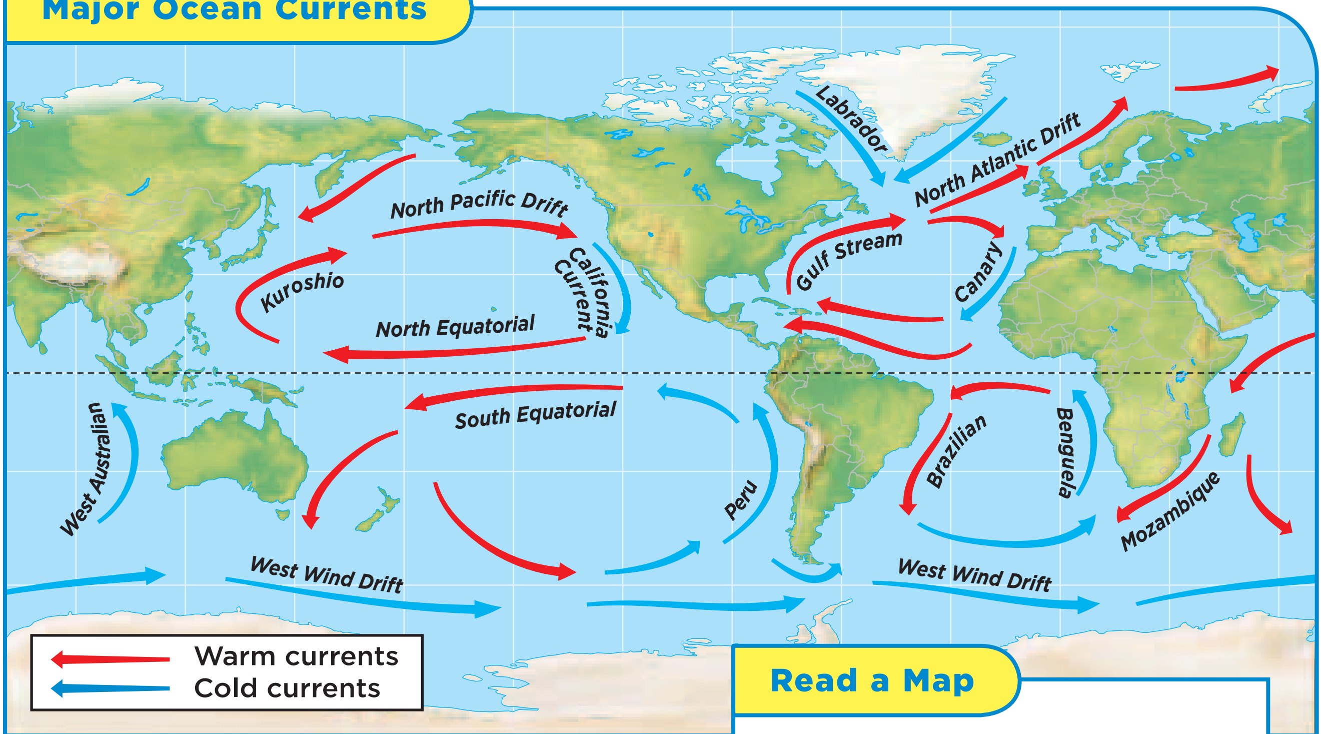
Critical Thinking How would you dress for a trip to the South Pole?

Quick Lab

Comparing Climates

1. Use an atlas or the Internet to gather data about the climate of your city or town. Record information such as latitude and longitude, average temperature, and annual precipitation.
2. Choose a city about 400 km north or south of your area that is at about the same longitude as yours.
3. Repeat step 1 for the city you chose in step 2.
4. **Interpret Data** How do the average temperatures and annual precipitation of the two locations compare?
5. **Draw Conclusions** Describe the climate of each location. How can you account for any differences?

Major Ocean Currents



Read a Map

Suppose you put a message in a bottle and dropped it into the ocean off the California coast. Where might the bottle travel?

Clue: Determine where the currents generally flow off the coast of California.

What affects climate?

Temperature and precipitation are the two main factors that determine climate. They, in turn, are affected by other factors.

One factor that affects temperature is the nearness of bodies of water. Land and water heat and cool at different rates. Water heats up more slowly than land. Water also cools off more slowly, because it holds energy better than land does. As a result, air temperatures over land are warmer in summer and cooler in winter than air temperatures over nearby oceans.

Regions that are located within a large landmass have what is called a *continental climate*. Areas that have this type of climate often have hot summers, cold winters, and low annual precipitation.

Regions near an ocean or other large body of water have a *maritime climate*. These areas often have warm summers and mild winters. The nearby water helps keep the temperatures moderate. Maritime regions usually have high annual precipitation.

Water currents also affect climate. Global winds move water in currents across the surface of the oceans. As the water moves, it warms or cools the air above it. Land areas near warm currents, such as the Gulf Stream, tend to have warm temperatures. Areas near cool currents, such as the California Current, often have cool temperatures.

FACT Two sides of the same mountain range may have very different climates.

Winds can also affect climates over landmasses. In the United States, the prevailing winds blow from west to east. They push air masses and fronts across the country. They also bring warm, moist Pacific Ocean air to the West Coast. Areas in the path of a prevailing wind coming from the water usually receive a high amount of precipitation.

Mountains and Elevation

Elevation, the height of an area in relation to sea level, has an effect on climate. This effect is noticeable on mountains. For example, Mount Kilimanjaro in Africa has tropical rain forests at its base, yet the top of the mountain is often covered with snow. The air is colder at higher elevations. This difference in temperature is because the air higher up is under less pressure, and it therefore has less energy. Because of the decrease in energy, the temperature is cooler.

Mountain ranges also influence the climate of the land around them. For example, the Alps in Europe protect the Mediterranean coast from cold air that blows from the poles.

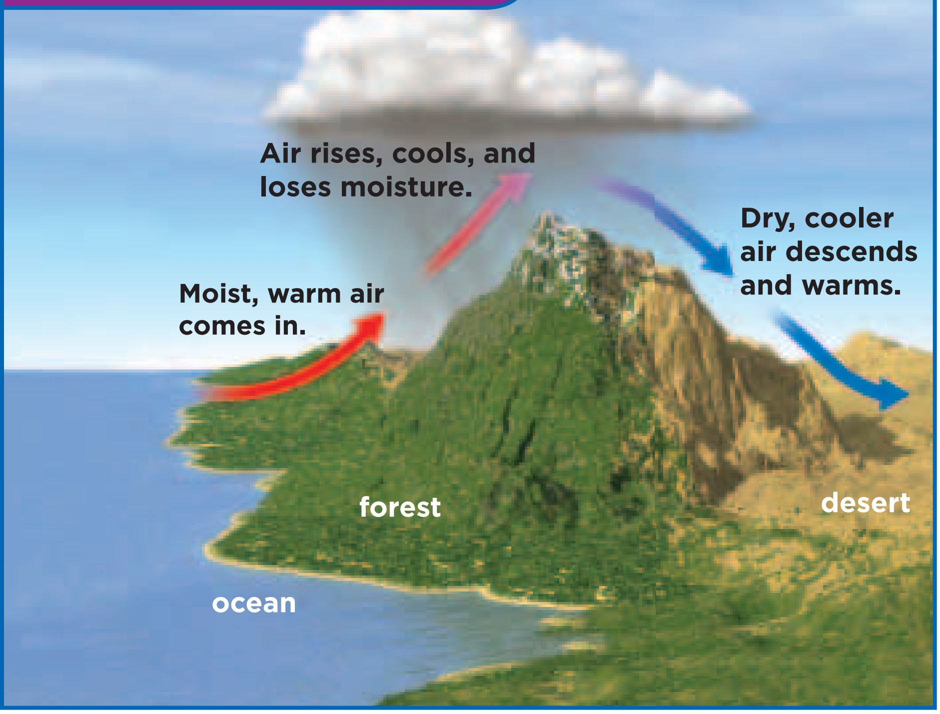
Wind patterns around mountains can affect a region's precipitation. As winds push air up the side of a mountain, the air cools. Clouds form and drop precipitation on the windward side. The air becomes dry and descends on the leeward side of the mountain. This side is said to be in a **rain shadow**.

Volcanoes

Erupting volcanoes send dust, ash, and gases into the atmosphere. The dust can block sunlight, cooling the air and the land. As a result, climate in the affected area can change considerably.

Long ago, eruptions occurred more often than they do now, greatly affecting climates. Today, eruptions still cause changes in the atmosphere. However, they do not affect climates as much as they did in the distant past.

Mountain Barrier



Quick Check

Draw Conclusions Suppose you live on the windward side of a coastal mountain range. A warm current flows along the coast. Describe the climate of your region.

Critical Thinking As you climb a mountain, you may pass through several climate zones. How is this possible?

Have climates changed over time?

There is much evidence that Earth's climates have changed over long periods of time. Evidence suggests that many factors can cause long-term climate changes, including variations in sunlight as well as plate tectonics.

The Sun

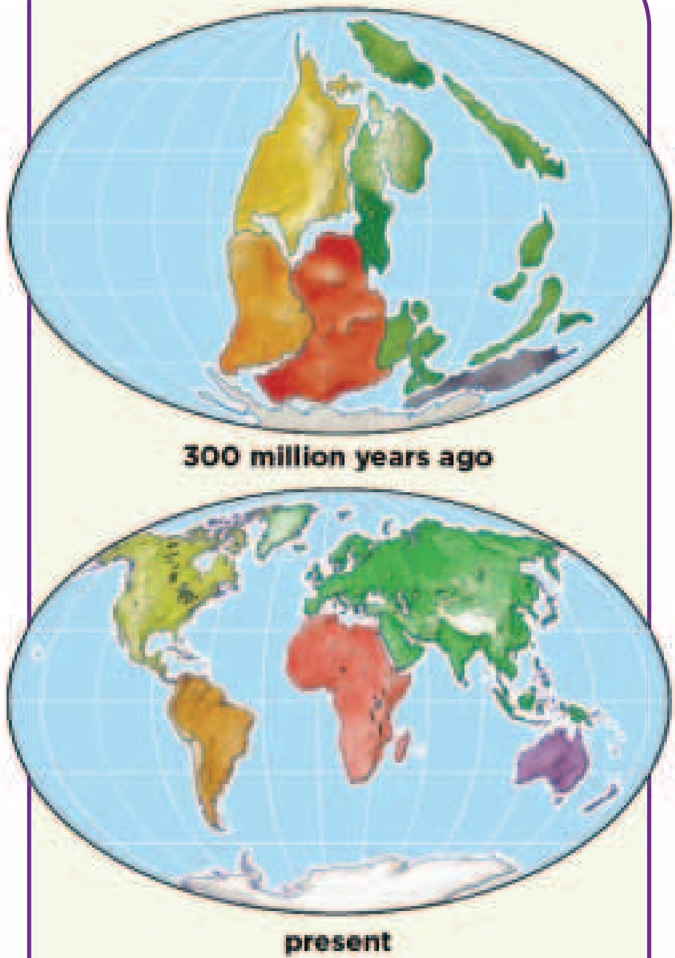
The energy output of the Sun varies. Evidence suggests that the brightness of the Sun has changed over the centuries. This could explain why cold periods, or ice ages, and warm periods have occurred in the past. Scientists continue to study the Sun to understand how these changes might affect Earth's present climates.

Scientists know that the Sun goes through a sunspot cycle every 11 years. **Sunspots** are dark areas that appear temporarily on the Sun's surface. These spots are related to the Sun's magnetic field. During the cycle the number of sunspots rises to a maximum and then drops to a minimum. Scientists have noted that during a sunspot maximum, Earth's average temperature tends to rise. The occurrence of droughts and very cold winters may also be influenced by the sunspot cycle. Sunspots have additionally been connected to disruptions of cell phones and other satellite-based equipment.

Plate Tectonics

Scientists think that cold areas such as Canada and Alaska may have had very different climates in the past, compared to today. Fossil evidence indicates that tropical ferns once grew in what are presently very cold areas.

Changes in Climate



Continental drift causes gradual climate changes over large areas.

Continental drift changed the locations of these areas over a long period of time. These cold regions were once located much closer to the equator.

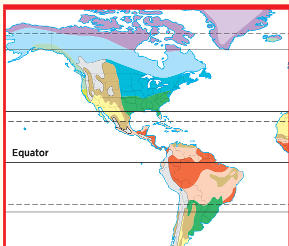
Quick Check

Draw Conclusions Scientists have learned that northern Europe once had a warm, wet climate. What led scientists to draw this conclusion?

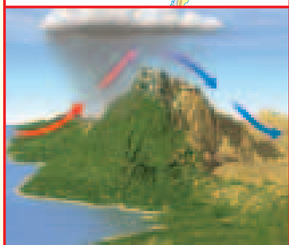
Critical Thinking What changes in the Sun might account for warm periods in Earth's history?

Lesson Review

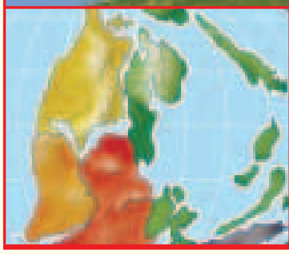
Visual Summary



Earth is divided into **climate zones** based on temperature and precipitation.



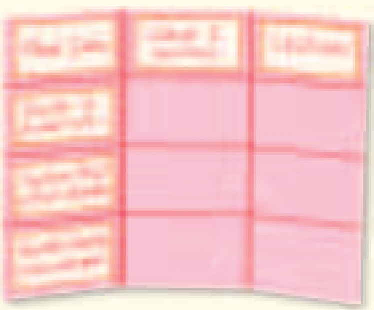
Factors that affect climate include latitude, winds, bodies of water, mountains, and volcanic eruptions.



Changes in Earth's climates over time may be due to **solar activity** and the movements of tectonic plates.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the phrases, and include a sketch for each climate-related topic.



Think, Talk, and Write

1. **Main Idea** Average temperature and precipitation in a given area are the main factors that determine an area's ________.
2. **Vocabulary** The Sun goes through an 11-year cycle that consists of an increase and a decrease in the number of ________.
3. **Draw Conclusions** An area has hot summers and very cold winters. It also experiences low precipitation. What kind of climate does this area have?

Text Clues	Conclusions

4. **Critical Thinking** Can people live in all climates? Explain your answer.
5. **Test Prep** **The elevation of a given area is based on the area's**
   A latitude.
   B longitude.
   C height above sea level.
   D average temperature.
6. **Test Prep** **As elevation increases, temperature generally**
   A increases.
   B decreases.
   C increases and decreases.
   D remains the same.

Writing Link

Writing a Story

Write a short science-fiction story describing a time-machine trip into the distant past or future. In your story, describe the climate in the era you have chosen. Share your story with the class.

Social Studies Link

Report on Sunspots

Research the effects that the sunspot cycle has on modern technology. How does this cycle affect cell phones and other electronic equipment used in communications?

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Writing in Science

Underground Homes

Are you allergic to dust and pollen? Is your family concerned about the cost of heating and cooling your home? Maybe your family could consider moving into an underground home.

A growing number of people in the United States have considered moving into this type of home. Although they are called underground homes, most of them are not completely underground. They often have a roof that lets in sunlight and fresh air. Many underground homes also have one or even two sides located at ground level.

Underground homes do have some advantages over aboveground ones. Unlike aboveground homes, underground homes let in very little dust or pollen. This is helpful for people with dust or pollen allergies. The temperature under the ground is 50°F (10°C) to 60°F (16°C) year-round. That makes these homes warmer in winter and cooler in summer. Your family could save money by using less oil, gas, and electricity than you now use to raise or lower the temperature in your home.

In contrast to aboveground homes, underground homes also need less painting and repair. In some ways, they can be safer as well. The ground surrounding the home can help protect the home from fires, storms, and even some of the damage caused by earthquakes.

Add up all these facts, and you might come to this conclusion: An underground home is an efficient and practical option when you are considering finding a new home.

Expository Writing

Good expository writing

- introduces the main idea and develops it with facts and details
- may use words of comparison, such as *like*, and words of contrast, such as *unlike*
- draws a conclusion based on the facts and details

Write About It

Expository Writing Choose one of these topics to compare and contrast.

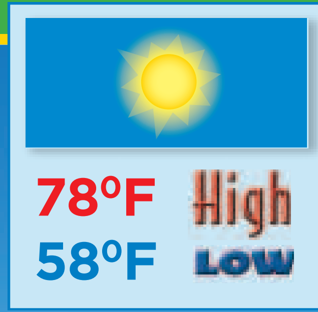
1. Compare and contrast the price of an energy-saving air conditioner or refrigerator with the savings in energy costs. How long would it take the appliance to save as much as it cost?
2. Compare and contrast two brands of refrigerators. Which is more energy efficient? Use energy-guide labels to make your comparison.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Castile-León, Spain

Math in Science

How Are Weather Highs and Lows Calculated?



San Diego, California

Month	Average Low Temperature	Average High Temperature
January	48.9°F	65.9°F
February	50.7°F	66.5°F
March	52.8°F	66.3°F
April	55.6°F	68.4°F
May	59.1°F	69.1°F
June	61.9°F	71.6°F
July	65.7°F	76.2°F
August	67.3°F	77.8°F
September	65.6°F	77.1°F
October	60.9°F	74.6°F
November	53.9°F	69.9°F
December	48.8°F	66.1°F

Source: NOAA

People describe weather events using words such as *most*, *least*, *highest*, and *lowest*. Most of these terms come from determining the average, or mean, occurrence of the weather event.

This table provides information about the monthly weather in San Diego, California.

Solve It

1. Using the data from the table, find the mean temperature for November in San Diego.
2. Find the median of the high-temperature data for San Diego. (Hint: Arrange the data from least to greatest value. For an even number of values, add the middle numbers and divide by 2.)
3. Make up your own problem about mean temperature. Trade papers with a classmate, and solve.

Find the Mean

To find the mean of numerical data,

- **add the values**

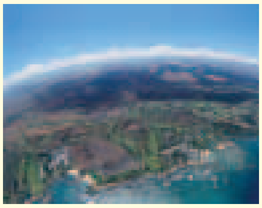
  $3 + 5 + 5 + 8 + 12 + 15 = 48$

- **divide the sum by the number of values**

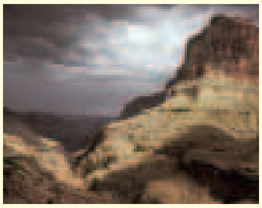
  $48 \div 6 = 8$

CHAPTER 7 Review

Visual Summary



Lesson 1 Many factors affect a region's weather.



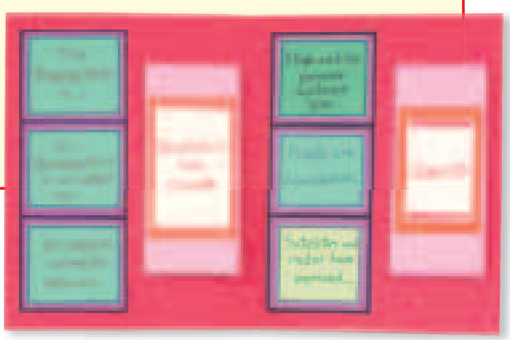
Lesson 2 Water vapor and changes in temperature are factors in cloud formation and in precipitation.

Lesson 3 To predict weather, scientists study air's properties and movement.

Lesson 4 A region's average weather pattern, which can change over time, determines its climate.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

air pressure, p. 374	**isobar**, p. 398
convection cell, p. 374	**rain shadow**, p. 411
evaporation, p. 382	**stratus clouds**, p. 384
front, p. 400	**sunspot**, p. 412

1. A line on a weather map that connects places with the same atmospheric pressure is called a(n) ________.

2. A dark area that appears temporarily on the Sun's surface is a(n) ________.

3. The changing of a liquid to a gas, called ________, occurs when particles vaporize at the surface.

4. A boundary between two different air masses is called a(n) ________.

5. An area on the side of the mountain that receives very little precipitation is in a(n) ________.

6. A blanketlike layer of ________ usually brings long-lasting rain.

7. A circular pattern of rising and sinking air is called a(n) ________.

8. The force exerted on an area by the weight of the air above it is called ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. **Classify** List the instruments that scientists use to predict the weather, and categorize the instruments by what they measure.

10. **Expository Writing** Explain how weather is related to the water cycle.

11. **Interpret Data** Suppose tomorrow's weather map for your area predicts that the air pressure will be low and that the humidity and temperature will be high. What kind of weather could you expect for tomorrow?

12. **Critical Thinking** Over the past century, Earth's average temperature has become warmer. This could cause the climate to change in many areas. Provide an example of the effect such a change might have on your area.

13. **Draw Conclusions** Use the diagram and what you know about weather to explain how a tornado is formed.

The Big Idea

14. What factors determine Earth's weather and climates? Explain the impact of each.

Performance Assessment

The Perfect Storm

Your goal is to compare and contrast storms in a given area and time period.

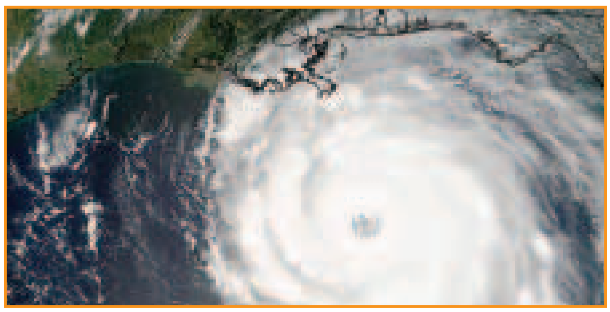
What to Do

1. Select the type of storm, the geographical area, and the time period you wish to study.
2. Locate storm data using the Internet or other resources. Compile data in a table like the one shown.

Hurricanes in Louisiana, 1996–2006				
Date	Name	Location	Wind Speed	Precipitation

Analyze Your Results

- What similarities and differences did you notice? Were there any obvious patterns over time? Write a paragraph on the conclusions that you drew.



Test Prep

1. Which weather condition causes the greatest effect on the strength of a hurricane or tornado?

A relative humidity

B air pressure

C wind speed

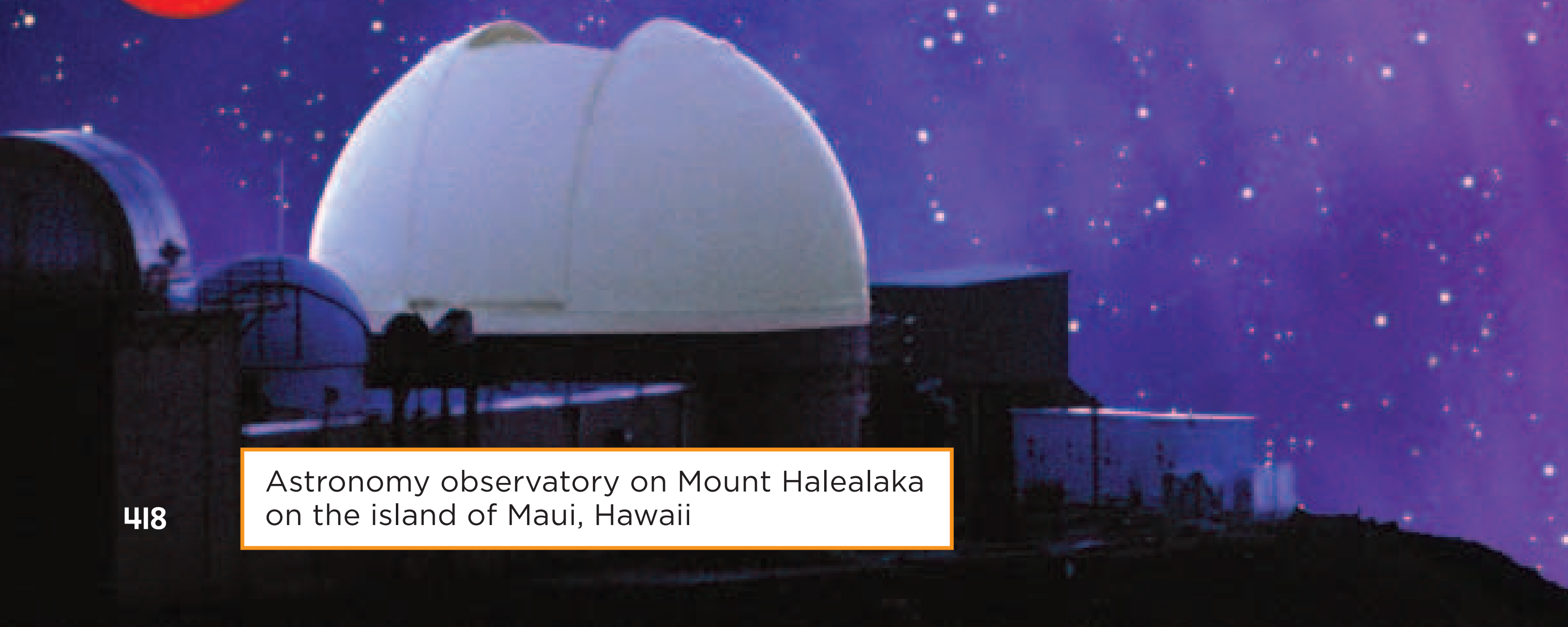
D cloud type

CHAPTER 8

Astronomy

The Big Idea

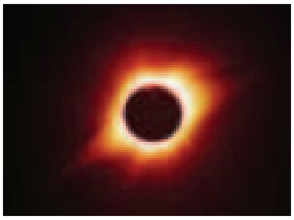
What is Earth's place in the universe?



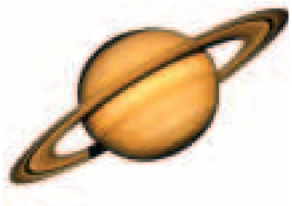
Astronomy observatory on Mount Halealaka on the island of Maui, Hawaii

Key Vocabulary

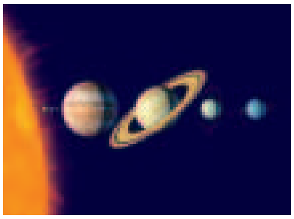
telescope
A device that collects light and magnifies images to make distant objects appear closer and larger. (p. 422)



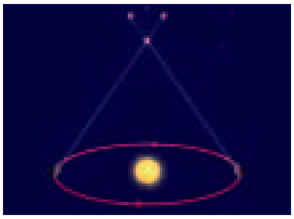
solar eclipse
A blocking of the Sun's light that happens when Earth passes through the Moon's shadow. (p. 438)



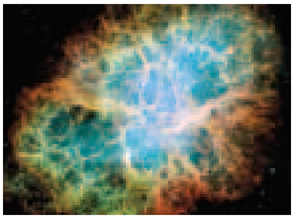
planet
A large body that orbits a star. (p. 446)



solar system
The Sun along with the planets, moons, and other bodies that travel around it. (p. 446)



parallax
The apparent shift in an object's position when viewed from two locations. (p. 459)



nebula
A huge cloud of gas and dust in space that is the first stage of star formation. (p. 462)

More Vocabulary

astronomy, p. 422

universe, p. 422

rotation, p. 424

revolution, p. 426

crater, p. 435

phase of the Moon, p. 437

lunar eclipse, p. 438

gravity, p. 440

inertia, p. 447

asteroid, p. 448

comet, p. 452

meteor, p. 452

meteorite, p. 452

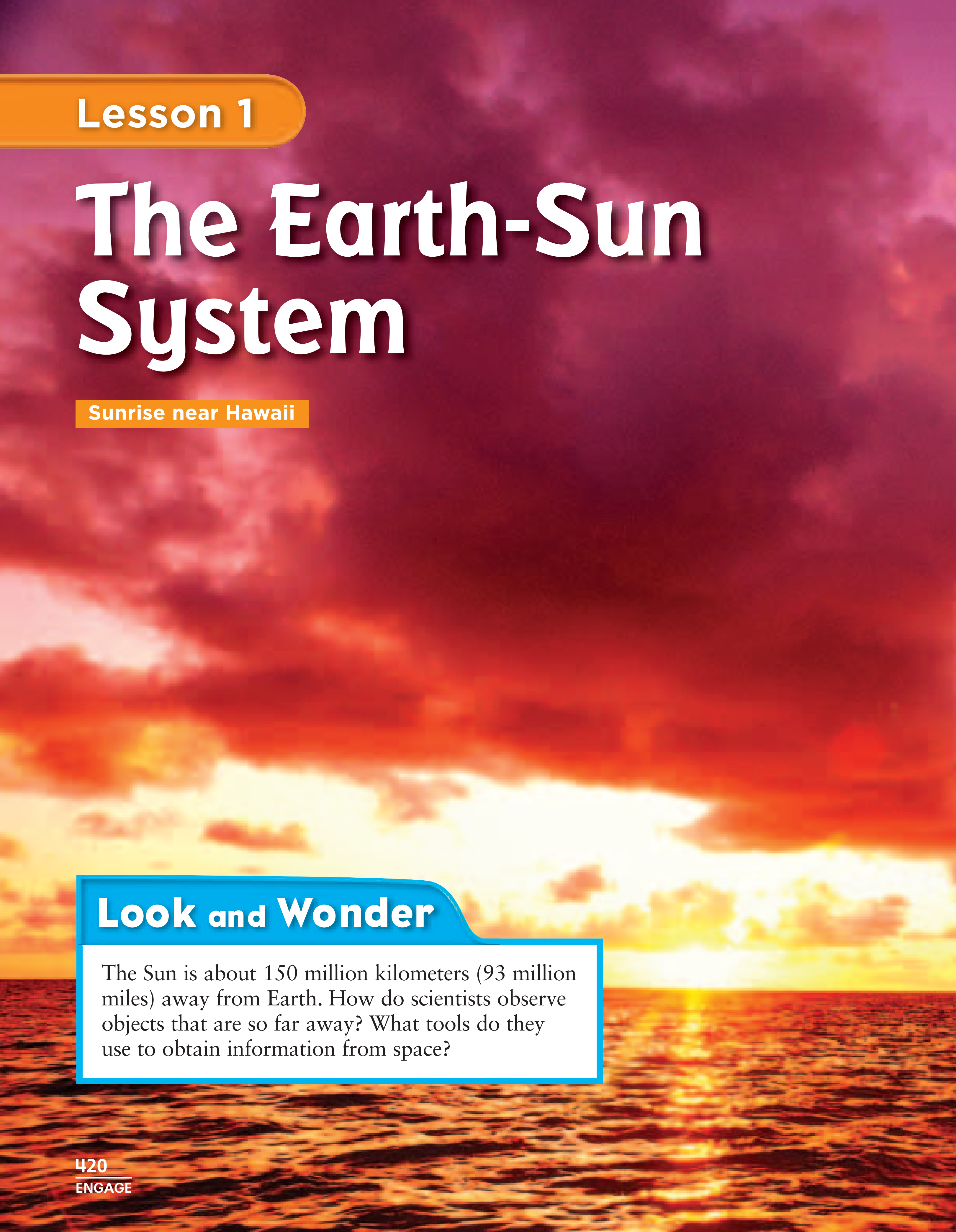
constellation, p. 458

galaxy, p. 470

spectrum, p. 472

Lesson 1

The Earth-Sun System



Sunrise near Hawaii

Look and Wonder

The Sun is about 150 million kilometers (93 million miles) away from Earth. How do scientists observe objects that are so far away? What tools do they use to obtain information from space?

Explore

Inquiry Activity

How do we learn about the planets?

Form a Hypothesis

Do the tools that scientists use to study stars and planets affect the information they obtain? Write your answer in the form of a hypothesis: "If I change the tools I use to look at an object, then . . ."

Test Your Hypothesis

1. **Make a Model** Cover a shoe box with newspaper, and tape the newspaper in place. The box represents a mystery planet. Place the box on the other side of the room.
2. **Observe** View the box through a sheet of tinted, transparent plastic. Draw what you see, and include as many details as you can.
3. **Observe** View the box without the sheet of plastic. Draw what you see. Describe the differences from your first observation.
4. **Observe** Walk near the box to view it at close range. Record what you observe.

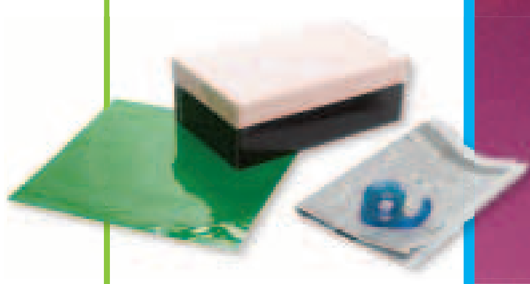
Draw Conclusions

5. **Infer** How did your observation through the tinted, transparent plastic differ from your observations without the plastic? What new information did you obtain from a close-up observation? Explain your observations.
6. **Infer** What is the difference between viewing a planet with a telescope on Earth and viewing it with a telescope in space? What causes the difference? What new information did you obtain from your "flyby" mission?

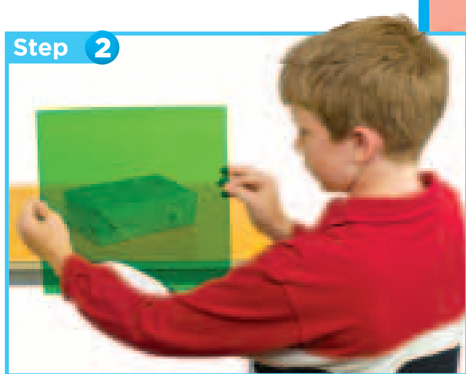
Explore More

What information might be obtained if a space probe landed on the mystery planet? How might you represent a landing with your model? Form a hypothesis, and design an experiment to test it.

Materials



- shoe box
- newspaper
- clear tape
- sheet of thin, tinted, transparent plastic



Read and Learn

Main Idea

Scientists use many tools to observe and study the universe.

Vocabulary

astronomy, p. 422
universe, p. 422
telescope, p. 422
rotation, p. 424
standard time zone, p. 425
International Date Line, p. 425
revolution, p. 426

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Reading Skill

Draw Conclusions

Text Clues	Conclusions

What is astronomy?

Have you ever looked at the sky on a clear night and wondered what was up there? What objects exist in space? **Astronomy** is the study of the universe. The **universe** is everything that exists, including Earth, the planets, the stars, and all of space.

An astronomer is a scientist who studies the universe and tries to explain what he or she observes. Astronomers can use the unaided eye to observe the positions of the Sun and the Moon. They can also locate some stars and planets this way. To get a closer look at objects in space, astronomers use telescopes. A **telescope** is a device that collects light and magnifies images to make distant objects appear closer, larger, and brighter. The larger image enables astronomers to see planets and stars in greater detail.

This telescope uses a combination of mirrors and lenses to focus light.

When you think of a telescope, you probably picture one that uses visible light to magnify images. *Visible light* is light that you can detect with your eyes.

There are two types of telescopes that use visible light. A *refracting telescope* uses lenses to gather light from a faraway object and magnify its image. In a refracting telescope, the visible light is bent and focused by an objective lens. The image is then magnified by lenses in the eyepiece. In a *reflecting telescope*, visible light reflects off a series of two or more mirrors, which amplify the image before it reaches lenses in the eyepiece. It is easier to build large mirrors than it is to build large lenses to gather more light, so most large telescopes are reflecting telescopes.

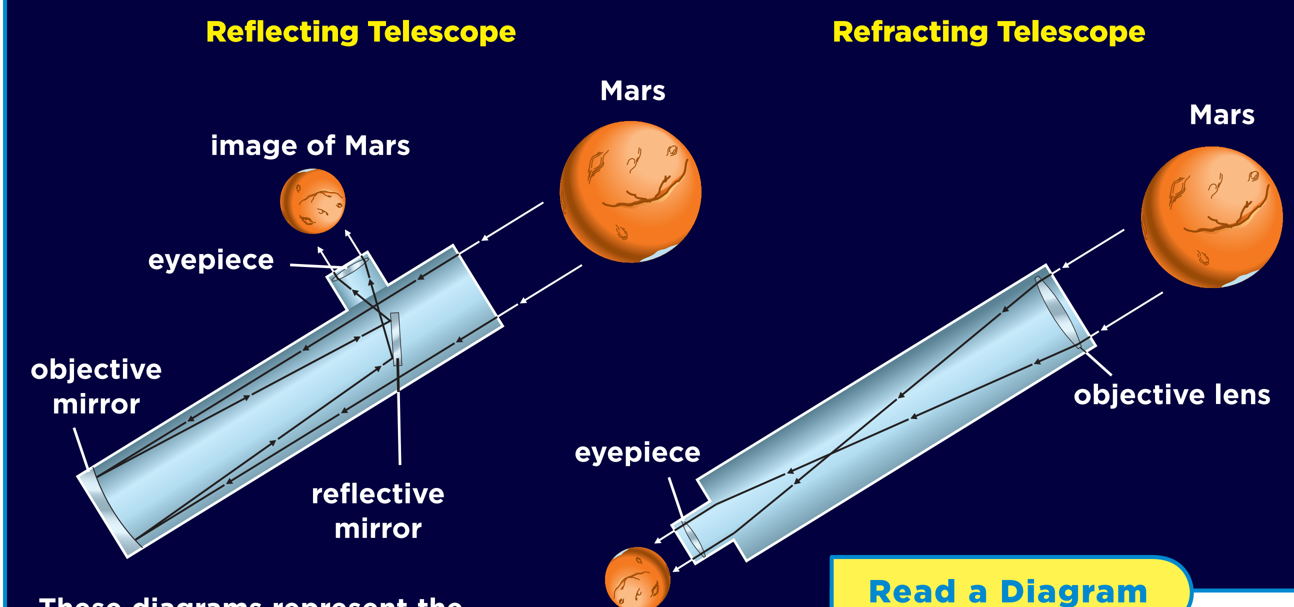
Invisible light is any light frequency in the electromagnetic spectrum that people cannot see. Special telescopes can detect waves such as radio waves, radar, infrared waves, ultraviolet light, or X rays. These telescopes can gather information that cannot be observed using visible light. For example, an infrared telescope can collect data about the heat being produced by a planet or star.

Quick Check

Draw Conclusions What kind of telescope would you expect to find in most observatories?

Critical Thinking Why might an astronomer study objects in space with an infrared telescope?

Two Types of Telescopes



These diagrams represent the planet Mars as observed through two different types of telescopes.

Read a Diagram

What do these two telescopes do to the image of Mars?

Clue: Compare the same feature on Mars in both images.

FACT The view of space from the Large Binocular Telescope in Arizona is ten times clearer than from the Hubble Space Telescope.

How can we prove that Earth rotates?

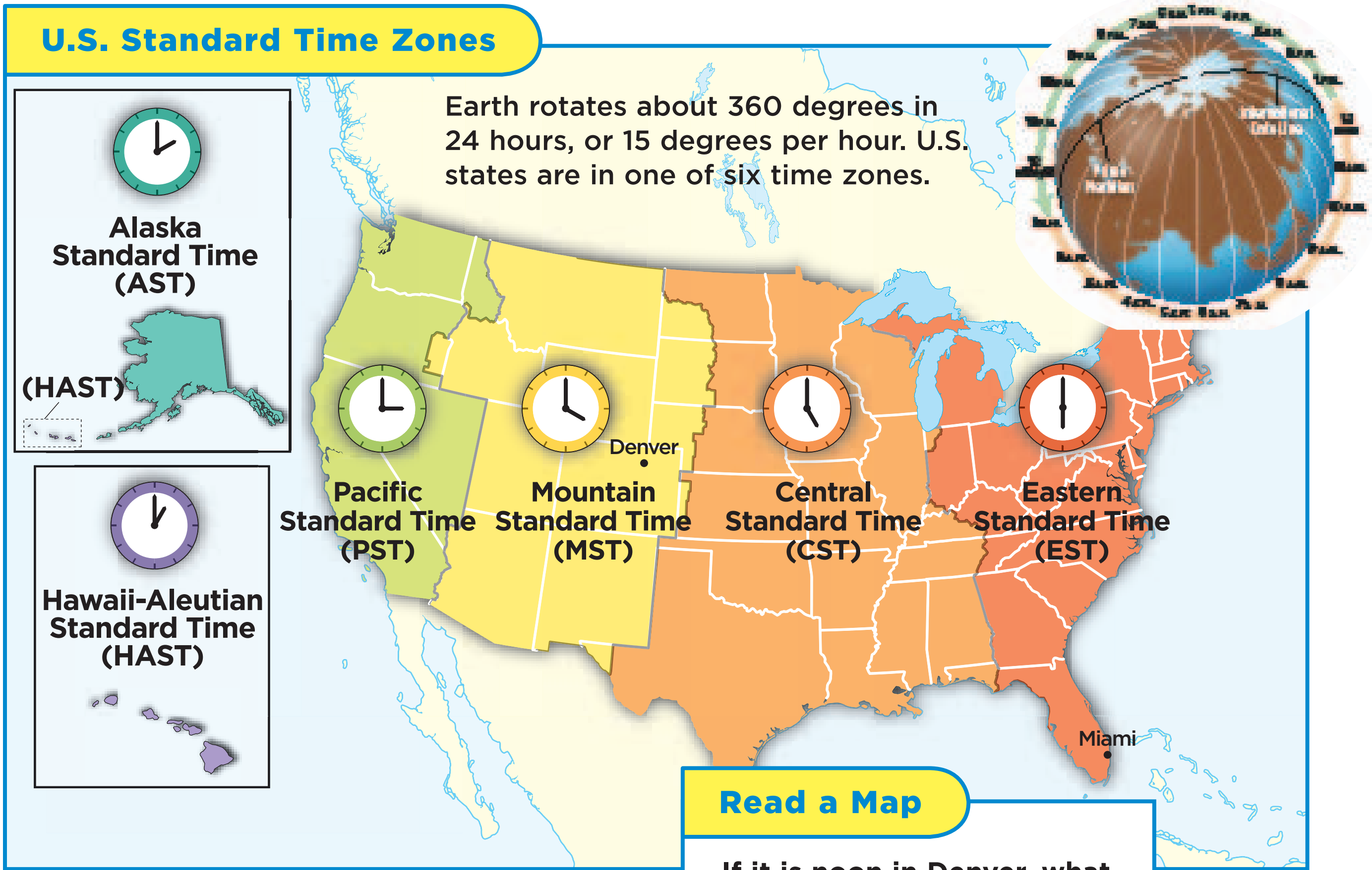
Earth's motion is similar to that of a spinning top. Earth spins on an imaginary line called an *axis*, which runs from the North Pole to the South Pole through the center of Earth. One complete spin on an axis is called a **rotation**. Earth makes 1 rotation about every 24 hours. During each rotation, all locations on Earth receive a certain amount of sunlight and a certain amount of darkness, depending on the time of year.

At one time, people thought that the Sun circled Earth every day. However, the Sun only seems to move because we are viewing the Sun from a spinning Earth. The Sun appears to rise in the east and travel west, reaching its highest point at midday. This is the *apparent path* of the Sun and is a result of Earth's rotation. You can follow this path by observing the changing shadows of objects at different times of day.

One piece of evidence for Earth's rotation comes from a simple pendulum swinging back and forth. In the 1850s, French scientist Jean Foucault hung a heavy ball by a long wire and placed sand on the floor in two semicircles. Attached to the ball was a device that could trace the pendulum's path across the sand. He pulled the ball back and let it swing back and forth undisturbed. At the end of each swing, the pendulum cut a little groove about 2 millimeters from the previous cut. The pendulum's back-and-forth path was slowly rotating. Foucault inferred that Earth was really rotating under the ball. Today, scientists can use satellites to directly observe the rotation of Earth from space.

▲ It takes Earth 24 hours, or 1 day, to complete a rotation.

This Foucault pendulum in Valencia, Spain, demonstrates that Earth rotates.



Read a Map

If it is noon in Denver, what time is it in Miami?

Clue: Determine which time zone each of the cities is in.

Standard Time Zones

When the Sun is at its highest over your town, it is midday. However, it is not midday everywhere else in the world at that same time. Earth rotates toward the east at a rate of about 360 degrees every 24 hours, or 15 degrees per hour. For this reason, we separate Earth into 24 zones known as standard time zones. A **standard time zone** is a vertical belt, about 15 degrees wide in longitude, in which all locations have the same time.

There is a one-hour difference between adjacent time zones. If you crossed one time zone going east, you would need to set your clock ahead one hour. If you traveled east across 24 time zones, you would return to the time zone in which you started, except that the date on your watch would be one day ahead of what it should be. Why?

The reason that the date would be wrong is that you would have set your watch ahead one hour 24 times during the trip. To prevent this problem, the **International Date Line** was established. It is a line at a longitude of 180 degrees. West of this International Date Line, it is one calendar day later than it is in places east of the line.

Quick Check

Draw Conclusions If it is 8:00 P.M. Mountain Standard Time, what time is it in Honolulu, Hawaii?

Critical Thinking What would happen if you traveled west across the International Date Line?

What makes a year?

During the year, the seasons change in a cycle. You may notice this as average temperatures rise and fall, as plants bloom, or as animals migrate. What causes the seasons to change? It is not the distance between the Sun and Earth. In fact, Earth is closest to the Sun in January, which is during winter in the Northern Hemisphere. What does cause the seasons?

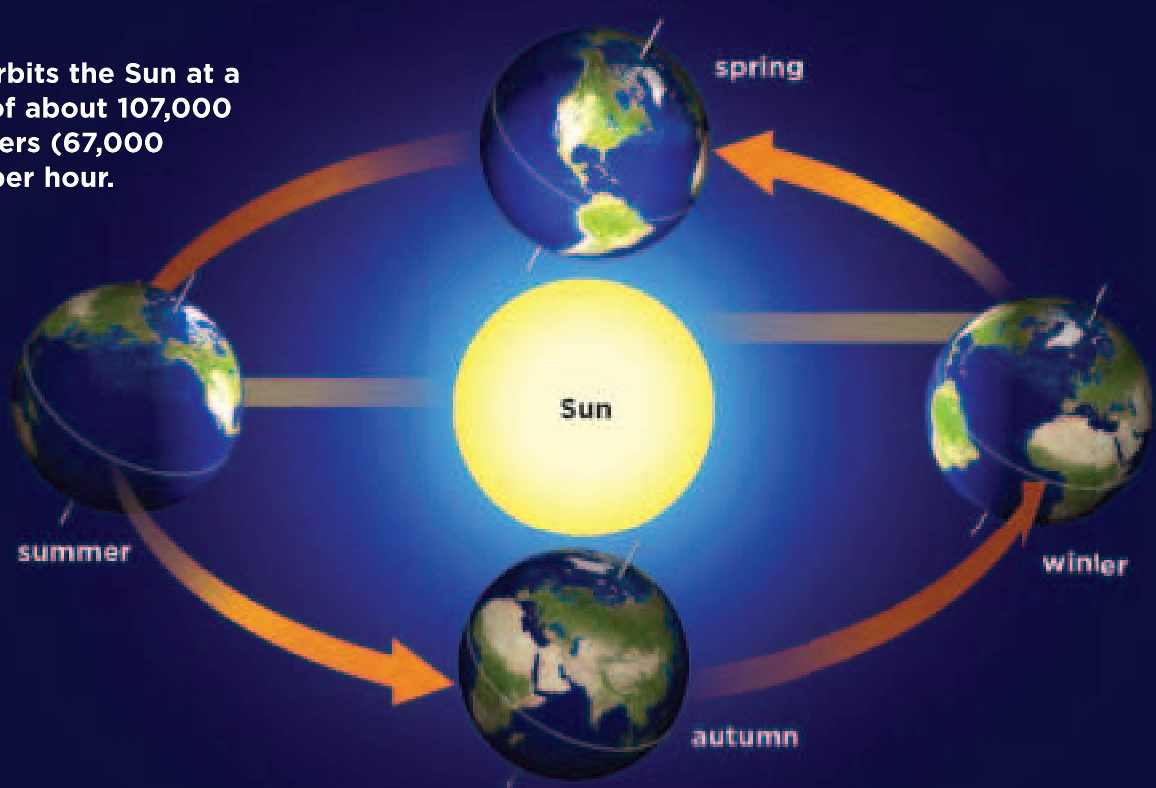
The seasons are caused by the tilt of Earth's axis of rotation. Earth's axis is tilted at an angle of 23.5 degrees, and it always points in the same direction in space. The northern end of Earth's axis happens to point toward Polaris. Polaris is also known as the North Star, because it appears above Earth's axis in the north. How does Earth's tilt cause the seasons to change?

Earth takes 365.24 days to orbit the Sun. One complete trip around the Sun is called a **revolution** (rev•uh•LEW•shuhn). As the diagram on this page shows, during summer in the Northern Hemisphere, that hemisphere is tilted toward the Sun. The Sun's rays strike that part of Earth at higher angles, so the Sun's rays hit that area with more intensity. Six months later, when the Southern Hemisphere is tilted toward the Sun, sunlight strikes the Northern Hemisphere at lower angles, providing less energy per unit of area there. It is then summer in the Southern Hemisphere and winter in the Northern Hemisphere.

Halfway between these seasons, the Sun's rays reach Earth at angles between those of the summer and winter positions. Then the Northern Hemisphere has spring or autumn.

Earth's Orbit and Seasons (Northern Hemisphere)

Earth orbits the Sun at a speed of about 107,000 kilometers (67,000 miles) per hour.



This “human sundial” is in Nice, France.

Quick Lab

Rotation and Revolution

1. **Make a Model** Work in groups of three students. Student 1 represents the Sun, student 2 represents Earth, and student 3 represents the Moon.
2. Student 1 should stand still, holding a flashlight that remains turned on.
3. Student 2 should spin slowly like a top. Then student 2 should walk around student 1 while continuing to spin. **Be Careful.** If you become dizzy while spinning, stop right away.
4. Student 3 should quickly walk around student 2, in such a way as to be always facing student 2.
5. **Observe** Describe how the light from the flashlight falls on students 2 and 3.

Changes in Sunlight

You have learned that the angle at which the Sun’s rays strike Earth causes the seasons. The angle is greatest in summer and least in winter. This means that the Sun is higher in the sky at noon in summer than at noon in winter.

Changes in the angle of the Sun’s rays affect the way objects cast shadows. In summer, when the Sun is higher at midday, objects cast shorter shadows. In winter, when the Sun is lower in the sky at midday, objects cast longer shadows. In autumn and spring, the Sun’s position is somewhere in between, and the length of an object’s shadow varies accordingly.

Quick Check

Draw Conclusions How do seasons in the Southern Hemisphere and Northern Hemisphere compare?

Critical Thinking You are an explorer who has just arrived on a planet in our solar system. You notice the Sun rising in the west and setting in the east. Based on these observations, what might you conclude about the planet’s rotation?

An astronaut replaces parts on the Hubble Space Telescope.

How can we explore space?

The atmosphere limits our ability to see space objects from Earth. To help solve this problem, scientists send space telescopes into orbit high above Earth. They also launch *artificial satellites* to study planet Earth. Artificial satellites can transmit data back to Earth with speed and accuracy.

To obtain close-up views of objects in space, scientists launch space probes. *Space probes* travel beyond Earth and use onboard instruments to study various objects in the solar system. Probes send images and data back to Earth for scientists to interpret.

Artificial satellites are sometimes sent into space by astronauts on a *space shuttle*, a reusable spacecraft. After a mission, astronauts ride back to Earth in the shuttle. For example, space-shuttle astronauts launched the Hubble Space Telescope, which orbits above most of Earth's atmosphere. Astronauts on later missions have repaired and maintained the telescope. Thanks to their work, the Hubble Space Telescope has given us detailed views of distant planets and stars.

Surviving in Space

Astronauts in space need supplies of oxygen, water, and food. A supply of soil for growing plants might also be needed. Experiments are being done on the International Space Station to see whether plants can grow in space. Plants would help provide food, remove carbon dioxide, and produce oxygen.

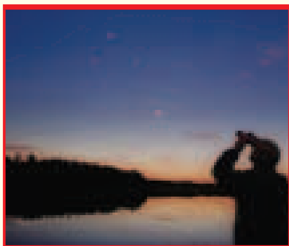
Quick Check

Draw Conclusions What type of data do you think an artificial satellite in orbit above Earth might gather?

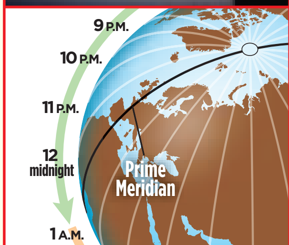
Critical Thinking What is the difference between planetary images taken from Earth and those taken from space?

Lesson Review

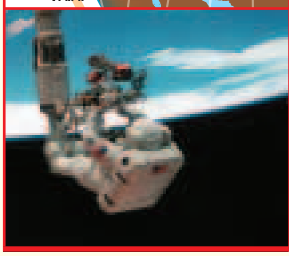
Visual Summary



Astronomers use many tools to study the **universe**.



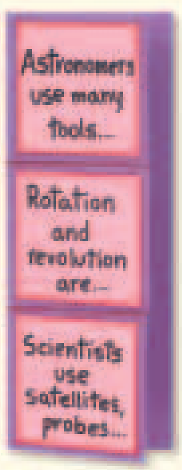
Earth's **rotation** and **revolution** are movements that give Earth its days and seasons.



Scientists use **artificial satellites**, **space probes**, and other devices to explore space.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide additional details.



Think, Talk, and Write

1. **Main Idea** How do scientists observe and study the universe?
2. **Vocabulary** The study of the universe is called ________.
3. **Draw Conclusions** Suppose a newly discovered planet had a breathable atmosphere but no life and very little water. Would this planet be a good place to colonize? Explain.

Text Clues	Conclusions

4. **Critical Thinking** How would sending astronauts into space to study the solar system compare to using telescopes and space probes?
5. **Test Prep** **The movement of a Foucault pendulum provides evidence of Earth's**
   A rotation.
   B revolution.
   C seasons.
   D axis.
6. **Test Prep** **The line of longitude at which the date changes is called the**
   A prime meridian.
   B equator.
   C International Date Line.
   D standard time zone.

Writing Link

Expository Writing

Choose a space mission such as the Mars Pathfinder mission or one from the Apollo or Voyager programs. Research the accomplishments of one mission, and write a report about your findings.

Social Studies Link

Draw a Picture

Research the problems that people would need to solve in order to set up a colony on Mars. Based on your research, draw a picture of what you think such a colony might look like.

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Focus on Skills

Inquiry Skill: Communicate

You have read about objects in our solar system that rotate and revolve. Gravity is the force that keeps the Moon orbiting Earth. It also keeps Earth and the other planets orbiting the Sun. How much is an object's orbit affected by gravity? What role does the object's speed and direction play? To answer questions such as these, scientists gather data and experiment. Then they **communicate** the results in books, online articles, television and newspaper interviews, and presentations.

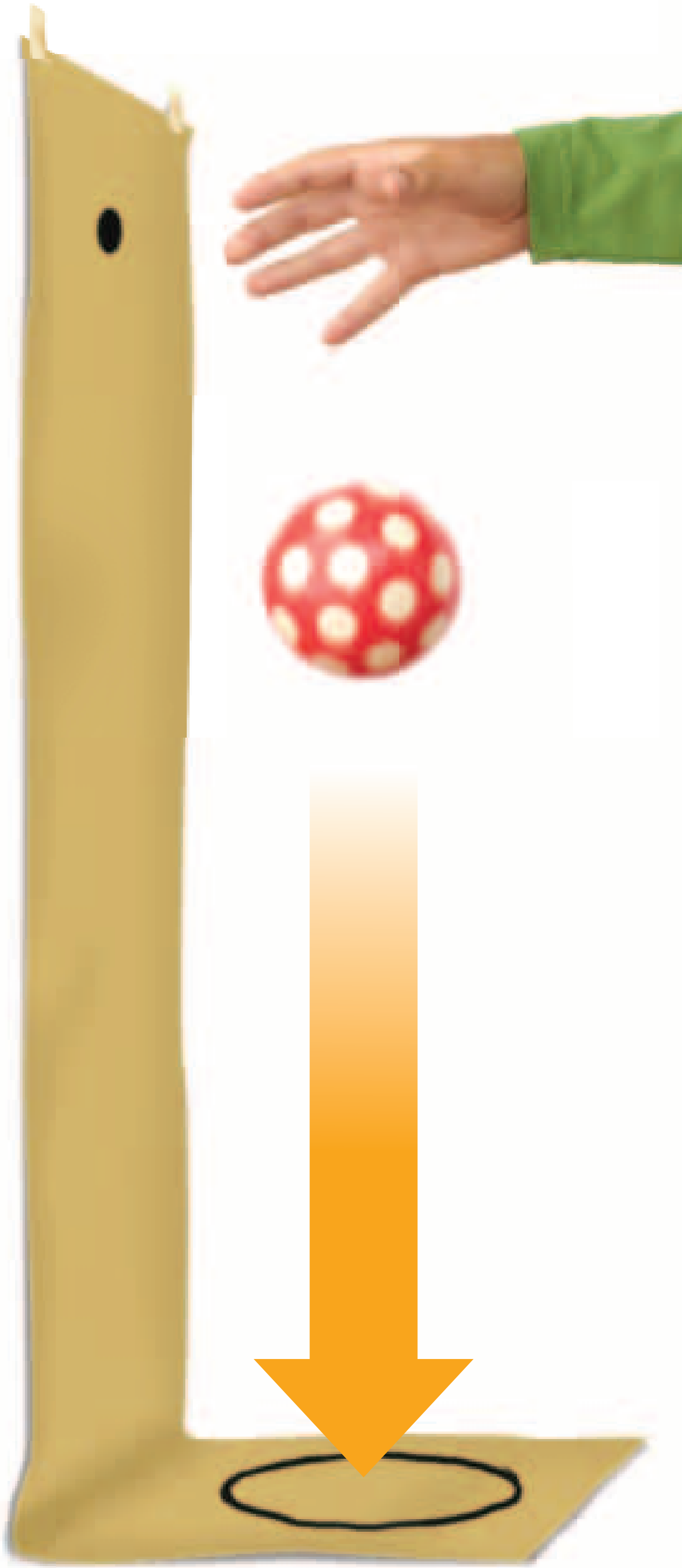
Learn It

When you **communicate**, you share information with others. You may do this by speaking, writing, drawing, using sign language, singing, dancing, or pantomiming. Before you can share information, though, you need to gather it. In the following activity, you will test how an object moves through "space," and then you will communicate your findings to your classmates.

Try It

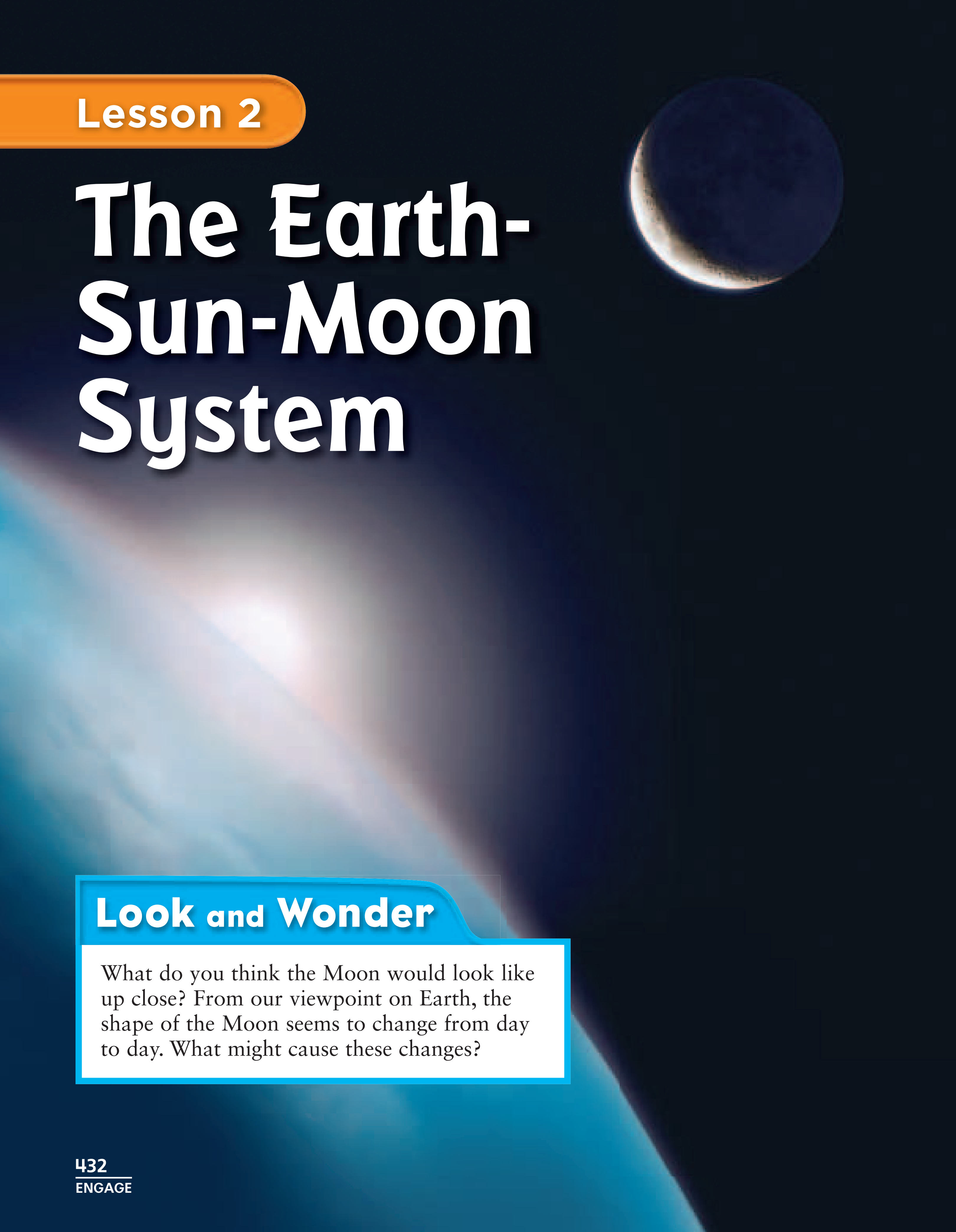
Materials **tape, sheet of butcher paper, meterstick, rubber ball**

1. Tape a sheet of butcher paper to the wall. Draw a large circle at the bottom of the paper to represent Earth's surface. Make a dot on the paper at 1 m above the ground.
2. Hold a rubber ball at the height of the dot, and drop it. Draw its path on the butcher paper.
3. Hold the ball at the same height, but this time toss it sideways with just a little force. Observe the ball's path, and draw it on the butcher paper. Repeat this procedure three more times, but throw the ball with a little more force each time. Draw each path on the butcher paper.



Apply It

1. When you threw the ball sideways, was its path straight or curved? Why do you think this was so?
2. How did gravity affect the ball as you threw it with more force?
3. What would happen if a cannon fired the ball into orbit around Earth? Draw the path you think the ball would take.
4. What do you think would happen if the ball could move fast enough to escape Earth's gravity? Draw that path.
5. **Communicate** your actions and results to your classmates. You may write a report, draw a cartoon strip, make a poster, pantomime your actions and the results, or compose and sing a song.



Lesson 2

The Earth-Sun-Moon System

Look and Wonder

What do you think the Moon would look like up close? From our viewpoint on Earth, the shape of the Moon seems to change from day to day. What might cause these changes?

Explore

Inquiry Activity

What causes the Moon to change appearance?

Purpose

Sometimes the Moon appears perfectly round. At other times, it looks like a small crescent or even seems to disappear. Why does the Moon appear in different shapes, or phases? To find out, model how the position of the Moon changes in relation to the Sun and to Earth.

Procedure

1. **Make a Model** The three balls of different sizes represent the Sun, the Moon, and Earth. Place the largest ball, representing the Sun, in one location. Use a marker to darken one half of another ball, representing the Moon. As the "Moon" moves around the third ball, representing Earth, the light side should always face the "Sun." The dark side should always face away from the "Sun."
2. **Observe** With a partner, arrange your model of Earth, the Sun, and the Moon in such a way that someone on Earth would see a full Moon.
3. **Record Data** Make a diagram of the locations of the Sun, the Moon, and Earth in your model. Label your diagram. Include a description of how the Moon would appear to an observer on Earth.
4. **Experiment** Move your model Moon around your model Earth. Compare how the Moon would look from Earth at different locations. Add this information to your diagram.

Draw Conclusions

5. **Interpret Data** Does the Moon actually change size or shape? If you could view the Moon from the Sun, would it appear to have phases? Explain.
6. **Interpret Data** What causes the Moon to appear to have phases?

Materials

- 3 balls of different sizes
- black marker

Step 1

Step 2

Explore More

Would Earth appear to have phases if you were standing on the Moon? Make a prediction. Then design a similar model to test your prediction. Conduct your experiment, and share your results with your class.

Read and Learn

Main Idea

The Moon revolves around Earth, causing different tides, eclipses, and phases of the Moon.

Vocabulary

crater, p. 435
phase of the Moon, p. 437
lunar eclipse, p. 438
solar eclipse, p. 438
tide, p. 440
gravity, p. 440

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Reading Skill

Cause and Effect

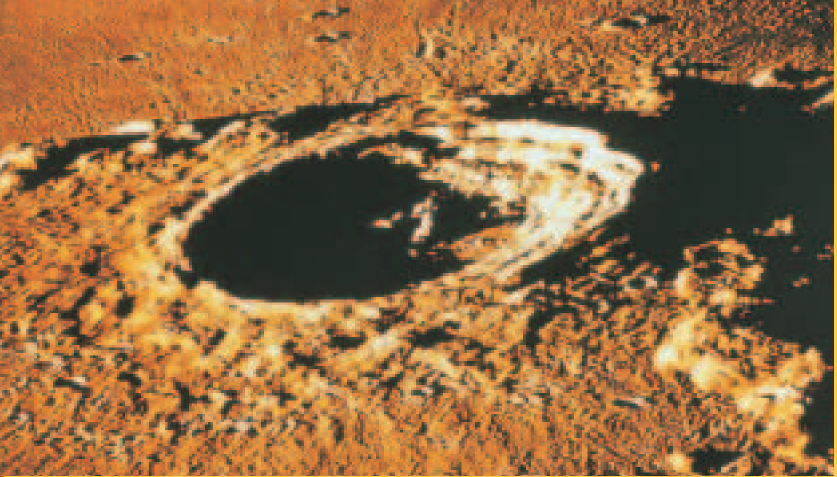
Cause → Effect
→
→
→
→

What is the Moon like?

The Moon has been a source of wonder throughout history. As technology has progressed, people have wanted to learn more and more about the Moon. Telescopes have provided scientists with a great deal of information. Space probes sent to the Moon have gathered valuable information as well. However, the greatest amount of information about the Moon has come from data gathered by the Apollo missions, which included six Moon landings between 1969 and 1972. We now know that the Moon currently has no magnetic field, though it may have had one in the past. Rock samples from the Moon have even given us clues about Earth's early history.

Long before the invention of the telescope, some observers claimed to see a "face" on the Moon's surface. When the Moon is viewed through a telescope, however, the "face" disappears. Instead, light- and dark-colored areas with bowl-shaped pits are visible on the Moon's surface. When the Apollo astronauts visited the Moon, they took close-up pictures of many of these features. Some of the features looked the same way they looked from Earth. Some of them looked very different. What are these features, and how did they form?

An astronaut walks on the Moon near the lunar module.



On the Moon, craters do not have sharp edges, and mountains do not have clearly defined peaks. These facts suggest that erosion is taking place, even without air or running water.

Lunar Landscape

Several different features have been identified on the Moon. Impacts from space objects have formed **craters**, or bowl-shaped depressions on the Moon's surface. Some craters have peaks in the center. When an object hits the Moon's surface, the impact sends out waves. The waves form rings, or rims, around some craters.

Even though the Moon and Earth are hit by space objects at about the same rate, there are more craters on the Moon. Earth's protective atmosphere causes most of the incoming objects to burn up. When objects do hit Earth, the craters that result from those impacts are eroded by wind and water.

Maria (MAHR•ee•uh) are large, dark, flat surface areas on the Moon. The singular form, *mare* (MAHR•ay), means "sea" in Latin. The smoothness of the maria led people long ago to think that they might be seas of water. Today scientists think the maria formed when huge space objects collided with the Moon's surface. These large areas of impact then filled in with lava. When the lava cooled, it gave the maria their smooth appearance and dark color.

Highlands on the Moon are light-colored regions near the lunar poles. They are higher in elevation compared to the maria. The surfaces of the highlands have more craters than the maria do, and therefore scientists believe that the highlands are geologically older landforms.

Mountains on the Moon are found around the edges of large maria. The mountains probably formed from the same impacts that formed the maria. Mountain ranges on the Moon are named after mountain ranges on Earth.

Valleys on the Moon are cigar-shaped depressions. Perhaps the most famous is the Alpine Valley, on the northeastern edge of Mare Imbrium. New evidence suggests that the floors of some very deep Moon valleys may contain small amounts of ice.

Quick Check

Cause and Effect What probably caused mountains to form around the edges of the maria?

Critical Thinking Do you think the Moon has had tectonic activity recently? Explain.

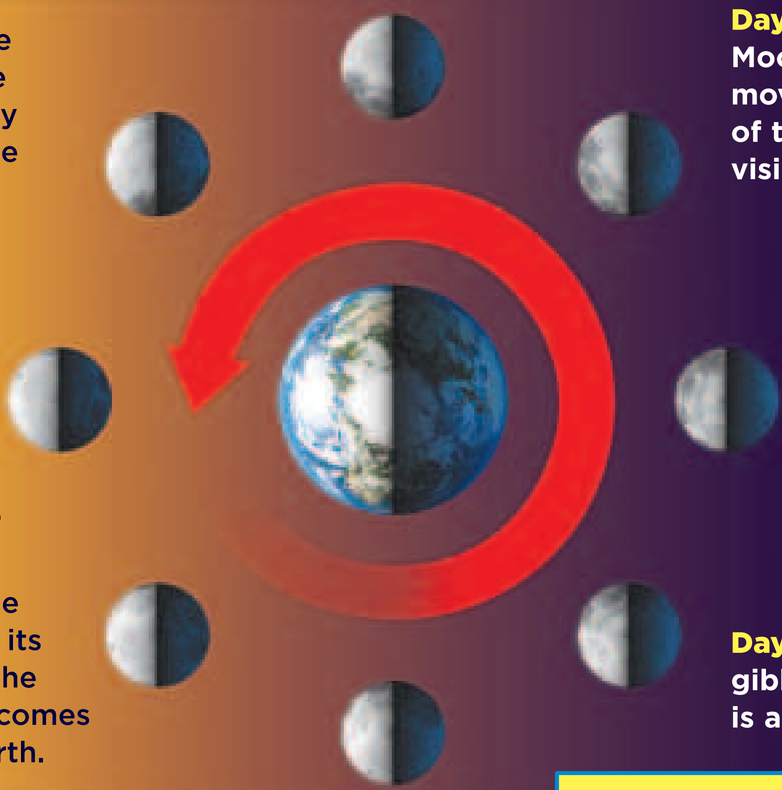
Phases of the Moon

Day 1	Days 4–5	Days 8–9	Days 12–13
new Moon	waxing crescent Moon	first-quarter Moon	waxing gibbous Moon

Days 23–24 The Moon is three quarters of the way around Earth. This is also called a half Moon.

Days 26–27 The left sliver of the Moon is the only part you can see lighted.

Days 19–20 As the Moon continues to move in its orbit, less of the lighted side is visible from Earth.



Day 1 The Moon is between the Sun and Earth. The reflected light of the Moon is not visible in the sky.

Days 15–16 Earth is between the Moon and the Sun. The entire lighted side of the Moon is visible.

Days 4–5 As the Moon moves in its orbit, more of the lighted side becomes visible from Earth.

Days 12–13 The gibbous Moon is almost full.

Days 8–9 The Moon is one quarter of the way around Earth. This is also called a half Moon.

Read a Diagram

How long is one complete cycle of all the Moon's phases?

Clue: Add the number of days in the waxing and waning phases.

LOG ON *Science in Motion* Watch the phases of the Moon at www.macmillanmh.com

What causes the phases of the Moon?

The Moon revolves around Earth, and Earth revolves around the Sun. When you look at the Moon, it appears to change shape. The shape of the Moon we see in the night sky is the **phase of the Moon**.

The Moon does not actually change shape. What changes is the amount of the Moon's lighted side that we can see. The Moon does not give off its own light; it reflects the light of the Sun. Half of the Moon always faces the Sun and is lighted by its rays. The other half of the Moon is always dark. During a *new Moon*, the Moon is between the Sun and Earth. The lighted side of the Moon faces away from Earth, so we cannot see it.

In the *waxing phases*, the lighted side of the Moon becomes more and more visible. If you see less than half of the Moon lighted on the right, it is a *waxing crescent Moon*. When you see the entire right half of the waxing Moon, it is a *first-quarter Moon*. As the Moon orbits Earth, more than half of the side facing Earth becomes visible. The Moon in this phase is a *waxing gibbous Moon*.

Finally, the Moon reaches the opposite side of its orbit, and its lighted side faces Earth. When its entire lighted side becomes visible, it is a *full Moon*. The period from the new Moon to the full Moon is about 14.5 days.

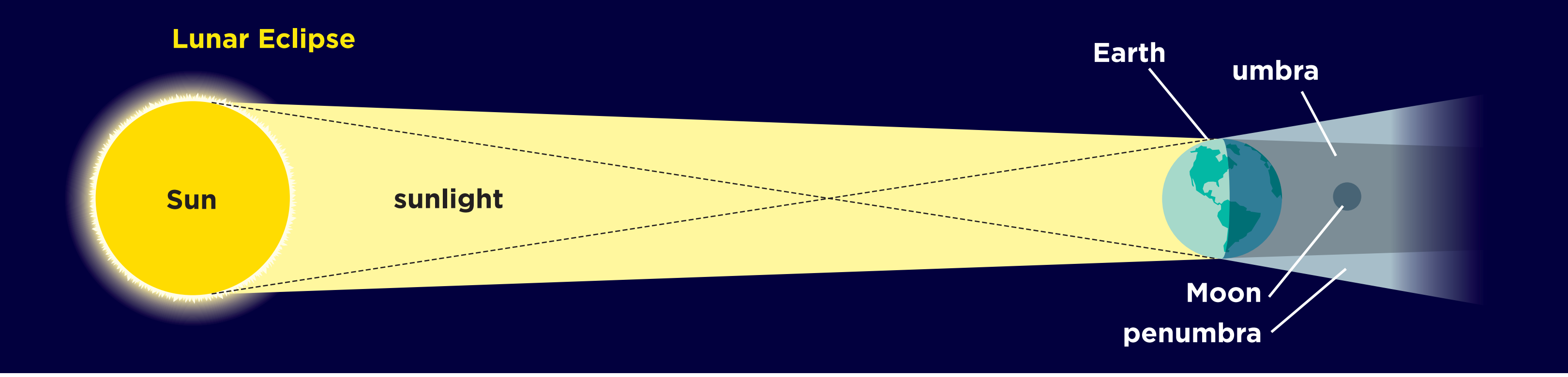
After the full Moon, we see less and less of the Moon's lighted side. The Moon is then in its *waning phases*. The first phase to appear is the *waning gibbous Moon*. This is followed by the *third-quarter Moon*, in which the left half of the lighted side is visible. Next is the *waning crescent Moon*, which decreases until the new Moon appears. The waning phases take about 14.5 days. Our concept of a month comes from the length of the cycle of phases of the Moon, about 29 days.

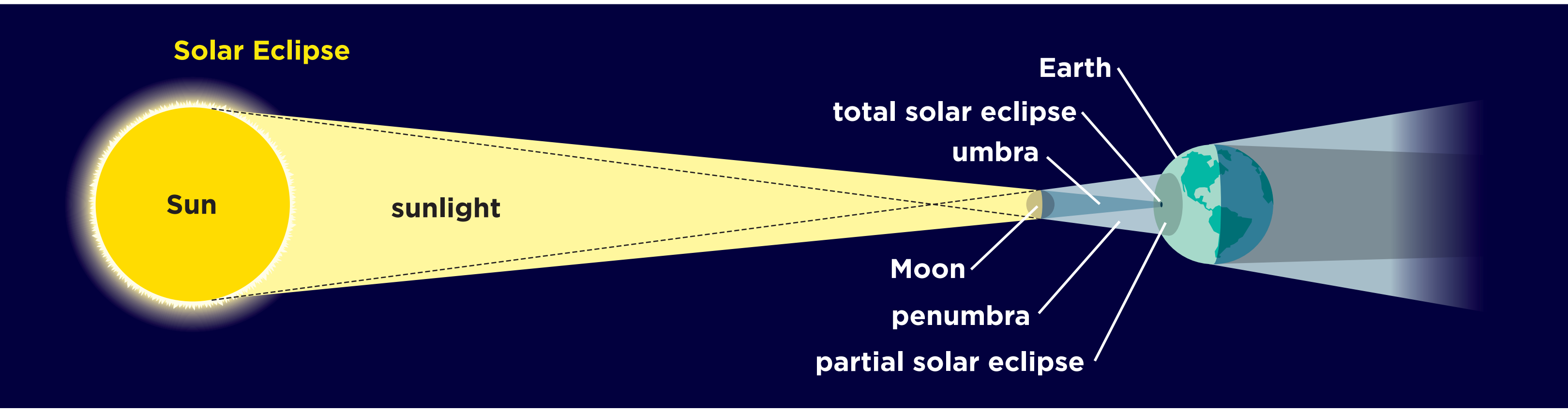
Quick Check

Cause and Effect What causes the phases of the Moon?

Critical Thinking If the direction of sunlight in the diagram were reversed, what would happen to the full Moon?

Eclipses





What causes eclipses?

When one object crosses in front of another, the first object can sometimes block the view of the second. In the case of space objects, this causes an eclipse. When one object passes through the shadow cast by another object, this also causes an eclipse.

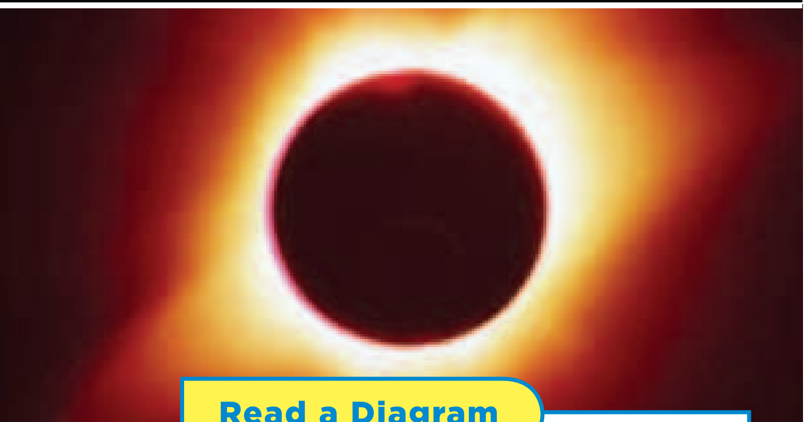
When Earth blocks sunlight from reaching the Moon, a **lunar eclipse** occurs. The Moon's orbital path is tilted compared to Earth's orbital path around the Sun. As a result, the Moon is usually above or below Earth's orbit. Twice each month, the Moon crosses the path of Earth's orbit. When this occurs at the time of a full Moon, the Moon can pass directly through Earth's shadow, so that no sunlight falls directly upon the Moon.

The Moon becomes dark until it moves out of Earth's shadow and the Sun's light hits the Moon once again. During a total lunar eclipse, the Moon may look reddish. The shade of color depends on how sunlight interacts with Earth's atmosphere on its way toward the Moon.

When the Moon passes through a part of Earth's shadow, a partial lunar eclipse occurs. Partial lunar eclipses are far more common than total eclipses.

Solar Eclipses

When Earth passes through the Moon's shadow, a **solar eclipse** occurs. For a total solar eclipse to occur, the Moon must be directly between the Sun and the observer on Earth. This can only happen during a new Moon.



Read a Diagram

Where must the Moon be in order for a lunar eclipse to occur?

Clue: Look at the Moon's position in relation to the Sun and Earth.

At the height of the eclipse, the Moon completely hides the Sun's disk. The body of the Sun appears completely dark. This is when the gases in the Sun's outer atmosphere can be seen.

Total solar eclipses do not last very long or occur very often. Even when a total solar eclipse occurs, it does not appear that way from every location on Earth. The Moon's *umbra*, or dark shadow, is relatively small. The Moon casts its shadow over a very small portion of Earth's surface. Only observers inside that umbra will see a total eclipse. Others elsewhere may see a partial solar eclipse. Often, the Moon and the Sun do not line up exactly. In these cases, the Sun's disk is only partly hidden. Sunlight is strong, so you should never look directly at the Sun, even during a total solar eclipse.

Quick Lab

Modeling Eclipses

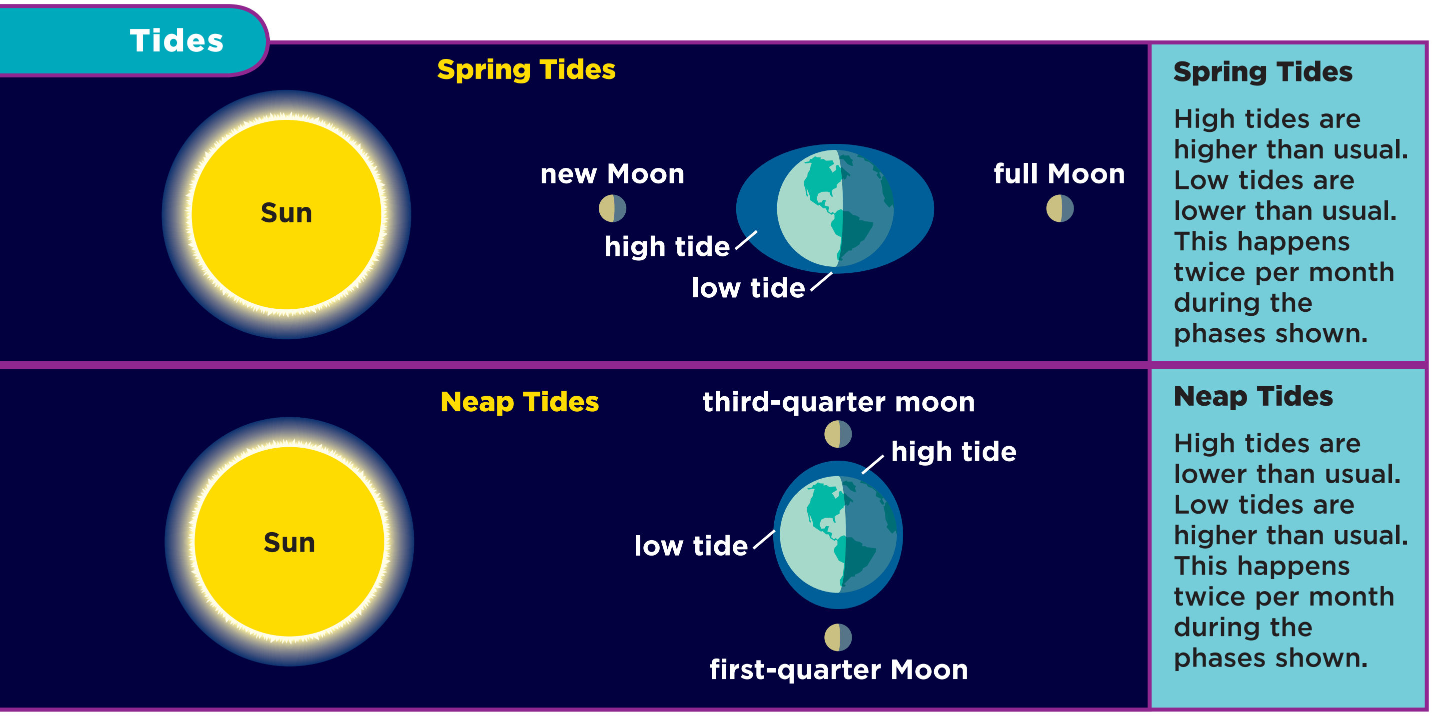
1. **Make a Model** Obtain two foam balls of different sizes. One should be at least twice as big as the other.
2. **Observe** Shine a flashlight directly at the larger ball from a distance of about 3 m. Place the smaller ball between the flashlight and the larger ball. The smaller ball should be about 10 cm away from the larger ball. Record your observations.

3. **Observe** Repeat step 2, this time placing the smaller ball behind the larger ball. The larger ball should be between the flashlight and the smaller ball.
4. **Infer** What do the flashlight and each ball represent in this model?
5. **Interpret Data** What event did you model in step 2? In step 3?

Quick Check

Cause and Effect What causes a lunar eclipse? What causes a solar eclipse?

Critical Thinking Are total solar eclipses visible from all locations on Earth? Explain.



What causes the tides?

Waves come higher up on the shore at some times than at others. The regular rise and fall of the water level along a shore is called a **tide**.

The pull of gravity between Earth and the Moon causes tides. **Gravity** is the force of attraction among all objects. The greater an object's mass is, the greater its gravitational pull. For example, your body has gravity, and so does Earth. However, Earth is much more massive, so its gravitational pull is much stronger than yours.

Gravity exists between the Sun and the planets and also between a planet and its moons. The pull of gravity changes with distance. In the case of Earth and the Moon, the pull is stronger on the side of Earth that is facing the Moon. This causes Earth's water to bulge on the Moon-facing side of Earth. A bulge also forms on the side facing away from the Moon. The water level rises where the bulge is and falls where it is not. This causes the regular rise and fall of the tides.

Sometimes, the way the Sun, the Moon, and Earth line up causes tides to be especially strong or weak. These tides happen twice a month. They depend on the gravitational pull of the Moon and the Sun. When the Sun, Earth, and the Moon are all in a line, a *spring tide* occurs. During spring tides, high tides are higher than usual, and low tides are lower than usual. If the gravitational pulls of the Sun and the Moon are at right angles, a *neap tide* occurs. During neap tide, high tides are lower than usual, and low tides are higher than usual.

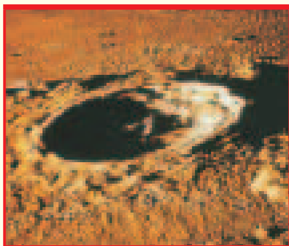
Quick Check

Cause and Effect What causes the tides?

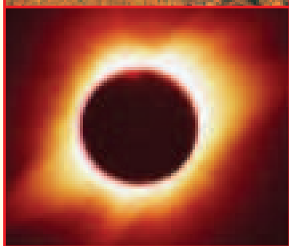
Critical Thinking Which type of tide might occur during a new Moon?

Lesson Review

Visual Summary



The **Moon** has features that give evidence of its history.

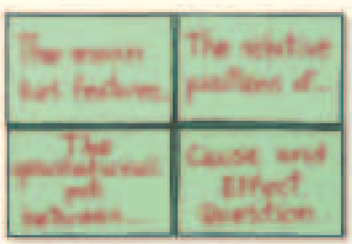


The **relative positions** of the Sun, the Moon, and Earth cause phases of the Moon and solar and lunar eclipses.

The **gravitational pull** between the Moon and Earth causes changes in the tides.

Make a FOLDABLES™ Study Guide

Make a Four-Door Book. Complete the statements shown, and include your work for the Cause and Effect question on this page.



Think, Talk, and Write

1. **Main Idea** What causes the phases of the Moon?
2. **Vocabulary** The amount of the Moon's lighted side that can be viewed from Earth's surface at a given time is the ________.
3. **Cause and Effect** What caused the craters on the Moon?

Cause → Effect
→
→
→
→

4. **Critical Thinking** During a total lunar eclipse, what do you think an observer on the Moon would see?
5. **Test Prep** **The Moon looks completely dark as seen from Earth during a**
   A full Moon.
   B first-quarter Moon.
   C new Moon.
   D third-quarter Moon.
6. **Test Prep** **Which of the following is NOT a feature found on the Moon?**
   A mountains
   B valleys
   C craters
   D oceans

Math Link

Calculate the Moon's Distance from Earth

Light travels at 299,792 km/s. If it takes a light beam approximately 1.3 s to travel from the Moon to Earth, how far is the Moon from Earth?

Social Studies Link

Evaluate a Model

Research how the Chinese of ancient times explained a solar eclipse. Then make a model to show your findings. Evaluate the model based on what you now know about solar eclipses.

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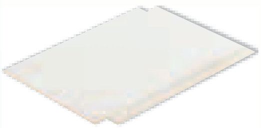
Be a Scientist

Materials



construction paper

markers

dowels

tape

30 m tape measure

Structured Inquiry

How can you model the solar system?

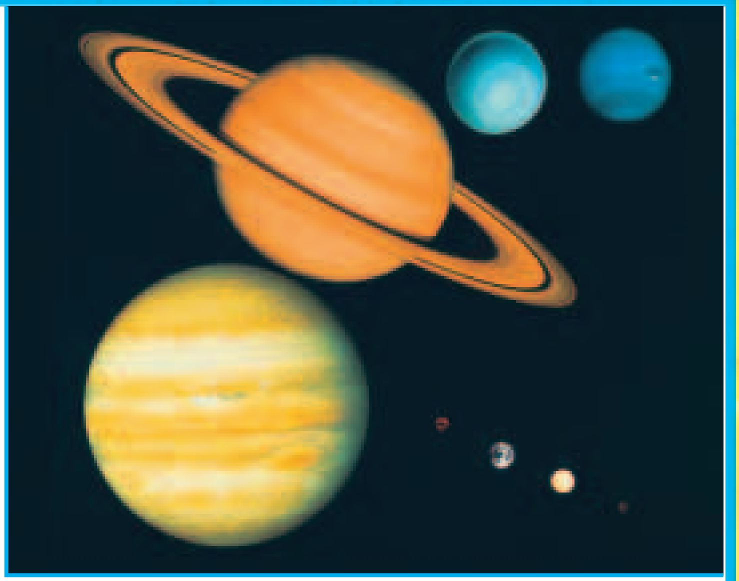
Purpose

Our solar system consists of the Sun, planets, moons, and other bodies, including asteroids, comets, and meteoroids. Each planet has its own orbit around the Sun. What can making a model of the solar system show you? Construct a model of the solar system on your playground, and use your model to compare the distances between planets.

Procedure

1. **Make a Model** Make construction-paper labels for each planet and the Sun. Attach each label to a dowel with tape.
2. Place the marker labeled *Sun* at one end of the playground.
3. **Measure** Use the table below to construct your model. Use a measuring tape to measure the scaled distance from the Sun to Mercury, and place the marker labeled *Mercury* in the ground.
4. Continue marking the distances of the planets from the Sun. Draw your model in your notebook, and record your observations about the solar system.

Planet	Distance from Sun (in kilometers)	Distance from Sun, to Scale (1 cm = 1,000,000 km)
Mercury	57,900,000	58 cm
Venus	108,200,000	1 m, 8 cm
Earth	149,600,000	1.5 m
Mars	227,900,000	2 m, 28 cm
Jupiter	778,400,000	7 m, 78 cm
Saturn	1,426,700,000	14 m, 27 cm
Uranus	2,871,000,000	28 m, 71 cm
Neptune	4,498,300,000	44 m, 98 cm



Draw Conclusions

5. **Interpret Data** Which planet is closest to the Sun? Which planet is closest to Earth?
6. **Interpret Data** What happens to the size of the solar system from the orbit of Jupiter to the orbit of Saturn? What happens to the size of the solar system from the orbit of Saturn to the orbit of Uranus?

Guided Inquiry

Could you model the solar system, including the planets' sizes and the distances between the planets?

Form a Hypothesis

Why is it so difficult to make a true scale model of the solar system? Write your answer in the form of a hypothesis: "If I try to model the sizes of the Sun and all the planets accurately, then . . ."

Test Your Hypothesis

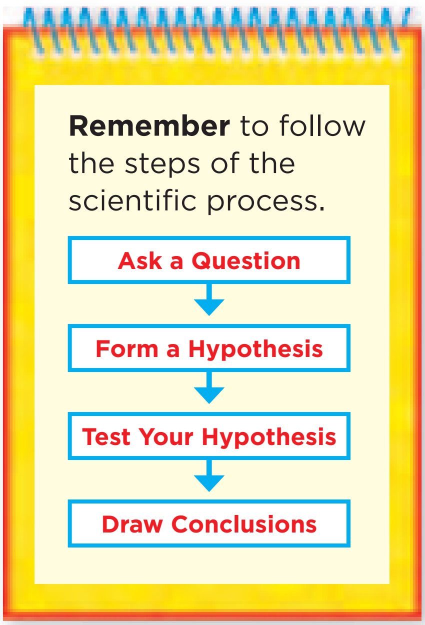
Decide what data you need to collect to make your model. Then choose a scale to use for your model, and calculate the sizes and positions of your model Sun and planets.

Draw Conclusions

How easy would it be to make your model? Explain.

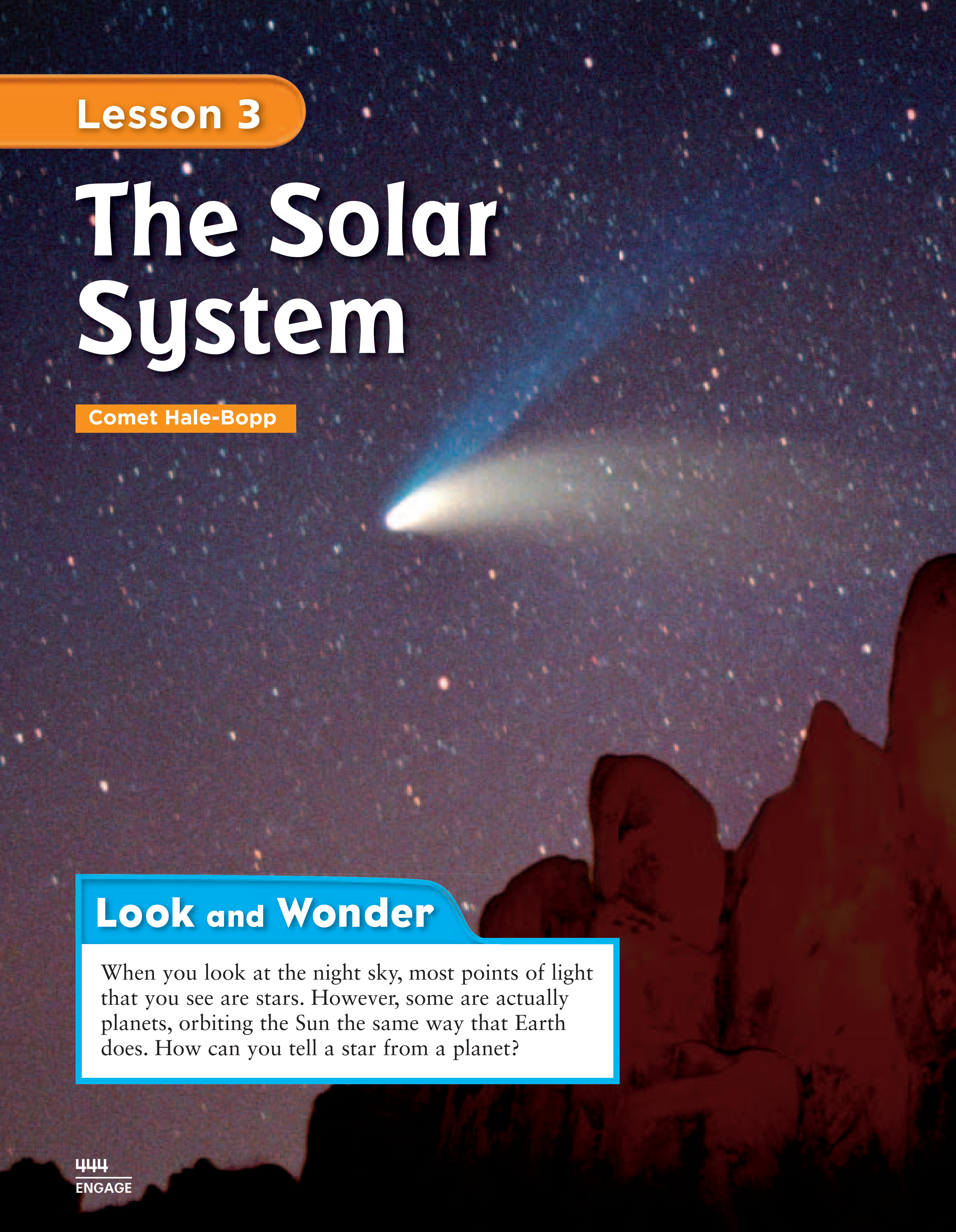
Open Inquiry

Think of a question about the solar system to investigate. For example, are the planets always the same distance from the Sun, or do their distances change? Design a data-collection process or method of research to answer your question. Your data must be organized to test only one variable, or one item being changed.



Lesson 3

The Solar System



Comet Hale-Bopp

Look and Wonder

When you look at the night sky, most points of light that you see are stars. However, some are actually planets, orbiting the Sun the same way that Earth does. How can you tell a star from a planet?

Explore

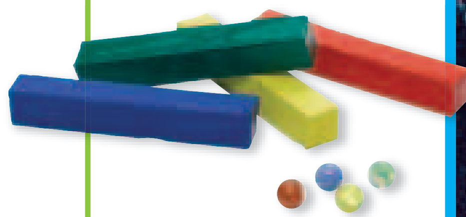
Inquiry Activity

How can you tell a planet from a star?

Make a Prediction

Some lights in the night sky appear to move in relation to others. How can you tell that a particular light is a planet, not a star? Write your answer in the form of a prediction: "If an object in the sky is a planet, then it will appear to . . ."

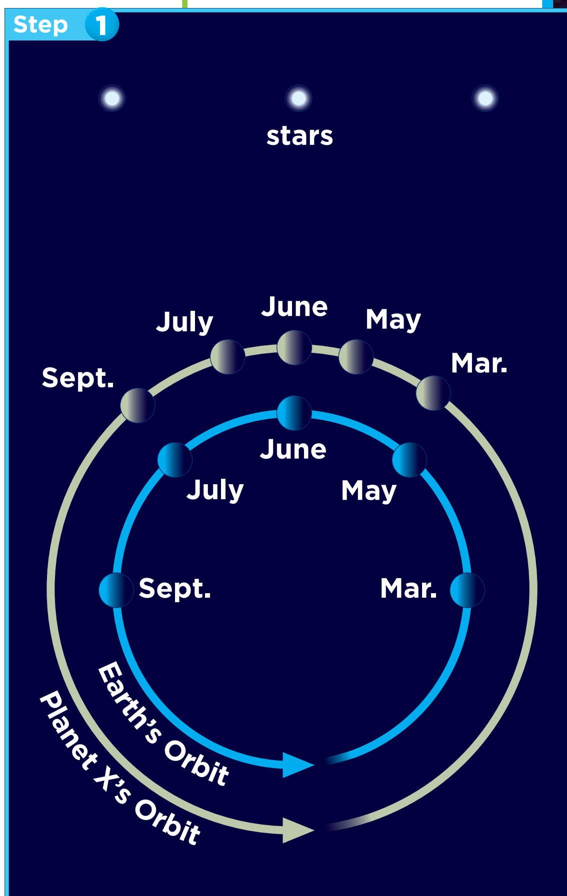
Materials



- diagram (shown)
- 4 lumps of clay
- 4 marbles

Test Your Prediction

1. **Make a Model** Make a copy of the drawing shown here. Use clay to fix a marble in each of the three star locations.
2. Use clay to fix a marble at the March position of planet X's orbit. Draw a line from Earth's March position to planet X's March position. Extend the line to the stars. Write a *1* to label where planet X appears in relation to the stars.
3. Repeat step 2 for the planets' positions in May, June, July, and September. Label these monthly observations *2*, *3*, *4*, and *5*, respectively.



Draw Conclusions

4. **Interpret Data** Describe the motion of planet X with respect to the stars from March to May. Compare this to the motion from May to June, from June to July, and from July to September.
5. **Infer** How can you tell a planet from a star?

Explore More

What would happen if you increased the distance between Earth's orbit and planet X's orbit? Make a prediction and test it.

Read and Learn

Main Idea

The solar system consists of the planets, their moons, and many other bodies orbiting the Sun.

Vocabulary

planet, p. 446
moon, p. 446
solar system, p. 446
inertia, p. 447
asteroid, p. 448
comet, p. 452
meteoroid, p. 452
meteor, p. 452
meteorite, p. 452

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Reading Skill

Classify

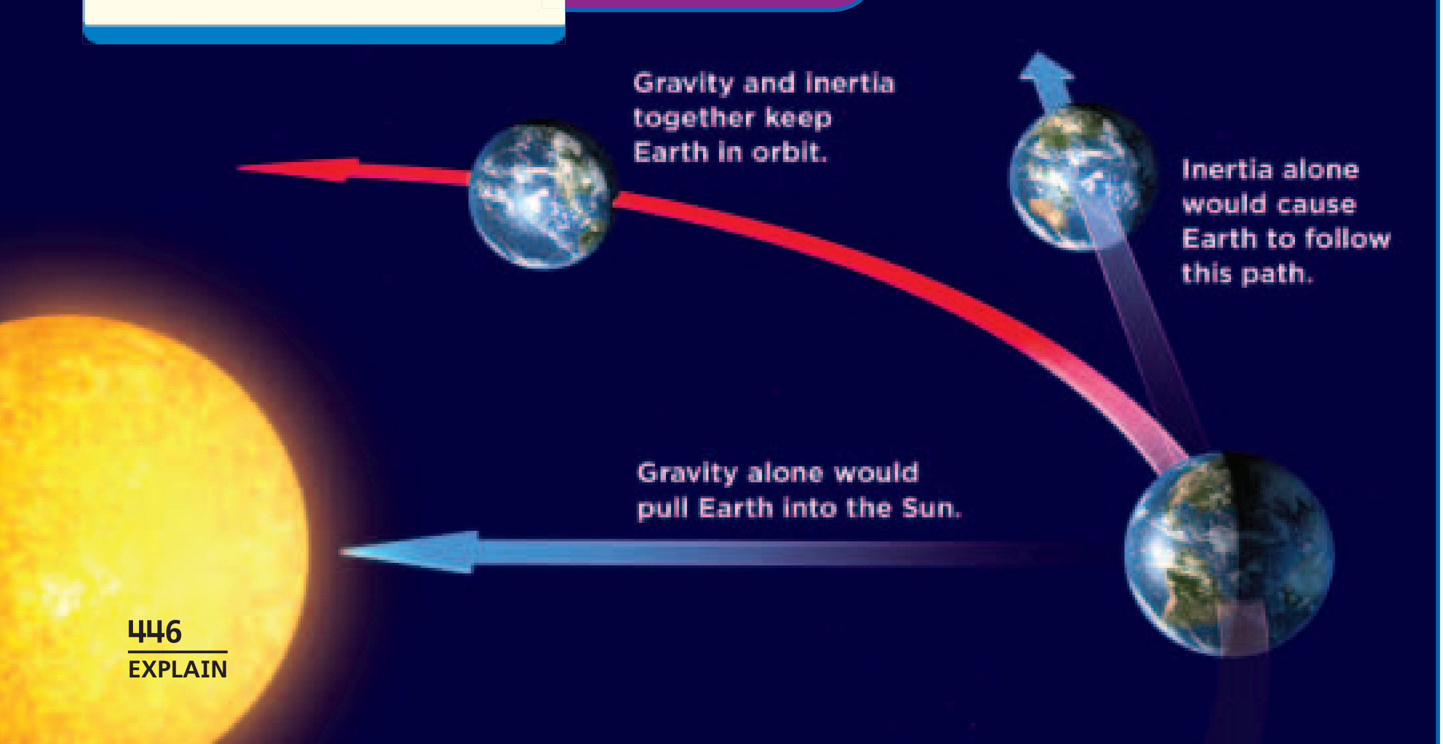
What is the solar system?

Long before the invention of telescopes, people studied the stars. As they observed the night sky, they noticed that some of the bright lights in the sky changed their positions relative to other lights. Ancient astronomers called these objects *planets*, a name that comes from a Greek word meaning "wanderer." A **planet** is a large body that orbits a star. A **moon** is an object that orbits a planet. Planets and moons are parts of solar systems. A **solar system** consists of a star, such as the Sun, as well as all the planets, moons, and other bodies traveling around it. All but two planets in our own solar system have one or more moons.

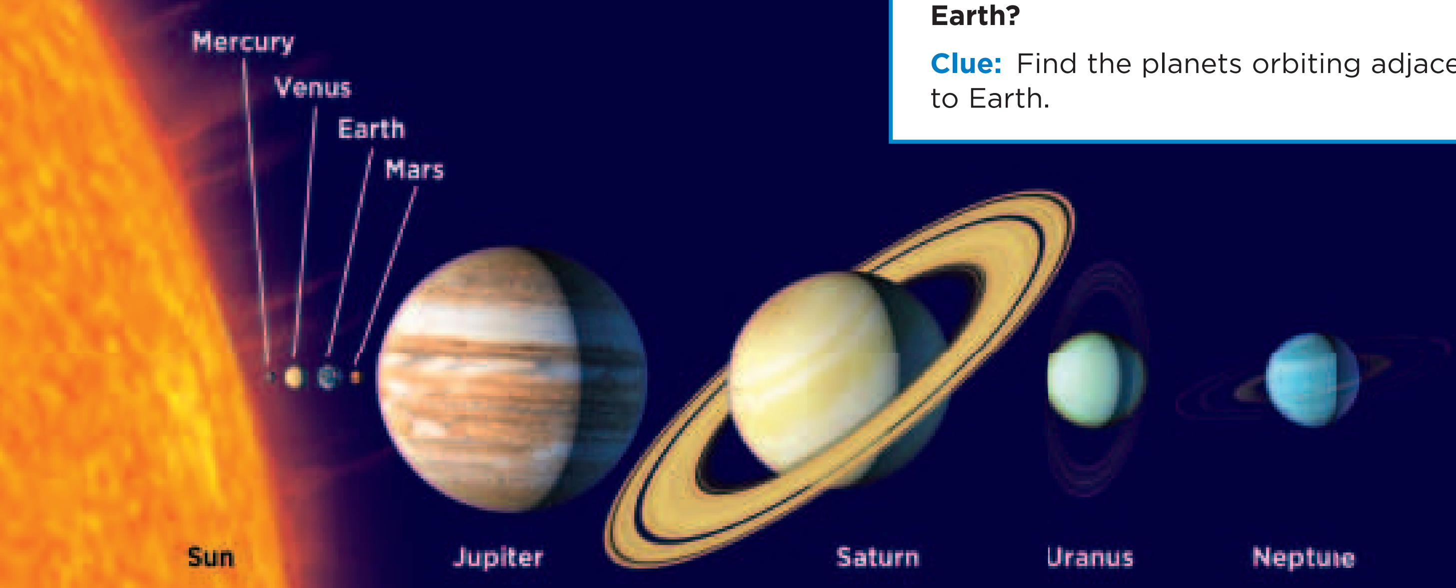
Planets and Orbits

Gravity is the force of attraction among all objects. Gravity causes something you drop to fall to the floor, and this same type of force keeps planets in orbit. The amount of gravitational force, such as that between the Sun and a planet, depends on mass. The greater the mass of each object, the greater the attraction between them. Distance is also a gravitational factor. The greater the distance is between a planet and the Sun, the smaller the pull of gravity.

Earth's Orbit



Solar System



Read a Diagram

Which two planets are in orbit next to Earth?

Clue: Find the planets orbiting adjacent to Earth.

The second property that keeps planets in orbit is **inertia**, the tendency of a moving object to stay in motion. Gravity alone would pull the planets into the Sun, because the Sun has so much mass. This does not happen, because the planets have inertia and are moving. Inertia alone, however, would cause the planets to move in straight lines. The balance between the force of gravity and the planets' inertia keeps the planets in their orbits around the Sun. The planets would move in straight paths because of inertia, but gravity pulls on the planets and curves their paths into orbits around the Sun.

Ideas About Planetary Motion

Ancient astronomers saw that the planets moved across the field of stars, but they did not know why. Over time, two early explanations emerged.

One ancient explanation of the planets considered Earth to be the center of the universe. According to this model, the Sun, the Moon, and the stars revolved around Earth. The other explanation stated that Earth, the Moon, the stars, and the other planets revolved around the Sun. This idea better explained the motions of the planets. However, it was unpopular when it was introduced. Many people of that time would not accept any idea that did not place Earth at the center of the universe.

Quick Check

Classify List the planets in order of increasing distance from the Sun.

Critical Thinking Would the pull of the Sun's gravity on a space probe be greater near Mercury or near Saturn? Explain.

What is in the inner solar system?

Mercury, Venus, Earth, and Mars are the planets located closest to the Sun. They are called the *inner planets*. The inner planets are alike in many ways. They have similar sizes and mostly rocky structures. They also have closely spaced orbits and few, if any, moons. All the inner planets rotate relatively slowly, and none of them have rings. Earth is the largest of the inner planets.

Asteroids

Between the orbits of Mars and Jupiter are **asteroids**, rocky or metallic objects that orbit the Sun. Most asteroids are located in the asteroid belt. The largest object in the asteroid belt is about one fourth the diameter of the Moon. Asteroids orbit the Sun just as planets do. Some asteroids travel as far from the Sun as Saturn's orbit. Other asteroids have orbits that cross Earth's path.

Scientists have accumulated a great deal of knowledge about asteroids in recent years. Space probes have sent back information that provides pictures of these orbiting objects. The space probe *Galileo* flew by two asteroids: Gaspra in 1991 and Ida in 1993. The space probe *NEAR Shoemaker* encountered the asteroid Mathilde in 1997 and successfully landed on the asteroid Eros in 2001.

Mercury

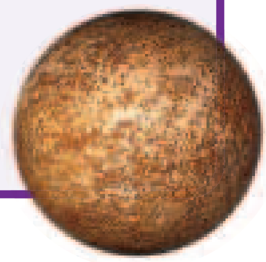
Diameter: 4,880 kilometers (3,030 miles)

Distance from the Sun: 57.9 million kilometers (36 million miles)

Length of Day: 59 Earth days

Length of Year: 88 Earth days

Special Features: Mercury has no moons. The temperature on the side of Mercury facing the Sun is hot enough to melt zinc. On the night side of Mercury, temperatures can drop to −274°F (−170°C). The surface of Mercury is heavily pockmarked with craters.



Venus

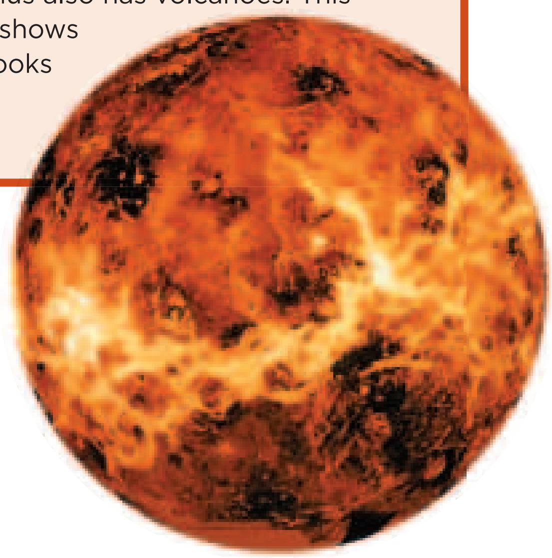
Diameter: 12,100 kilometers (7,500 miles)

Distance from the Sun: 108.2 million kilometers (67.2 million miles)

Length of Day: 243 Earth days

Length of Year: 225 Earth days

Special Features: Venus has no moons. It has a dense atmosphere of carbon dioxide, with atmospheric pressure 90 times greater than that of Earth. The temperature is about 900°F (500°C). Venus also has volcanoes. This radar image shows how Venus looks beneath its clouds.



Earth

Diameter: 12,750 kilometers (7,922 miles)

Distance from the Sun: 149.6 million kilometers (93 million miles)

Length of Day: 23 hours, 56 minutes, 4 seconds

Length of Year: 365.24 Earth days

Special Features: Earth has one moon. Its atmosphere supports a wide variety of life. Temperatures average about 59°F (15°C). Earth has a strong magnetic field and tectonic activity.

Size of Mercury, Venus and Mars shown compared to Earth.

Mars

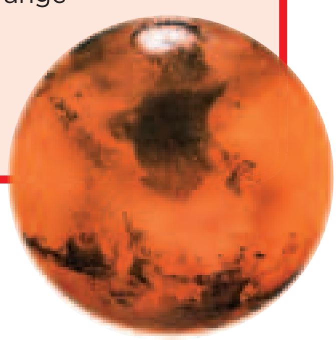
Diameter: 6,800 kilometers (4,200 miles)

Distance from the Sun: 227.9 million kilometers (141.6 million miles)

Length of Day: 24 hours, 37 minutes, 12 seconds

Length of Year: 687 Earth days

Special Features: Mars has two moons. It also has seasons. Temperatures range from about −193°F (−125°C) to 68°F (20°C). Mars has a thin atmosphere of carbon dioxide.



Quick Lab

Planet Sizes

1. **Use Numbers** Look at the table of planet diameters. Suppose in a scale model Earth's diameter is 2 cm. Calculate the diameters of the other planets to scale in centimeters by multiplying each planet's diameter by 2.

Planet Diameters
(compared to Earth's)

Planet	Diameter (in Earth diameters)
Mercury	0.38 × Earth
Venus	0.95 × Earth
Earth	1.0 × Earth
Mars	0.53 × Earth
Jupiter	11.2 × Earth
Saturn	9.5 × Earth
Uranus	4.0 × Earth
Neptune	3.9 × Earth

2. **Make a Model** On one sheet of paper, draw a circle for each planet using the diameters you calculated in step 1. Draw the smaller circles inside the larger circles. Label each circle with the name of the planet.
3. **Compare** Which planet is the largest? Which is the smallest?
4. The largest moon in the solar system has a diameter 0.4 times that of Earth. Which inner planet is closest to this moon in size?

Quick Check

Classify List the inner planets in order from smallest to largest.

Critical Thinking In what ways are asteroids similar to planets?

What are the outer planets?

Beyond the asteroid belt is another group of planets that includes Jupiter, Saturn, Uranus, and Neptune. These planets, known as the *outer planets*, are very different from the inner planets. The four outer planets are similar in size to one another. They are called the *gas giants*. Each of these huge planets has a small, metallic core and a thick atmosphere. The gas giants are much larger than the inner planets, and their orbits are much farther apart. The gas giants all have rings and many moons. They also spin very rapidly, so a day on a gas giant is very short.

Beyond the outer planets are smaller, icy worlds. One of the largest of these, Pluto, was once known as the ninth planet. For years, scientists had debated whether Pluto should be called a planet. In 2003, astronomers

Jupiter

Diameter: 143,000 kilometers (89,000 miles)

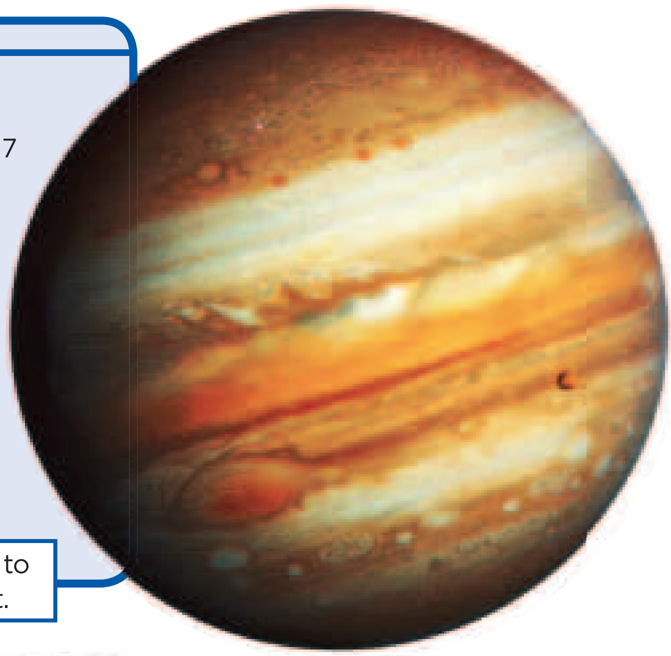
Distance from the Sun: 778.4 million kilometers (483.7 million miles)

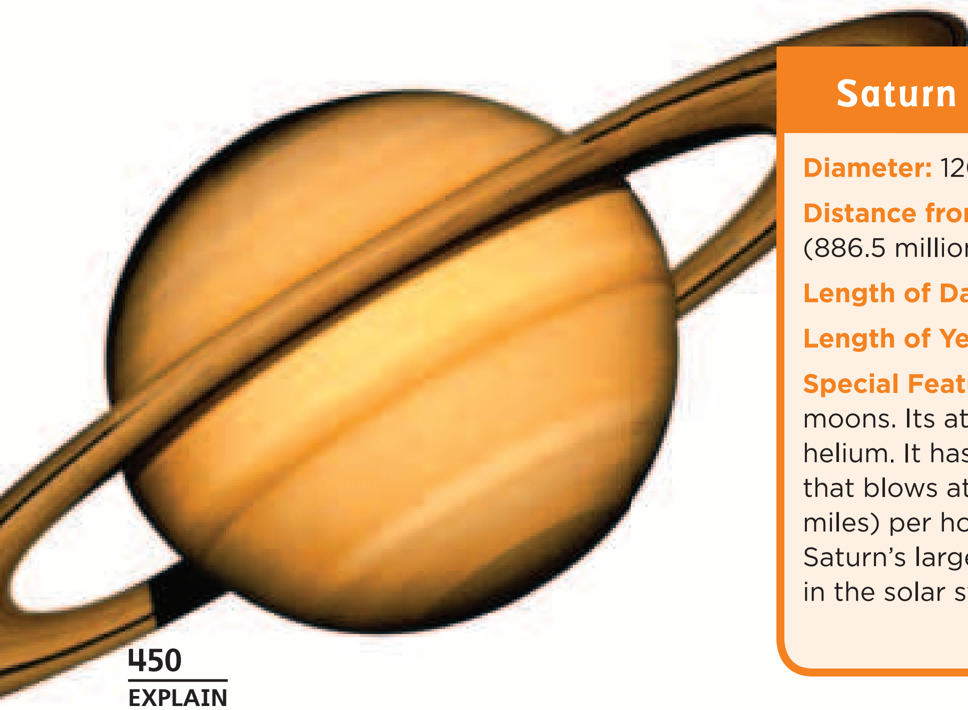
Length of Day: 9 hours, 55 minutes

Length of Year: about 12 Earth years

Special Features: Jupiter has at least 63 moons. It is the largest planet. Its atmosphere is mostly hydrogen and helium. The great red spot is a "storm" that has lasted more than 300 years. Ganymede is the largest moon in the solar system. Europa may have an ocean of water beneath its icy crust. Io has active volcanoes.

Size of Saturn, Uranus and Neptune shown compared to Jupiter. Earth would fit inside Jupiter's Great Red Spot.





Saturn

Diameter: 120,500 kilometers (74,900 miles)

Distance from the Sun: 1.43 billion kilometers (886.5 million miles)

Length of Day: 10 hours, 40 minutes

Length of Year: about 29 Earth years

Special Features: Saturn has at least 56 moons. Its atmosphere is mainly hydrogen and helium. It has huge storms and a jet stream that blows at more than 1,600 kilometers (990 miles) per hour. It also has a huge ring system. Saturn's largest moon, Titan, is the only moon in the solar system with a cloudy atmosphere.

discovered a similar, slightly larger world beyond the orbit of Pluto. In 2005, scientists also found a moon orbiting this newly discovered world.

In 2006, the International Astronomical Union (IAU) officially reclassified Pluto as a dwarf planet.

Quick Check

Classify List the outer planets in order from smallest to largest.

Critical Thinking How is Pluto different from the outer planets?

Uranus

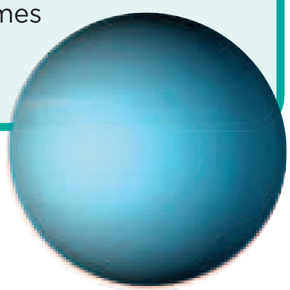
Diameter: 51,000 kilometers (32,000 miles)

Distance from the Sun: 2.87 billion kilometers (1.78 billion miles)

Length of Day: 17 hours, 14 minutes

Length of Year: about 84 Earth years

Special Features: Uranus has at least 27 moons and 11 rings. Its atmosphere is mostly hydrogen and helium, with a small amount of methane, which gives Uranus its blue-green color. Uranus's moon Miranda looks as though it broke apart and the pieces clumped back together several times as it formed.



Neptune

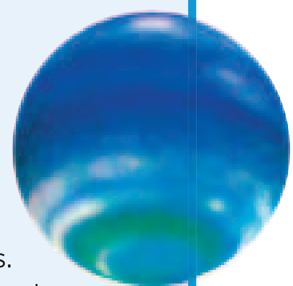
Diameter: 49,500 kilometers (30,800 miles)

Distance from the Sun: 4.5 billion kilometers (2.8 billion miles)

Length of Day: 16 hours, 7 minutes

Length of Year: about 165 Earth years

Special Features: Neptune has at least 13 moons. Its atmosphere is mostly hydrogen, helium, and methane. There may be an ocean under Neptune's clouds. Neptune has the strongest winds of any planet in the solar system. One of its moons, Triton, is larger than Pluto and has "ice volcanoes" that shoot material up to 8 kilometers (5 miles) high.



Dwarf Planets

In August 2006, the International Astronomical Union (IAU) reclassified Pluto as a dwarf planet. Others in this category include Ceres, which is found in the asteroid belt, and 2003 UB313 which is larger than Pluto and even farther from the Sun.

What are other objects in our solar system?

A **comet** is a ball of ice and rock that orbits the Sun. Comets come from the outer fringes of the solar system. As a comet approaches the Sun, the sunlight warms the comet's ice, causing the ice to turn from a solid to a gas and form a cloud of gas and dust. Near the Sun, the solar radiation and sunlight push the cloud away, and this forms a comet tail that points away from the Sun.

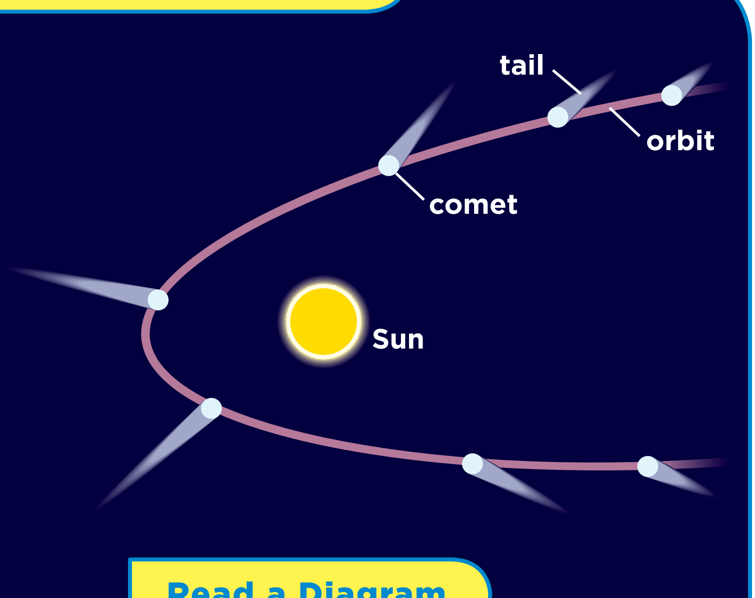
Some comets come from a region just beyond Pluto's orbit called the *Kuiper* (KIGH•puhr) *belt*. The Kuiper belt contains more than 70,000 objects the size of large asteroids.

▲ This crater in northern Arizona resulted from a meteorite impact.

Other comets originate in an area called the *Oort* (awrt) *cloud*, a region surrounding the solar system at a distance of about 30 trillion kilometers (18 trillion miles) from the Sun.

Meteoroids are small, rocky or metallic objects that orbit the Sun in both the inner and outer regions of the solar system. The craters on the Moon were formed by meteoroid collisions. A **meteor** is a meteoroid that enters Earth's atmosphere. It appears as a bright streak in the sky. If a meteor fails to break apart and burn up in the atmosphere, it can hit Earth's surface. A meteoroid that strikes Earth's surface is a **meteorite**. Many places on Earth show evidence of meteorite impacts.

Comet's Path



Read a Diagram

What happens to a comet's tail during its orbit?

Clue: Trace the comet's path with your finger.

Quick Check

Classify How are space objects classified as meteoroids, meteors, and meteorites?

Critical Thinking Is the tail of a comet in front of or behind the comet? Explain your answer.

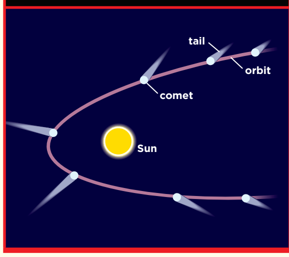
FACT Many meteoroids are no bigger than grains of sand. They are "dust" left behind from comets' tails.

Lesson Review

Visual Summary

The **inner planets** include Mercury, Venus, Earth, and Mars.

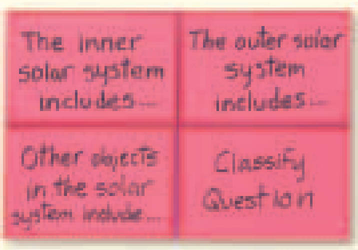
The **outer planets** include Jupiter, Saturn, Uranus, and Neptune.



Other objects in the solar system include the **asteroid belt**, **dwarf planets**, **comets**, the **Kuiper belt**, the **Oort cloud**, and **meteoroids**.

Make a FOLDABLES™ Study Guide

Make a Four-Door Book. Complete the statements shown, and include your work for the Classify question on this page.



Think, Talk, and Write

1. **Main Idea** What does the solar system consist of?
2. **Vocabulary** Large objects that orbit planets are called ________.
3. **Classify** What are some ways you could classify planets in the solar system?

4. **Critical Thinking** Suppose you throw a ball horizontally. How is the way the ball moves similar to the motion of planets around the Sun?
5. **Test Prep** **Which planet is MOST similar in size to Earth?**
   A Mercury
   B Venus
   C Mars
   D Jupiter
6. **Test Prep** **What do astronomers call space rocks that hit Earth's surface?**
   A meteors
   B meteorites
   C meteoroids
   D comets

Writing Link

Persuasive Writing

What are the advantages and disadvantages of sending robots instead of people into space? Research different points of view, and write a paper advocating your own position.

Art Link

Model the Solar System

Make a three-dimensional exhibit of an early model of the solar system. Include an explanation of how later discoveries added to scientists' understanding of the solar system.

Is Pluto a Planet?

Is Pluto the ninth planet in our solar system? I believe that scientific evidence proves it is not. A planet is a large body, often made of rock or gases, that orbits a star. It may have moons. Asteroids and comets also orbit stars. Both asteroids and comets are significantly smaller than planets.

Think about the issue of size. Pluto is smaller than any of the outer planets. The largest of the outer planets is Jupiter. Its diameter is 143,000 kilometers. Pluto's diameter is a mere 2,300 kilometers. The next smallest is Neptune, with a diameter of 49,500 kilometers.

The four inner planets are much smaller than the outer planets. Still, Pluto is even smaller than the smallest inner planet, Mercury, which has a diameter of 4,880 kilometers.

Pluto is inside the Kuiper belt, a vast collection of icy bodies beyond the orbit of Neptune. Recently, astronomers discovered "Eris," another object within the Kuiper belt. Eris is slightly larger than Pluto and sometimes comes even closer to the Sun in its orbit than Pluto does.

Pluto has been called a planet because it has moons. One moon, Charon, is almost as big as Pluto. Its other two moons, Nix and Hydra, are much smaller. However, Eris also has a moon. Are both Pluto and Eris planets? Pluto, in fact, has much more in common with its fellow Kuiper-belt objects than it does with any other planets in our solar system.

Finally, Pluto's orbit is unlike the orbit of any other planet. Pluto's orbit is more inclined, or tilted, and much more oval-shaped. Why does Pluto not behave like a planet? Could the answer be that it is not a planet? In my opinion, that is the only conclusion you can reach after looking at the facts.

Persuasive Writing

Good persuasive writing

- clearly states an opinion about a specific topic
- uses convincing reasons and arguments
- organizes reasons in a logical order
- usually saves the strongest argument for last
- includes opinion words

Write About It

Persuasive Writing Recently, the International Astronomical Union (IAU) decided to drop Pluto from the list of planets in our solar system. Write a letter to the editor of your local newspaper arguing either for or against this decision. Include facts that back up your opinion.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Math in Science

Scale of the Solar System

You want to make a model of the solar system that is small enough to work with. For the planets' sizes and their distances from the Sun to be accurate, you need to make the distances between the planets proportional to the actual distances. You also need to make the planets' diameters proportional to their actual diameters. To make your model to scale, you multiply distance by a scale factor.

In the table below, the first column tells how many times larger or smaller each planet's diameter is than Earth's. The second column tells how the planet's distance from the Sun compares with Earth's.

Planet	Scale Factor 1: Diameter (compared to Earth's)	Scale Factor 2: Distance from the Sun (compared to Earth's)
Mercury	0.38	0.39
Venus	0.95	0.72
Earth	1.0	1.0
Mars	0.53	1.52
Jupiter	11.2	5.20
Saturn	9.45	9.54
Uranus	4.0	19.19
Neptune	3.88	30.07

Source: NASA

Solve It

1. Which planet has the smallest diameter? Which has the largest diameter?
2. If you used a golf ball with a diameter of 4.2 cm to represent Earth, what diameter would Mercury be? What diameter would Saturn be?
3. Why is it difficult to make a true model of the solar system? (Hint: Earth's diameter is 12,756 km. The distance from Earth to the Sun is about 150,000,000 km.)

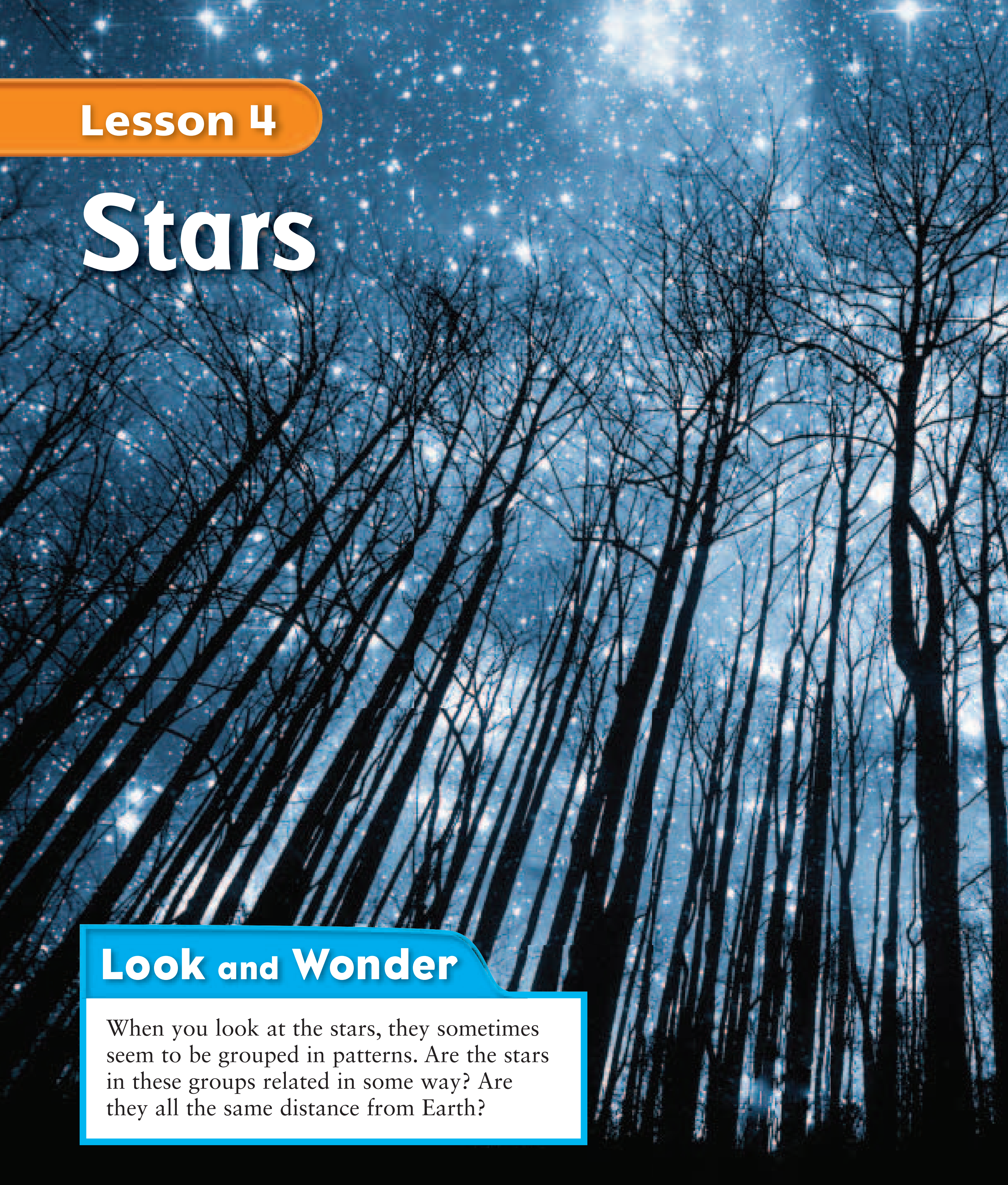
Use Scale Factors

- A scale factor tells you how many times larger or smaller one object is than another. Mars's scale factor for diameter is about 0.5, so Mars is about half the size of Earth. Neptune's scale factor for diameter is 4.0, so Neptune is four times the size of Earth.
- To use a scale factor, multiply it by the quantity you know. To find a model Uranus's diameter if a model Earth's is 10 cm and Uranus's scale factor for diameter is 4.0, use this equation:

$$4.0 \times 10 \text{ cm} = 40 \text{ cm}$$

Lesson 4

Stars



Look and Wonder

When you look at the stars, they sometimes seem to be grouped in patterns. Are the stars in these groups related in some way? Are they all the same distance from Earth?

Explore

Inquiry Activity

How does a star's distance from Earth affect its brightness?

Make a Prediction

Can you tell how bright a star actually is by looking at it from Earth? Write your answer in the form of a prediction: "If a bright object is very far away from me, then it will . . ."

Test Your Prediction

1. **Observe** Two partners should each hold one of the two flashlights 2 m away from a third student, who will act as the observer. The observer should record what he or she sees. Is one flashlight now brighter than the other? How can you tell?
2. **Observe** One partner should hold the smaller flashlight less than 0.5 m from the observer, and the other partner should hold the larger flashlight more than 8 m from the observer. The observer should record what he or she sees. Does one flashlight now seem brighter than the other? What has changed?
3. **Measure** The two partners should move forward and backward as directed by the observer until the two flashlights seem to be the same brightness. Measure the distance from the observer to each flashlight.

Draw Conclusions

4. **Interpret Data** If you see two lights in the distance, will how bright they appear to be always tell you how bright they actually are?

Explore More

Do other factors affect how bright a star appears to be? Research this question, and then design an experiment to test one of these other factors.

Materials

- small penlight or pocket flashlight
- large flashlight
- meterstick

Step 1

Step 2

Read and Learn

Main Idea

Stars vary in their size, their brightness, and their distance from Earth.

Vocabulary

star, p. 458
constellation, p. 458
parallax, p. 459
light-year, p. 459
nebula, p. 462
supernova, p. 463
black hole, p. 463

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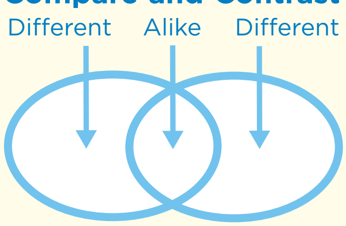
Reading Skill

Compare and Contrast



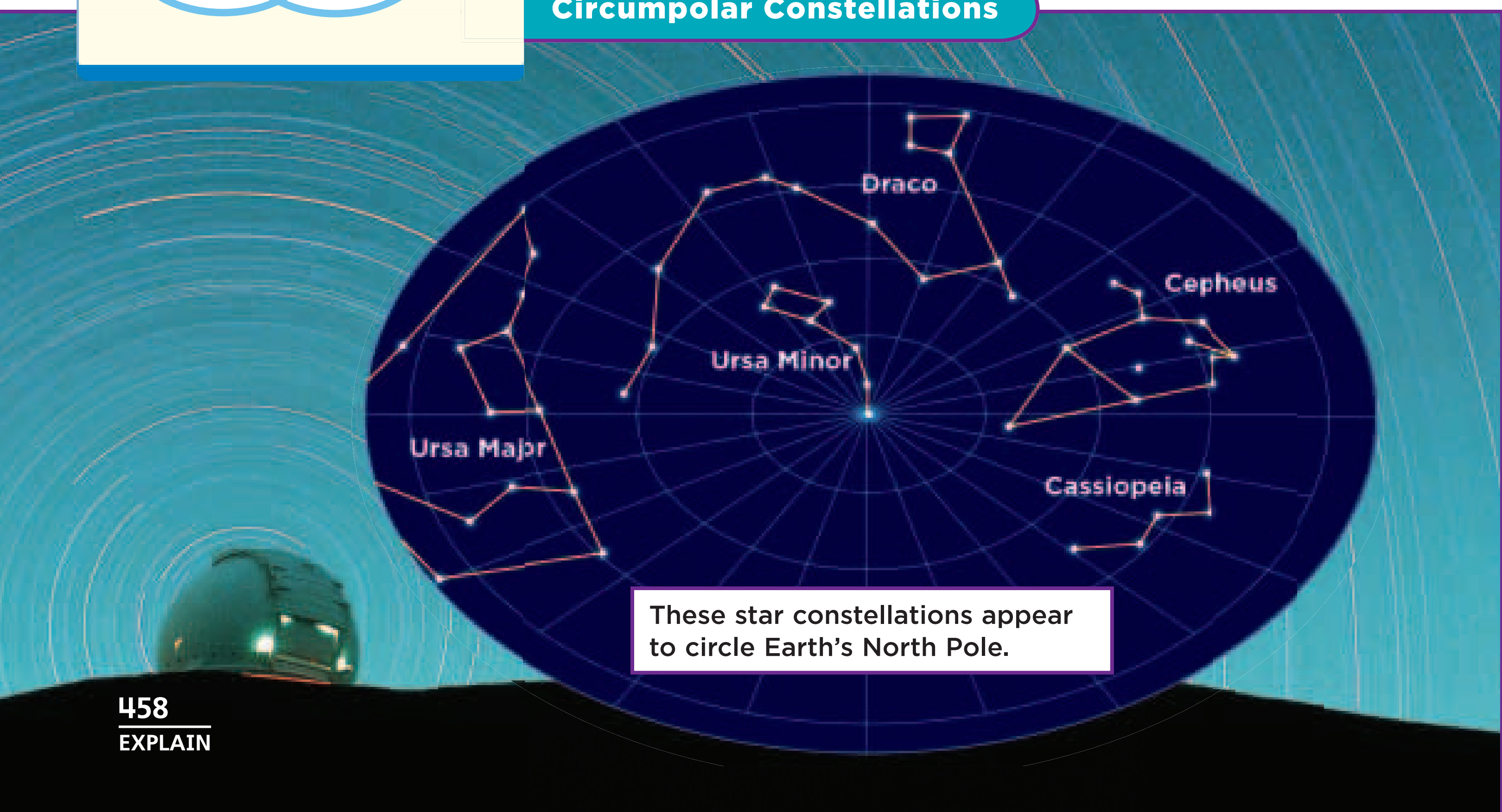
What are stars?

A **star** is a large, hot ball of gases, held together by gravity, that gives off its own light. A **constellation** is a group of stars that appear to form a pattern. For example, Rigel is a star in the constellation of Orion, the hunter.

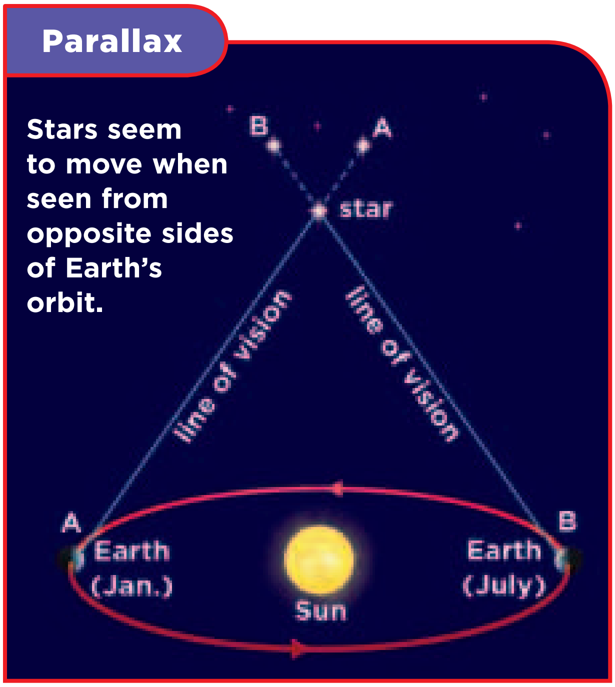
As Earth revolves around the Sun, different constellations are visible to observers on Earth. For example, Orion is a winter constellation in the Northern Hemisphere and can be seen there at night during the winter months. As the season changes, Orion sets earlier and earlier each night. In May, Orion disappears from the night sky in the Northern Hemisphere. In June, the constellation Scorpius, the scorpion, becomes visible.

Finding the Big Dipper in Ursa Major, the great bear, can help you find Polaris, the North Star. The North Star can help if you are unsure of directions. The stars in the sky only appear to form pictures because of our perspective as we look at them from Earth. If we looked at the stars from well outside our solar system, the pictures would not look the same.

Circumpolar Constellations



These star constellations appear to circle Earth's North Pole.



Finding the Distance to a Star

Viewed from different points in Earth's orbit, some stars seem to change position slightly compared to stars farther away. The apparent shift in an object's position when viewed from two locations is called **parallax** (PAR•uh•laks). Astronomers use parallax to find the distance of a star from Earth. The closer a star is to Earth, the greater the parallax. Scientists measure a star's parallax and use geometry to calculate its actual distance from Earth. For stars very far away, scientists use other measures, such as changes in brightness.

It would not be practical to measure the distance from your home to school in millimeters, because the total number would be so large. A more useful unit of measurement would be the kilometer. When astronomers measure the distance from Earth to a star, even a kilometer is far too small. They use a measurement of distance called a **light-year**, the distance that light travels in one year.

Quick Lab

How Parallax Works

1. **Make a Model** Close your right eye. Look at a distant object with your left eye. Hold your thumb about 10 cm in front of your face. Hide the object with your thumb, and look at it again with your left eye. Write or draw your observations.

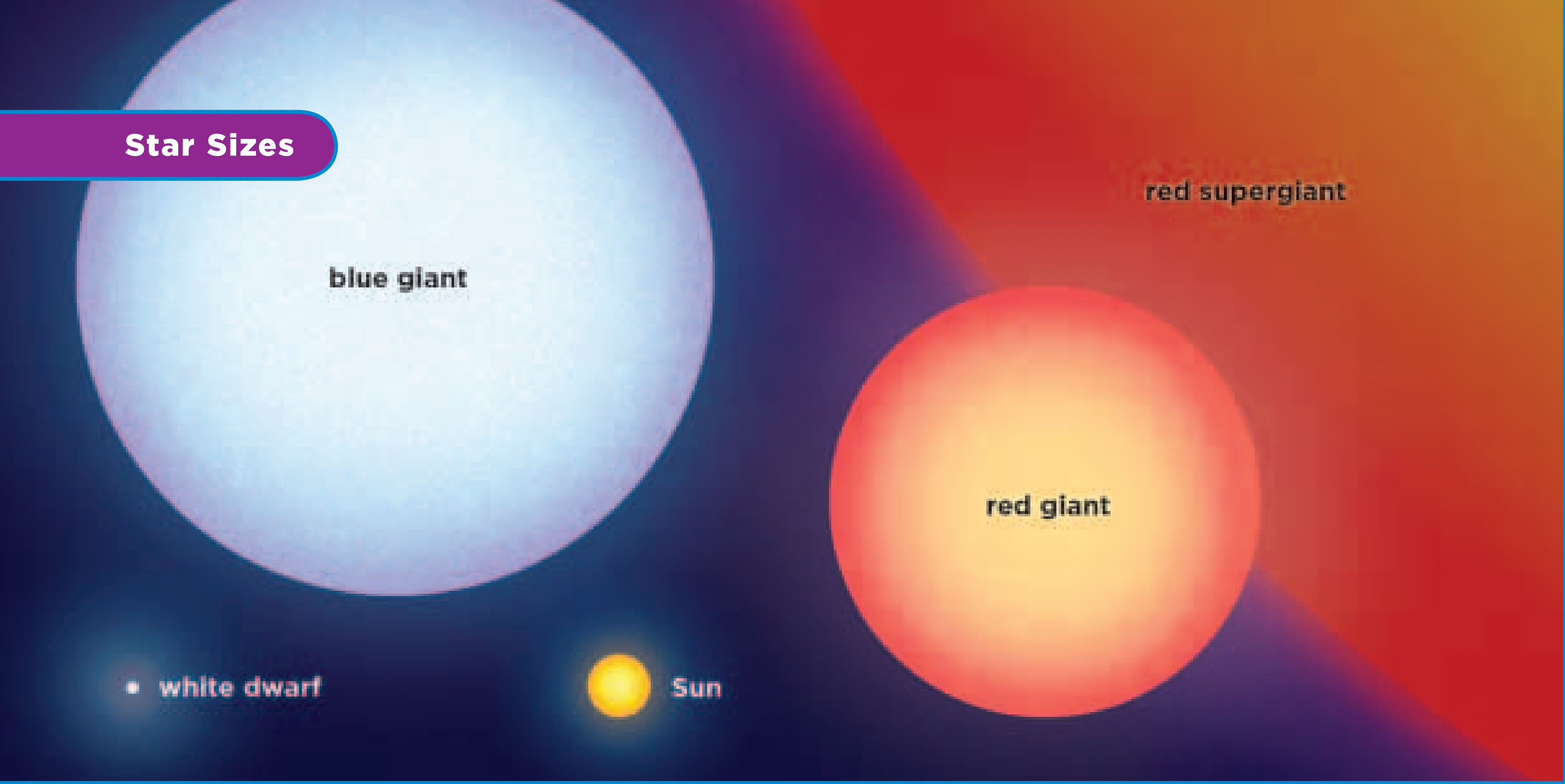
2. **Use Variables** Now close your left eye, and open your right eye. Look at the object with your right eye. Note your observations.
3. Repeat steps 1 and 2, holding your thumb at arm's length. Record your observations.
4. **Infer** What does your thumb represent in this model?
5. **Interpret Data** Compare the parallax you noticed in each case.

One light-year is more than 9 trillion kilometers (6 trillion miles). The nearest star, Alpha Centauri, is about 4.3 light-years away from Earth. The light we see when we look at Alpha Centauri left that star about 4.3 years ago.

Quick Check

Compare and Contrast How are the constellations alike? How are they different?

Critical Thinking It takes sunlight about 8 minutes to reach Earth. Is the Sun more than or less than a light-year away? Explain.



Stars come in widely varying sizes. A white dwarf can be as small as Earth.

What are some properties of stars?

Some stars are brighter than others. Stars appear less bright the farther they are from Earth. For example, Sirius (SEER•ee•uhs) seems brighter than Rigel. However, Rigel is actually much brighter than Sirius. Can you guess which star is closer to Earth? Sirius is only 9 light-years away, and Rigel is hundreds of light-years away. Think of two flashlights, one much brighter than the other. If you placed them side by side, the difference in brightness would be easy to see. However, if you moved the brighter flashlight much farther from you, it would seem dimmer. The brightness of a star is called its magnitude. A star's actual brightness is called its *absolute magnitude*. How bright a star looks in Earth's night sky is its *apparent magnitude*. Apparent magnitude depends on how much light a star gives off and how far away it is from Earth.

Another property of stars is color. A star's color tells you about its surface temperature. Think about the coils inside a toaster. As the coils heat up, they turn red, then orange, then orange-yellow. This same relationship between color and temperature applies to stars. Red and orange colors indicate cooler stars. Yellow indicates hotter stars, and blue-white indicates the hottest stars. Rigel, which is blue-white, is a much hotter star than a star such as Betelgeuse (BEE•tuhl•jewz), which is red. Like Rigel, Betelgeuse is a star in the constellation Orion.

Stars also come in different sizes. Our Sun is an average-sized star. Red supergiants are the largest stars. White dwarfs are among the smallest. A white dwarf with the same mass as our Sun is only about the size of Earth.

Brightness and Temperature

Two astronomers, Ejnar Hertzsprung and Henry Norris Russell, looked for a relationship between a star's brightness and its temperature. The *Hertzsprung-Russell (H-R) diagram* is the result of their work. An H-R diagram compares the absolute magnitudes and temperatures of stars. When the astronomers made their diagram, they found that stars appeared in groups.

To read an H-R diagram, start near the lower left corner. The stars here are very dim but very hot. White dwarfs fall into this category. In the lower right corner are dim, very cool stars. Diagonally up and left from the lower right corner, there is a long band. Most stars are found in this band of *main-sequence stars*.

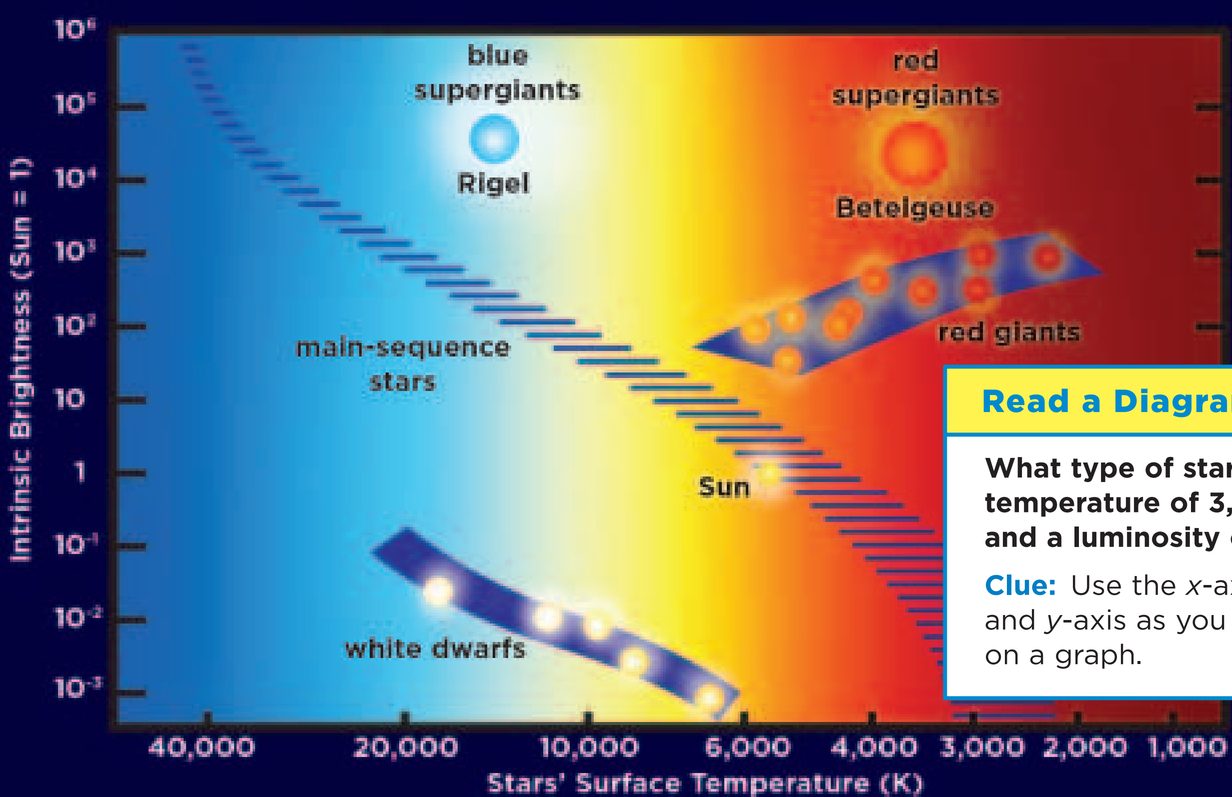
At the top of the scale of absolute magnitude are the supergiants, which are extremely large stars. Some are much hotter than others. The remaining group, the giants, includes stars larger than main-sequence stars but smaller than supergiants. They are also dimmer than the supergiants. The giants are located just below the supergiants in the chart.

Quick Check

Compare and Contrast How are absolute magnitude and apparent magnitude similar?

Critical Thinking What are three properties that all stars have, and how do they relate to one another?

The H-R Diagram



Read a Diagram

What type of star has a temperature of 3,000 K and a luminosity of 10^3?

Clue: Use the *x*-axis and *y*-axis as you would on a graph.

How do stars develop?

An H-R diagram plots stars according to temperature and magnitude. It also provides information about the stages of development that stars go through. Stars are born, they mature and grow older, and finally they die. The main factor that affects how a star goes through this cycle of development is the star's mass.

Protostars

Every star begins as a **nebula**, a huge cloud of gas and dust in space. Over time, gravity causes the nebula to contract. As the cloud shrinks, it heats up and becomes a *protostar*, or a young star. The protostar continues to gain mass because of its gravitational pull. Its heat makes it glow.

Newborn stars are emerging from the Horsehead Nebula in Orion.

Main-Sequence Stars

Eventually, the center of the protostar reaches a temperature of millions of degrees Celsius. At this point, nuclear reactions begin. In these reactions, hydrogen atoms fuse and form helium atoms, releasing a large amount of energy. The energy released pushes outward against the pull of gravity. At this point, the star is classified as a main-sequence star on the H-R diagram. A main-sequence star is a star that is fusing hydrogen into helium, releasing large amounts of energy. Stars spend most of their time as main-sequence stars.

Red Giants and Supergiants

As a star uses up the hydrogen in its core, it begins to expand. As the star expands, its surface becomes cooler, and its color becomes redder. The star becomes a red giant or a supergiant, depending on its mass. Instead of using hydrogen in its nuclear reactions, the star now uses helium.

Final Stages

The final stages of a star's life also depend on its mass. Stars up to about ten times the mass of the Sun become red giants. Nuclear reactions in a red giant give off energy, which builds up in the outer layers. This causes the star to release huge clouds of gases. A layer of gases, called a *planetary nebula*, forms around the star. This expanding layer of gases spreads far out into space. Meanwhile, the star's core continues to shrink. The surface of the star heats up, becoming white-hot. The star has then become a white dwarf.

The Crab Nebula shows the elements released by a supernova explosion.

A white dwarf is so hot that it gives off enough radiation to make its surrounding shell of gas and dust glow. When the shell glows brightly enough, we see it as a planetary nebula. The star slowly dims over time. A white dwarf may take billions of years to cool off. When it does cool off and stops emitting light, the star will become a black dwarf.

Stars with masses greater than about ten times the mass of the Sun follow a different path. These large stars become supergiants. They use up energy at a fantastic rate, giving off very large amounts of energy. In a relatively short amount of time, the star can no longer fuse atoms and give off energy at the same rate.

When a supergiant can no longer produce enough energy to balance the pull of gravity, it collapses and then explodes. It becomes a **supernova** (SEW•puhr•noh•vuh), an exploded star.

The next stage depends on the star's mass. Most of the time, what remains of a supernova becomes a *neutron star*, an extremely dense star made of tightly packed particles called neutrons. Neutron stars rotate very quickly. As they rotate they may appear to blink like a lighthouse beacon. When this happens the star is called a *pulsar*.

If a star is very massive, the supernova does not become a neutron star. Instead, the core collapses, and it becomes a tiny but very massive object called a black hole. A **black hole** is an object whose gravity is so strong that even light cannot escape from it.

Black holes cannot be seen directly. They are detected by the effect they have on other objects. Often, gases from a nearby companion star or nebula are pulled in by the intense gravity of the black hole. As the gases approach the black hole, they emit X rays. Scientists consider the detection of X rays emitted in this way as perhaps some of the best evidence of the existence of a black hole.

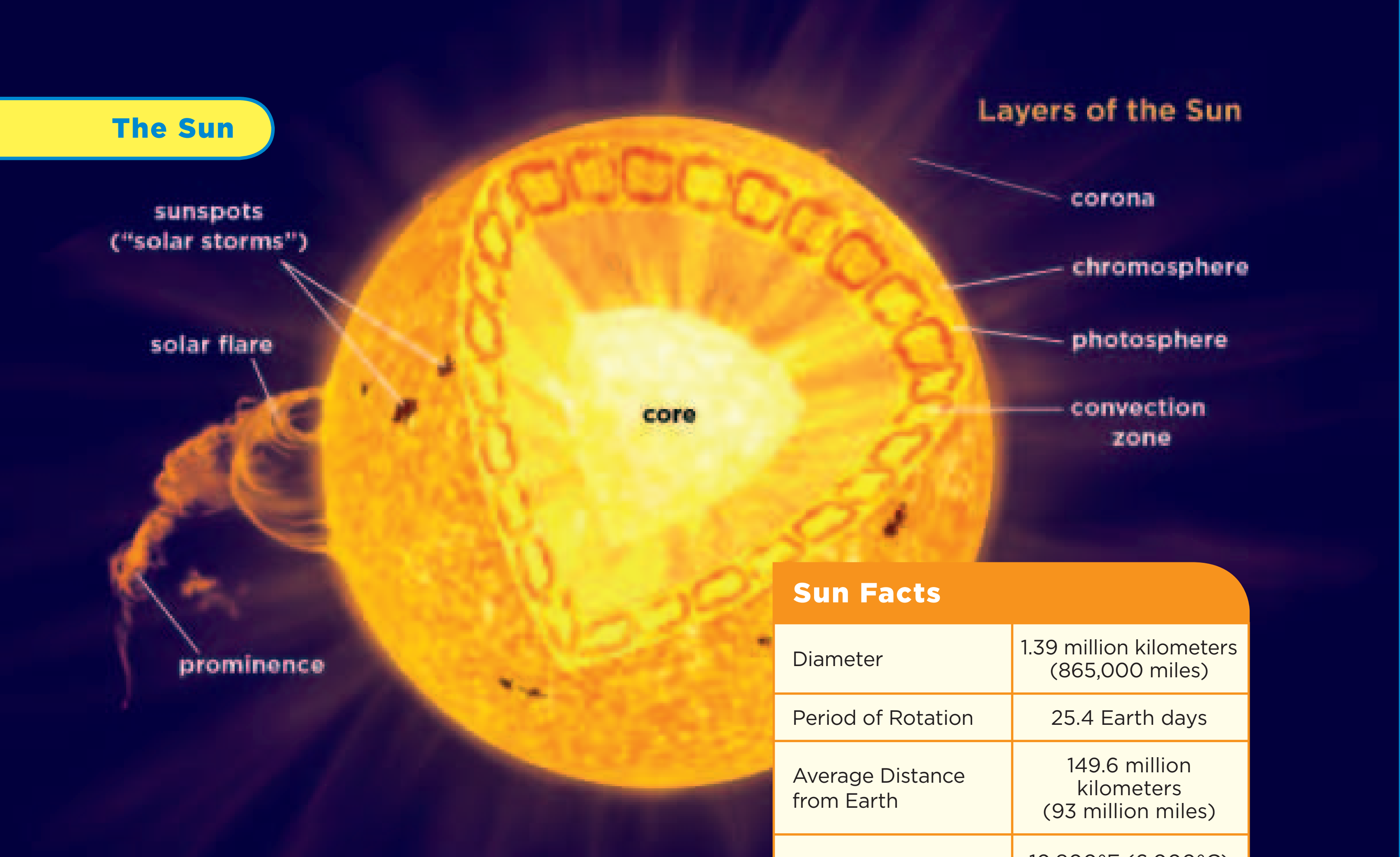
Quick Check

Compare and Contrast Compare the development of a less-massive star with that of a more-massive star.

Critical Thinking Why will the Sun not become a black hole someday?

FACT Supernovas are the source of all elements heavier than iron.

The Sun



Sun Facts

Diameter	1.39 million kilometers (865,000 miles)
Period of Rotation	25.4 Earth days
Average Distance from Earth	149.6 million kilometers (93 million miles)
Surface Temperature	10,800°F (6,000°C)
Core Temperature	27,000,000°F (15,000,000°C)
Size Relative to Earth	1.3 million × Earth

Read a Diagram

What are the layers of the Sun, beginning in the interior and moving outward?

Clue: Work your way outward from the center of the diagram.

What kind of star is the Sun?

The Sun is a main-sequence star. It lies at about the middle of the H-R diagram. The Sun has been shining for about 5 billion years. It will continue this way for another 5 billion years. At that point, it will become a red giant.

The Sun contains 99.9 percent of the solar system's mass. It is 92 percent hydrogen. Its hydrogen is being changed into helium by nuclear reactions.

You should never look at the Sun directly, because its brightness can harm your eyes. For more facts about the Sun, look at the table and the diagram on this page.

Quick Check

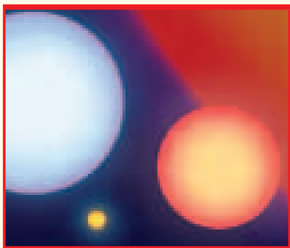
Compare and Contrast How is the Sun like other stars?

Critical Thinking Do you think the Sun is less massive or more massive than other stars? Why?

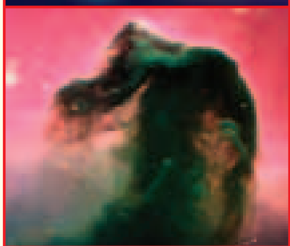
FACT Sunspots are solar "storms" powerful enough to interfere with Earth's radio transmissions and satellites.

Lesson Review

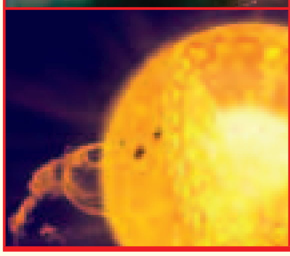
Visual Summary



Stars have **properties** that can be studied and compared.



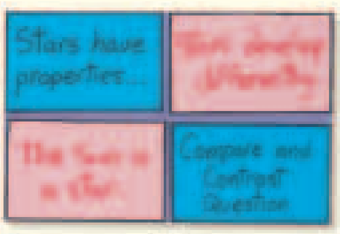
Stars develop in different ways, depending on their masses.



The **Sun** is an average-sized star with properties common to most stars.

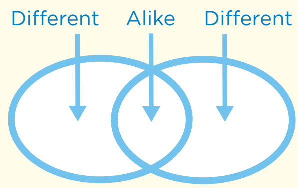
Make a FOLDABLES™ Study Guide

Make a Four-Door Book. Complete the statements shown, and include your work for the Compare and Contrast question on this page.



Think, Talk, and Write

1. **Main Idea** What are some properties of stars?
2. **Vocabulary** A grouping of stars that suggests a pattern is called a(n) ________.
3. **Compare and Contrast** How does the temperature of the Sun compare to the temperature of a red supergiant?



4. **Critical Thinking** If a star is very massive, what is likely to be its final stage?
5. **Test Prep** **Which object has such strong gravity that not even light can escape it?**
   A a white dwarf
   B a black hole
   C a neutron star
   D a pulsar
6. **Test Prep** **The Sun will one day become a**
   A neutron star.
   B black hole.
   C white dwarf.
   D blue supergiant.

Math Link

Compare Diameters
The diameter of Jupiter is about 143,000 km. About how much bigger is the Sun's diameter than Jupiter's diameter?

Art Link

Draw Constellations
Look at the night sky on a clear evening. Draw the stars you see. Connect the stars to make your own constellations. Use a star chart to check your drawings against those of familiar constellations.

Colors of Stars

The colors of light coming from a star give astronomers clues to the nature of the star. Blue-white stars are hottest; red stars are coolest. Scientists can tell what elements a star is producing by analyzing the light coming from the star. Astronomers study not only the visible light coming from stars but also the heat and other radiation, such as X rays, that stars emit.

The images on these pages are all views of the galaxy known as Messier 82, or M82. M82 is about 12 million light years away from Earth. M82 is smaller than our own Milky Way galaxy.

The center of M82 is a vast stellar "nursery" where huge numbers of stars are forming. Since so many stars are forming there so rapidly, M82 is also known as a starburst galaxy.

Fictional Narrative

A good fictional narrative

- describes a setting that tells when and where the story takes place
- has characters that move the action along
- has a plot with a problem that is solved at the end
- uses dialogue to make the story seem more real

Hubble Space Telescope Image
This is actually a series of images of M82 combining views of the galaxy in visible light with views in infrared, or heat radiation, and views in the light given off by glowing hydrogen.

Chandra X-ray Observatory Image
This image shows gas, heated to millions of degrees, blasting out of M82 from the central region where stars are forming. Red areas show low-energy X rays. Green areas show medium-energy X rays. Blue areas show high-energy X rays.

Spitzer Space Telescope Infared Image
M82 is extremely bright in infrared light. Dust particles, shown in red, are being blown out into space by the galaxy's hot stars. Infrared waves with the longest wavelengths are shown in red, and those with the shortest wavelengths are shown in blue.

combining views of M82

A combination of the visible, X-ray, and infrared images on the opposite page produced this spectacular look at M82. The data from Hubble includes the glowing hydrogen shown in orange, and the bluest visible light is shown in yellow-green. Chandra's X-ray data is shown in blue. Spitzer's infrared image is shown in red.

Write About It

Fictional Narrative Write a science-fiction story about traveling to M82. What plans do the characters need to make in order to allow people to travel such great distances? Use an appropriate point of view, and add dialogue to make your story come alive.

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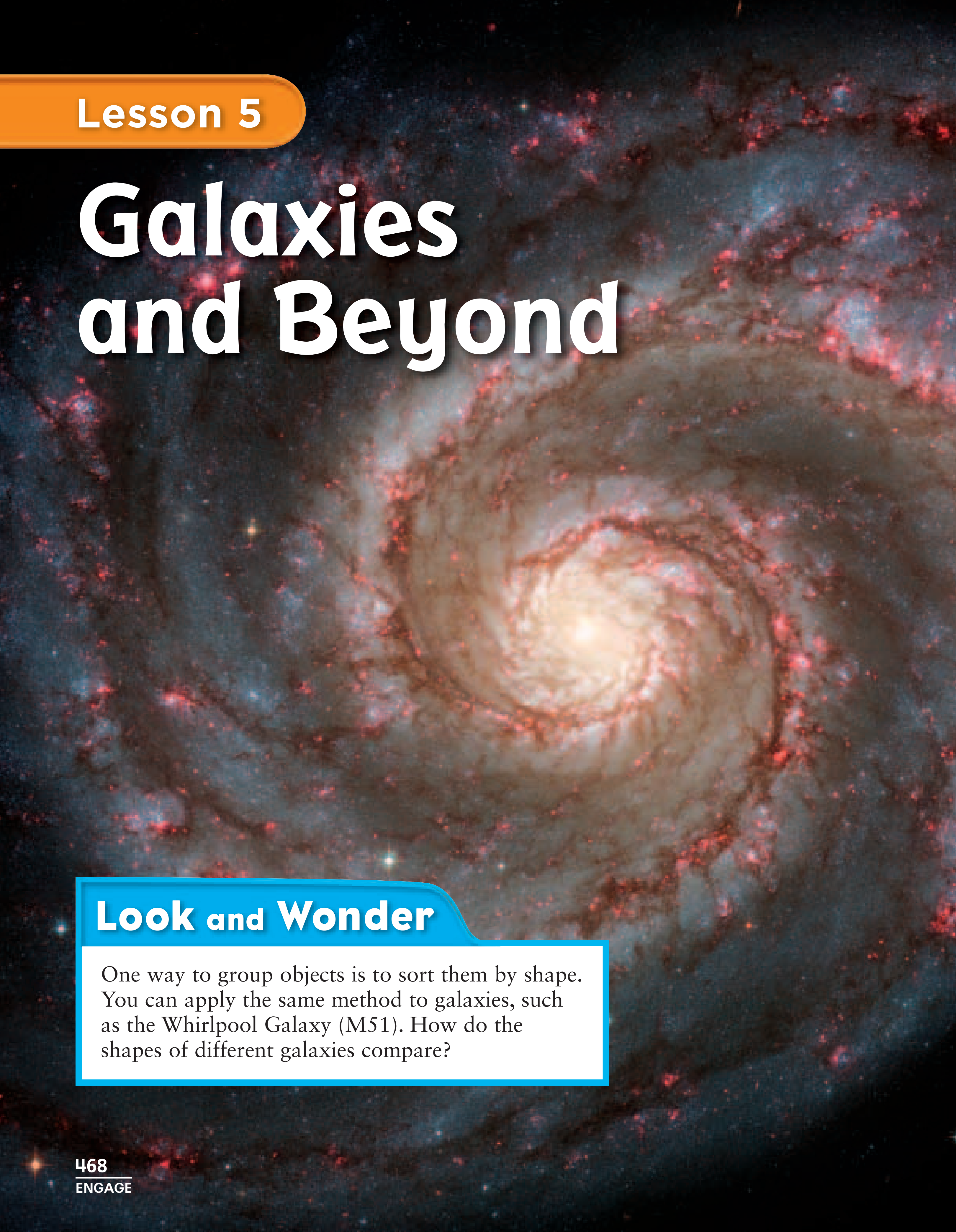
Lesson 5

Galaxies and Beyond



Look and Wonder

One way to group objects is to sort them by shape. You can apply the same method to galaxies, such as the Whirlpool Galaxy (M51). How do the shapes of different galaxies compare?

Explore

Inquiry Activity

How are galaxies classified?

Materials

- galaxy diagrams (shown)
- pictures of various galaxies

Make a Prediction

Do some galaxies have visible similarities by which they can be grouped? How could you classify galaxies into three major groups? Write your answer in the form of a prediction: "If I compare diagrams of different galaxies, then I will be able to classify them based on their . . ."

Test Your Prediction

1. **Observe** With your team, study the three galaxy diagrams shown here. Write a short description of anything you notice that is different in each picture. Name each grouping according to the description that you gave to its diagram on this page.
2. **Communicate** Examine available pictures of different galaxies, or find pictures of galaxies using the Internet or library sources. Discuss with your team which of the three galaxy categories each picture best resembles.
3. **Classify** Sort the galaxy pictures into three major groups.
4. What property did you use to classify the galaxy pictures?

Draw Conclusions

5. **Communicate** Look at how other teams classified the galaxies. Explain how their classifications compared to those of your team.

Explore More

Find additional information on different galaxies. What other information might you use to classify and categorize galaxies? Try classifying galaxies in a different way based on your new research. Then share your ideas with others in your class.

Read and Learn

Main Idea

The Milky Way is one of billions of galaxies that are moving away from each other in an expanding universe.

Vocabulary

galaxy, p. 470
Milky Way, p. 471
spectrum, p. 472
expansion redshift, p. 472
big bang, p. 472
background radiation, p. 473

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Reading Skill

Fact and Opinion

Fact	Opinion

What are galaxies?

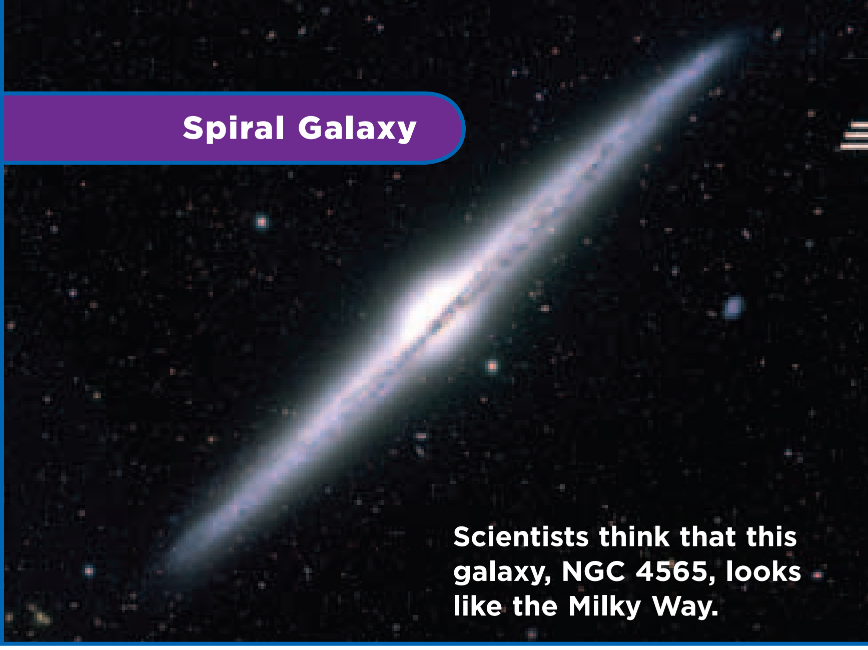
A **galaxy** is a group of star clusters held together by gravity. Astronomers estimate that our own galaxy may contain more than 200 billion stars and that the universe may have as many as 100 billion galaxies. Stars move around the center of their galaxy in the same way that planets orbit a star.

Galaxies differ in size, age, and structure. Astronomers place them in three main groups based on their shapes: spiral, elliptical, and irregular.

- A spiral galaxy looks like a whirlpool. The spiral arms can be tightly or loosely wound around the galaxy's core, and they often contain a great deal of dust. Some spiral galaxies are barred galaxies. A barred galaxy has a "bar" of stars, gas, and dust through its center. The spiral arms emerge from this bar.
- An elliptical galaxy is shaped a bit like a football. It has no spiral arms and little or no dust.
- An irregular galaxy has no recognizable shape. The amount of dust and gas varies. The irregular shape may have been caused by collisions with other galaxies.

This is part of our own Milky Way galaxy, as seen above a forest in Arizona.

Spiral Galaxy



Scientists think that this galaxy, NGC 4565, looks like the Milky Way.

The Milky Way Galaxy

Suppose you are in the countryside on a summer evening, far away from city lights. The sky is dark, and you look overhead. What do you see? A broad band of light stretches across the sky. You are looking at part of the Milky Way. The **Milky Way** is our home galaxy.

The Milky Way is a spiral galaxy. The stars are grouped in a bulge around a core. All of the stars in the Milky Way, including our Sun, orbit this core. The closer a star is to the core, the faster its orbit is. Several spiral arms extend out from the core.

Our solar system is located on one of these spiral arms. The arms contain most of the Milky Way's gas and dust. We cannot see the center of the Milky Way, because there is dust between us and the core. However, from Earth we can see more stars when we look in the direction of the galaxy's center than when we look in other directions. To find our galaxy's center, look in the direction of the constellation Sagittarius (saj•i•TAYR•ee•uhs), the archer.

Quick Lab

A Changing Universe

1. **Make a Model** Inflate a balloon about one third of the way. Use a tape measure to measure the circumference around the widest part of the balloon. Hold it closed, and have a partner draw three dots on its surface. Label the dots *A*, *B*, and *C*. Measure the distance between each pair of dots.
2. **Record Data** Inflate the balloon until the circumference is twice as large as it was in step 1. What has happened to the dots? Measure and record how far dots A and B are from dot C.
3. **Observe** What happened to the dots as you inflated the balloon?

4. **Infer** Suppose you were standing at dot A, B, or C. How would the other two locations appear to you as the balloon was inflated?

Quick Check

Fact and Opinion "The Milky Way is a spiral galaxy." Is this statement a fact or an opinion? Why?

Critical Thinking How are the three types of galaxies similar? How are they different?

What was the big bang?

When light passes through water droplets, it separates into a band of colors. This is because white light is really a combination of all the colors of the rainbow. This band of colors is called a **spectrum**.

The heated gases of stars produce light. As the light passes through a star's outer atmosphere, some of the light is absorbed by the star's atmosphere. When scientists look at a spectrum of this starlight, they see that the absorbed light has "dropped out" of the spectrum, forming dark lines called *absorption lines*.

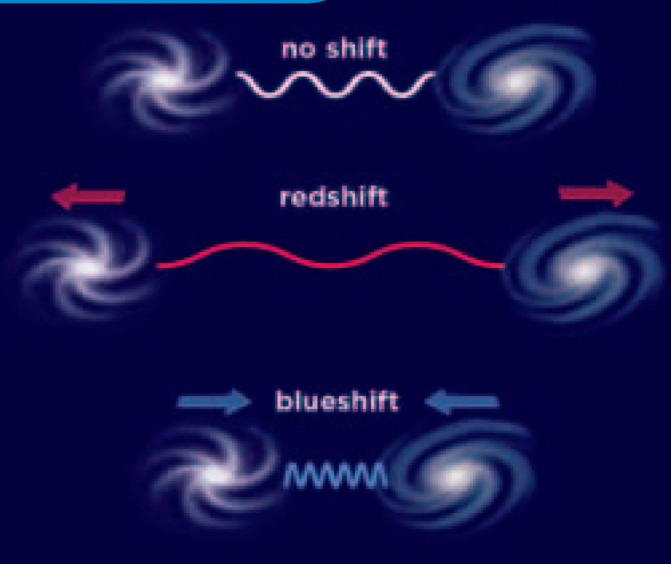
When we look at a spectrum from a galaxy, the absorption-line patterns do not appear at the same point in the spectrum as they would if they had formed here on Earth. Instead, the position of the pattern is shifted. This is because the galaxies are all moving away from each other as the space between them expands.

If the absorption lines of a spectrum are shifted toward the blue end of the spectrum—a blueshift—it means the galaxy is moving toward us. If the lines are shifted toward the red end of the spectrum—a redshift—the galaxy is moving away from us. The lines of nearly all galaxies are redshifted.

As space expands, the absorption lines show an **expansion redshift**. There is no center to this expansion. Observers in each galaxy could consider themselves to be at the center. Each observer would see the other galaxies moving away.

Astronomers think the galaxies must have been closer to each other in the past. The early universe was very dense, and its temperature was high. At the beginning moment, the universe was extremely tiny, hot, and dense. From this tiny beginning, the universe expanded rapidly. This expansion, called the **big bang**, sent matter out in all directions.

Wavelength Shift



No Shift This is how a light wave between our galaxy and another galaxy would look if the galaxies were not moving.

Redshift If the galaxies are moving away from each other, the wavelength appears to stretch out or become longer.

Blueshift If the galaxies are moving closer together, the wavelength appears to be compressed or shortened.

Star Formation

Much of the universe formed shortly after the big bang, but stars and galaxies are still forming.

Read a Diagram

How does this region of galaxy M33 resemble "starburst" galaxies?

Clue: What is in the center of this region?

According to the big bang theory, the universe is expanding, and its density and temperature are decreasing. Gravity has caused matter to collect into clumps, forming stars and galaxies. The galaxies continue to move outward. Evidence for the big bang comes from background radiation. **Background radiation** comes from all directions in space. This radiation is left over from the beginning moments of the universe.

Formation of the Solar System

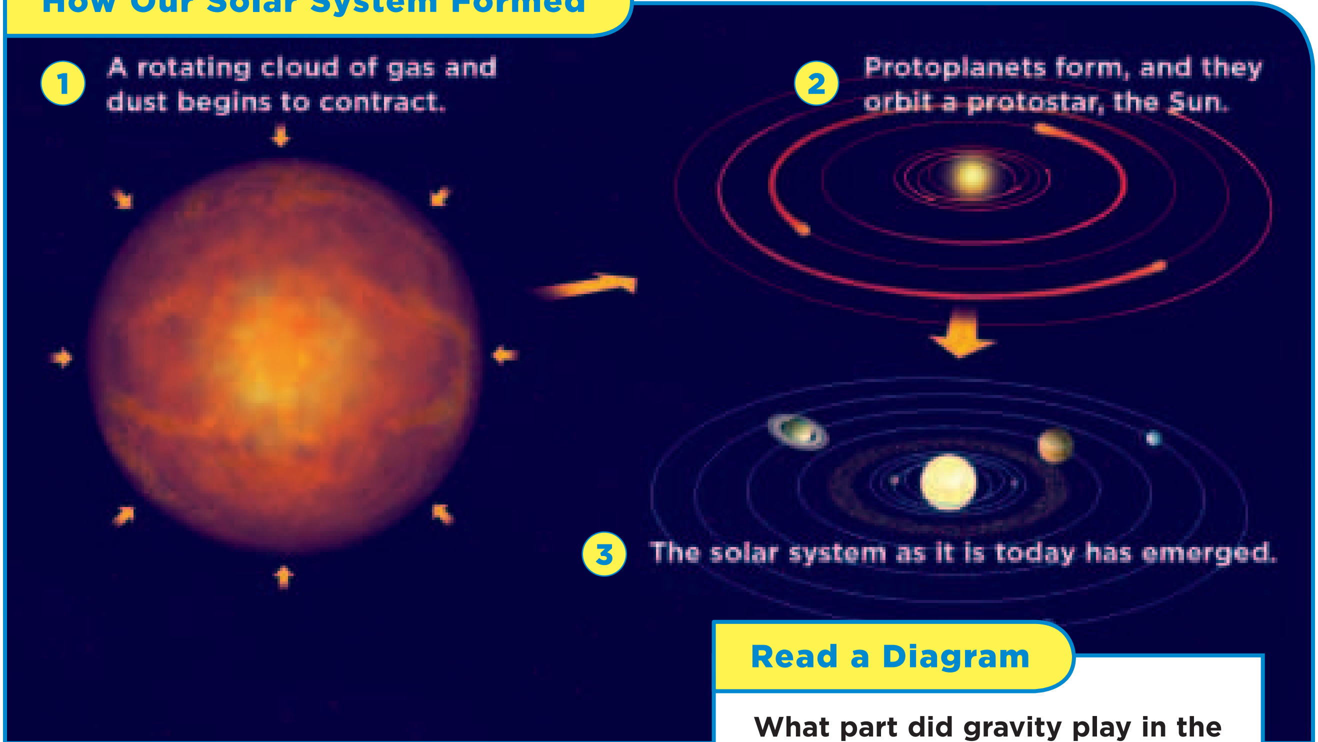
How did our solar system form? Scientists believe that billions of years after the big bang, dust and gas in a part of the Milky Way gathered into a nebula massive enough to rotate. A shock wave from a supernova hit the nebula. The wave caused clumps of gas and dust to form. Gravity caused these clumps to contract. As the nebula contracted, it rotated. Gravity at the center of the cloud grew stronger. Most clumps were pulled toward the center. Then the clumps combined, forming a protostar. The remaining clumps became protoplanets, or very young planets. The center of the cloud swept up more dust and gas, growing hotter and more massive. The temperature became high enough for the star to become a main-sequence star, the Sun, surrounded by planets.

Quick Check

Fact and Opinion "Scientists theorize that the universe was very hot and dense in its first moments." Is this a fact or an opinion? Why?

Critical Thinking What do astronomers think caused the background radiation found in space?

How Our Solar System Formed



Read a Diagram

What part did gravity play in the formation of the solar system?

Clue: Where do you see the effects of gravity?

How did Earth form?

Scientists think that Earth is about 4.6 billion years old. What caused it to form? Astronomers think that Earth and its atmosphere developed in a series of stages.

The process began in the nebula that formed the Sun. Dust and ice particles moved within the nebula, occasionally colliding. They merged and stuck together.

The clumps of particles grew until they became the young Earth, or proto-Earth. The protoplanet's larger mass and gravity attracted smaller bodies to it. Collisions increased. Over time, proto-Earth became large enough that its gravity could hold an atmosphere.

Earth's original atmosphere was mostly hydrogen and helium. The heat of the molten planet and impacts of space objects blew away much of that atmosphere, leaving water vapor, sulfur, carbon dioxide, and nitrogen released by volcanic eruptions. The atmosphere did not yet contain oxygen, as it does today. Atmospheric oxygen developed as a waste product of photosynthesis.

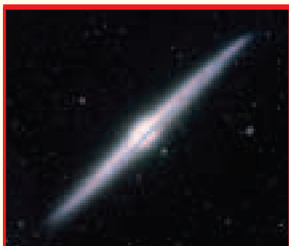
Quick Check

Fact and Opinion "Plants did not exist on Earth in its first years, because the atmosphere lacked oxygen." Is this statement a fact or an opinion? Why?

Critical Thinking How did Earth's original atmosphere evolve into its present one?

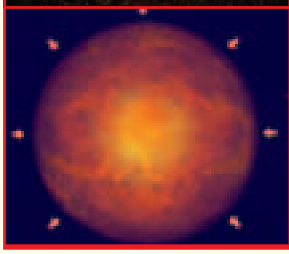
Lesson Review

Visual Summary



Galaxies are groups of billions of stars held together by gravity.

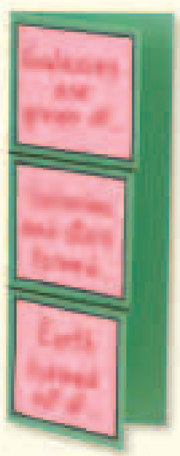
Galaxies and stars formed as a result of the **big bang**.



Earth formed out of the nebula that formed the Sun.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide additional details.



Think, Talk, and Write

1. **Main Idea** How do scientists know that most galaxies are moving away from ours?
2. **Vocabulary** At the beginning moment, the tiny, hot, dense universe expanded rapidly in what is called the ________.
3. **Fact and Opinion** "Galaxies are held together by gravity." Is this statement a fact or an opinion? Why?

Fact	Opinion

4. **Critical Thinking** What might we learn by studying other galaxies?
5. **Test Prep** **Which of the following is NOT a galaxy shape?**
   - **A** spiral
   - **B** elliptical
   - **C** irregular
   - **D** square
6. **Test Prep** **Ever since the big bang, the universe has been**
   - **A** heating up.
   - **B** contracting.
   - **C** expanding.
   - **D** exploding.

Writing Link

Descriptive Writing

Compose a story about the formation of Earth. In your story mention or describe the changes that occurred at each stage.

Social Studies Link

Conduct a Debate

Research the big bang theory. Then have a class debate about the future of the universe. Will it continue to expand forever, or will it contract again and eventually cause another big bang?

Meet Mordecai-Mark Mac Low

Far out in space, incredibly bright objects shine at the centers of some galaxies. These objects, called quasars, are brighter than a trillion suns.

Mordecai-Mark Mac Low is an astrophysicist at the American Museum of Natural History. He studies galaxies and quasars to learn about the history of the universe.

Mordecai is an astrophysicist. That is a scientist who studies how the universe works.

Quasars were discovered in the 1960s, when astrophysicists used telescopes to find the sources of radio waves coming from space. One type of source they saw came from faint, blue points of light similar to stars. They called these objects "quasi-stellar radio sources," or quasars for short.

Astrophysicists later discovered that these quasars were not in our galaxy but were actually billions of light-years away. Now we know that quasars lie at the centers of some distant galaxies. Why do they shine so brightly?

At the center of a quasar is a black hole, an object so massive that gas, stars, and even light cannot escape its gravity. Near the black hole, the gravity is so strong that matter falling into it is squeezed and heated to millions of degrees. This makes the hot gas shine so brightly that we can see it from across the universe.

Scientists like Mordecai compare observations taken with powerful telescopes to supercomputer models. They work to further understand the properties of quasars and galaxies as well as changes in the universe over time.

radio telescope in New Mexico

Mordecai is interested in quasars because they help him understand how the universe is changing over time. Since its origin in the big bang almost 14 billion years ago, the universe has been expanding. The first quasars formed about 10 billion years ago. Like all objects not held in place by gravity, quasars and galaxies are moving farther and farther away from us and from each other, some at more than half the speed of light! Even though quasars are very far away, they are so bright that astrophysicists can use them to study the formation and development of faraway galaxies.

Write About It

Draw Conclusions

1. Why do quasars look like faint points of light when viewed from Earth?
2. If scientists observe that a quasar is moving away from us, what can they conclude about its galaxy?

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Draw Conclusions

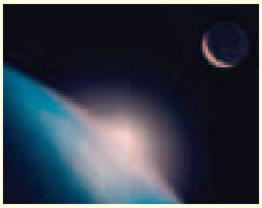
- Review the facts and details.
- Think about what they suggest about the topic.

American Museum of Natural History

CHAPTER 8 Review

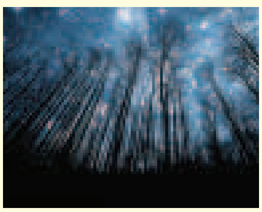
Visual Summary

Lesson 1 Scientists use many tools to observe and study the universe.

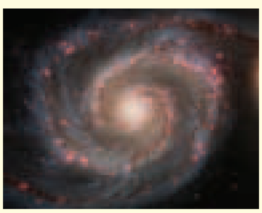


Lesson 2 The Moon revolves around Earth, causing different tides, eclipses, and phases of the Moon.

Lesson 3 The solar system consists of the planets, their moons, and many other bodies orbiting the Sun.



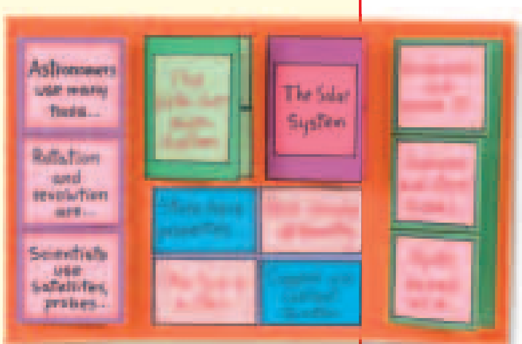
Lesson 4 Stars vary in their size, their brightness, and their distance from Earth.



Lesson 5 The Milky Way is one of billions of galaxies that are moving away from each other in an expanding universe.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

asteroid, p. 448	**parallax**, p. 459
comet, p. 452	**revolution**, p. 426
galaxy, p. 470	**rotation**, p. 424
gravity, p. 440	**spectrum**, p. 472

1. An Earth year is the time it takes Earth to make one ________ around the Sun.

2. The force of attraction between two or more masses is called ________.

3. A rocky object that orbits the Sun but is too small to be a planet is a(n) ________.

4. A group of star clusters held together by gravity is called a(n) ________.

5. A ball of ice and rock that has a very elongated orbit around the Sun is a(n) ________.

6. The band of colors in a rainbow is an example of a(n) ________.

7. An Earth day is the time it takes Earth to complete one ________ on its axis.

8. The apparent shift in an object's position when viewed from two locations is called ________.

LOG ON e-Review Summaries and quizzes online at www.macmillanmh.com

Skills and Concepts

Answer each of the following in complete sentences.

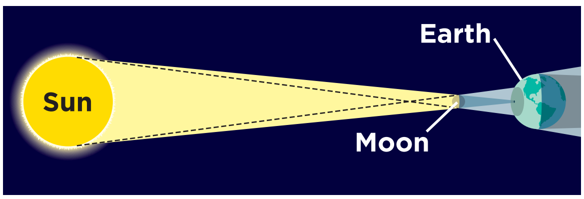
9. **Draw Conclusions** What conditions would have to exist for ice to remain on the Moon? In what kind of area on the Moon is ice most likely to be found?

10. **Persuasive Writing** Some people think that the space program is important. Others feel that the money would be better spent on other needs. Write an essay persuading your government officials to vote for or against the space program.

11. **Communicate** Describe the importance of finding the redshift observed in the absorption lines of most objects in the universe.

12. **Critical Thinking** Why is it important to determine the absolute magnitude of stars?

13. **Interpret Data** Which astronomical event is caused by the positions of the Sun, the Moon, and Earth as shown in the diagram below?



Big Idea

14. What is Earth's place in the universe? Describe it in relation to the Sun, the Moon, other planets, stars, solar systems, galaxies, and the universe.

Performance Assessment

Different Tilts

Your goal is to see how the tilt of Earth's axis affects the length of a day.

What to Do

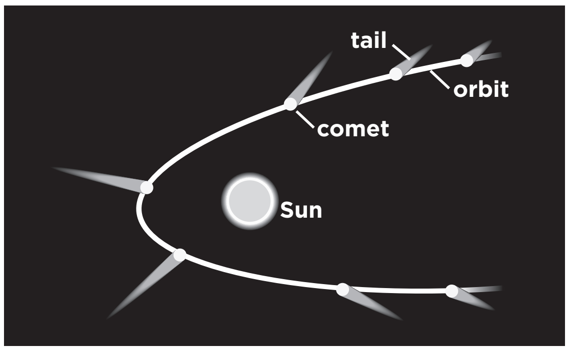
1. Use a ball to represent Earth. Use a flashlight to represent the Sun. Mark Earth's poles. Mark one point near the North Pole and one near the equator.
2. In a dark room, shine the flashlight on Earth at a 90-degree angle. Mark the boundary of Earth's lighted portion.
3. Repeat step 2 with Earth's axis tilted. Use a dotted line for this new boundary.

Analyze Your Results

- Compare the length of a day at different points on Earth with its axis upright and with its axis tilted. Explain your results.

Test Prep

1. Look at the diagram below.



How does the appearance of the comet's tail change as it approaches the Sun?

A It trails away from the Sun.

B It trails toward the Sun.

C The length decreases.

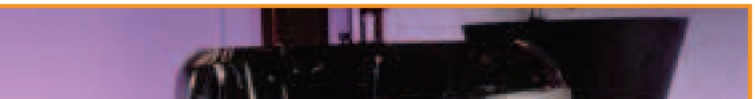
D The length increases.

Video-Production Assistant

Are you creative, hardworking, and detail oriented? If so, you might enjoy working as a video-production assistant. People in this profession work on teams that produce films on various topics for television or the Internet. A day in the life of a video-production assistant might include working with computers, following a script, or operating video equipment such as cameras, microphones, and lights. To start out you would need experience in video, photographic, and audio recording as well as enthusiasm for the media industry.

▲ Video production requires a steady hand and a sharp eye.

▼ Aerospace engineers must pay close attention to every detail.



Aerospace Engineer

Do you ever look at the night sky and think about the vehicles that soar into outer space? As an aerospace engineer, you could make flights into space possible by helping build high-speed spacecraft. You could also make travel closer to Earth faster and safer by improving aircraft design. Whether you were interested in designing spacecraft, missiles, helicopters, or military jets, it would all begin with at least a bachelor's degree in aerospace engineering. This is one career where the sky is not the limit.

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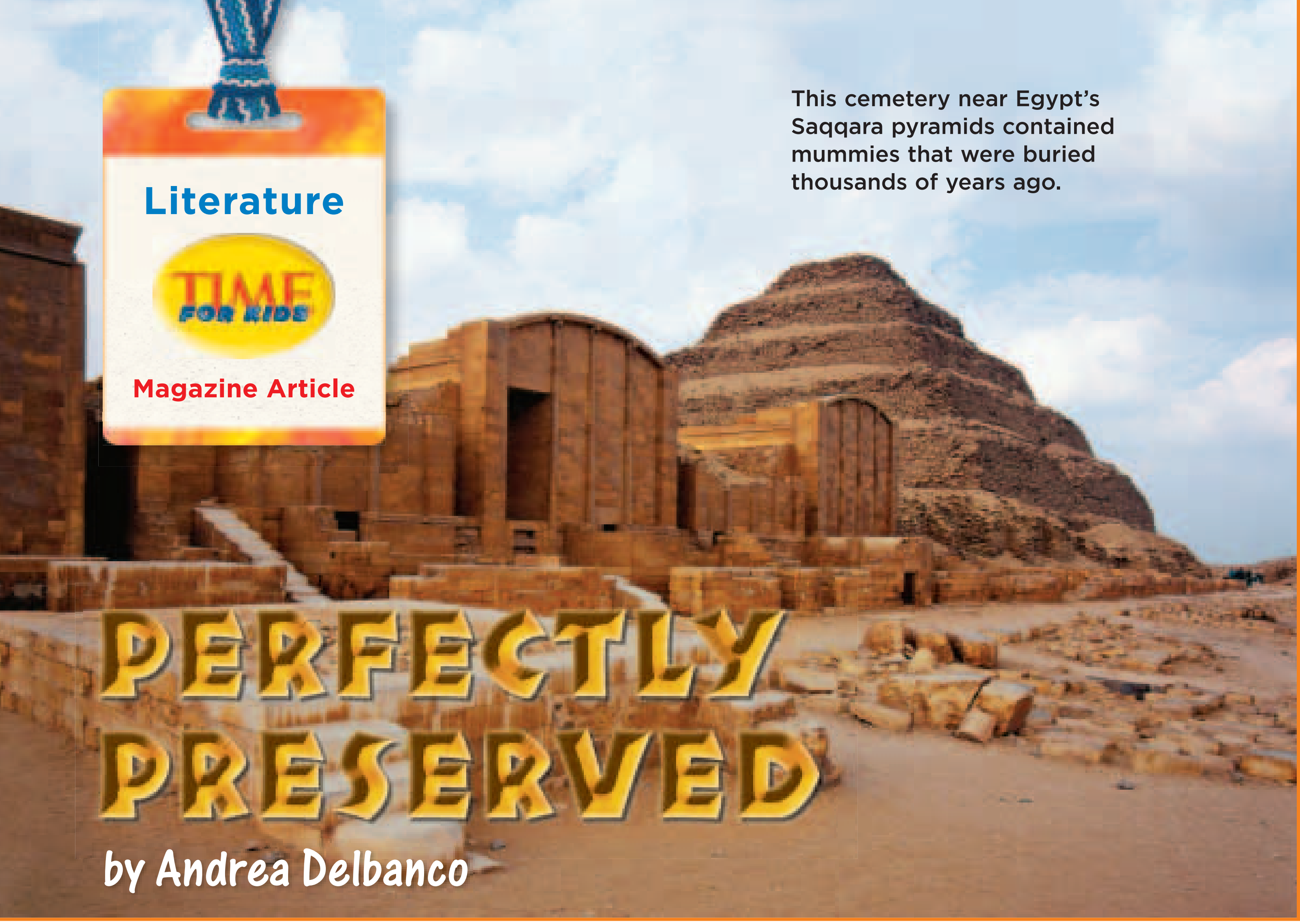
Matter

Molten copper was used to make the sheathing on the Statue of Liberty located in New York Harbor.



Literature

Magazine Article

This cemetery near Egypt's Saqqara pyramids contained mummies that were buried thousands of years ago.

PERFECTLY PRESERVED

by Andrea Delbanco

ARCHAEOLOGISTS FIND ANCIENT MUMMIES IN EGYPT

Inside an ancient tomb, hidden behind a statue, is a secret door. Archaeologists pry the door open to reveal a secret chamber. There lie three coffins, each containing a mummy. It may sound like a scene from a creepy movie, but it's exactly what happened to archaeologists while working in Egypt.

The team of Australian archaeologists was exploring tombs in a cemetery near the Saqqara pyramids, 15 miles south of Cairo, Egypt's capital. While digging in a tomb that dates back 4,200 years, the scientists moved the statue and made a surprising discovery.

The hidden tomb contained three wooden coffins shaped like human beings. These types of coffins are called anthropoids. The coffins had markings indicating that they were from Egypt's Twenty-Sixth Dynasty, which took place about 2,500 years ago.

Beaded necklaces buried with mummies are rarely found in such excellent condition.

A Magnificent Mummy

Ancient Egyptians believed that the dead should look as they did when they were alive. Bodies were treated with special chemicals that helped stop decay. To help the bodies retain their shape, they were tightly wrapped in linen strips. They were often decorated with beads and buried with their belongings.

Zahi Hawass, Egypt's top archaeologist, is excited about the discovery. He believes the mummies will offer important information about the Twenty-Sixth Dynasty.

"Inside one coffin was maybe one of the best mummies ever preserved," he says. "The chest is covered with beads. [With] most of the mummies of this period, the beads are completely gone, but this mummy has them all."

Write About It

Response to Literature The author of this article describes some recently discovered mummies. Where were the mummies found? How were they preserved? Think about how the archaeologists probably felt when they found the mummies. Then write a story describing their discovery of the mummies.

LOG ON e-Journal Write about it online at www.macmillanmh.com

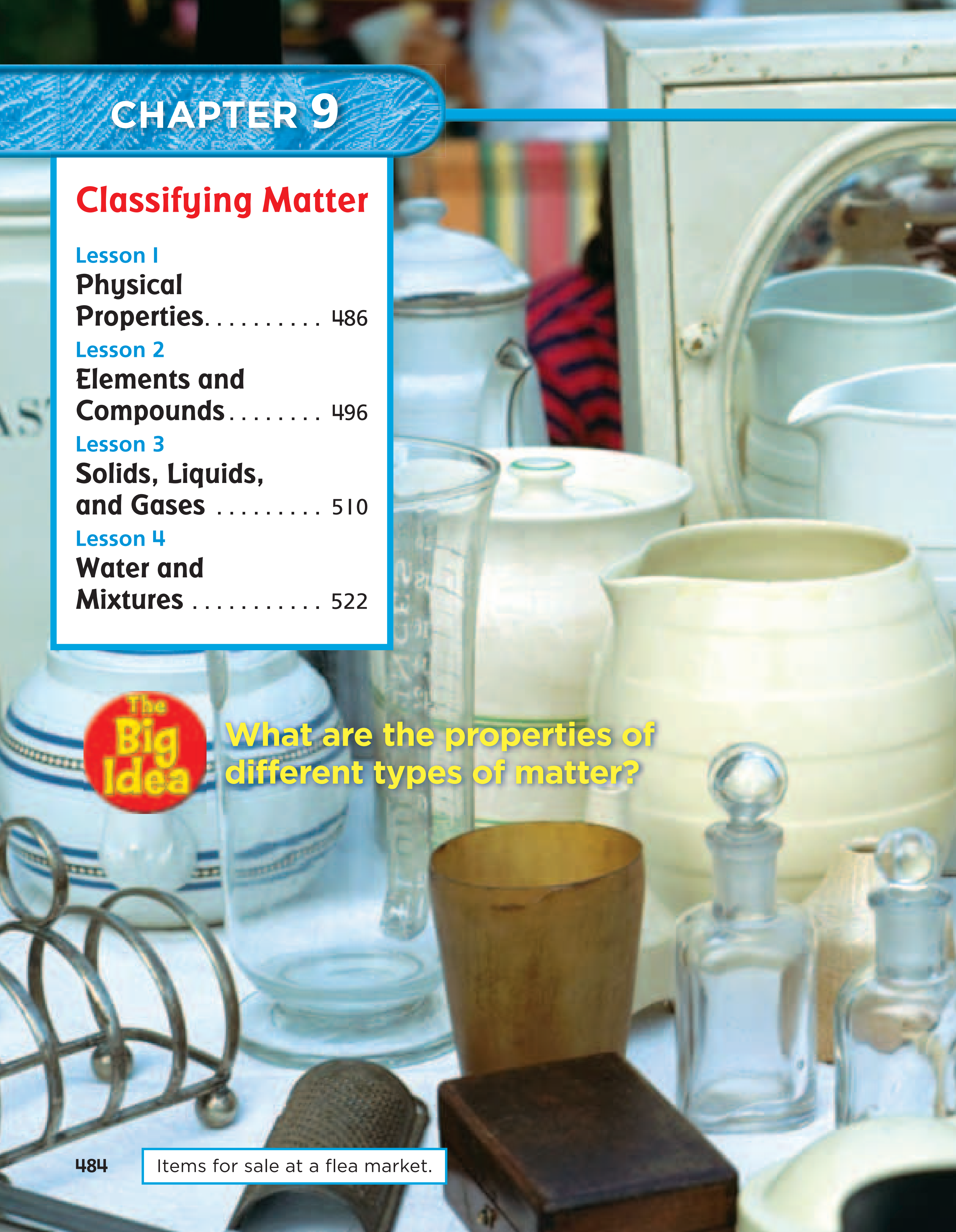
Egyptian sarcophagus

CHAPTER 9

Classifying Matter

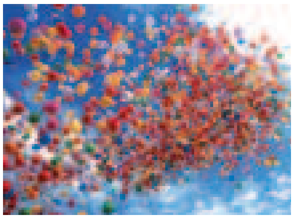
The Big Idea

What are the properties of different types of matter?

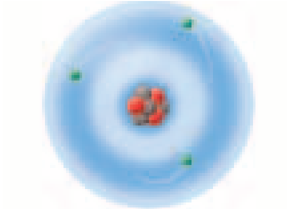


Items for sale at a flea market.

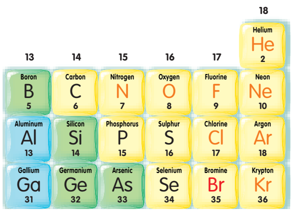
Key Vocabulary



gas
Matter that has no definite shape and does not take up a definite amount of space. (p. 489)

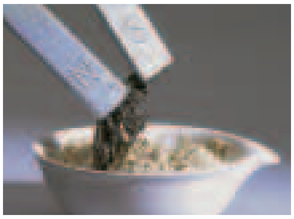


atom
The smallest particle of an element that has the same chemical properties as the element. (p. 500)



periodic table
A chart that shows the elements in order of increasing atomic number. (p. 502)

temperature
A measurement of how hot or cold something is. (p. 512)



mixture
A physical combination of two or more substances that blend together without forming new substances. (p. 524)

solution
A mixture of one substance dissolved in another. (p. 528)

More Vocabulary

mass, p. 488

weight, p. 488

volume, p. 488

solid, p. 489

liquid, p. 489

density, p. 490

physical property, p. 492

nucleus, p. 501

neutron, p. 501

proton, p. 501

atomic number, p. 501

electron, p. 501

molecule, p. 506

melting point, p. 514

freezing point, p. 514

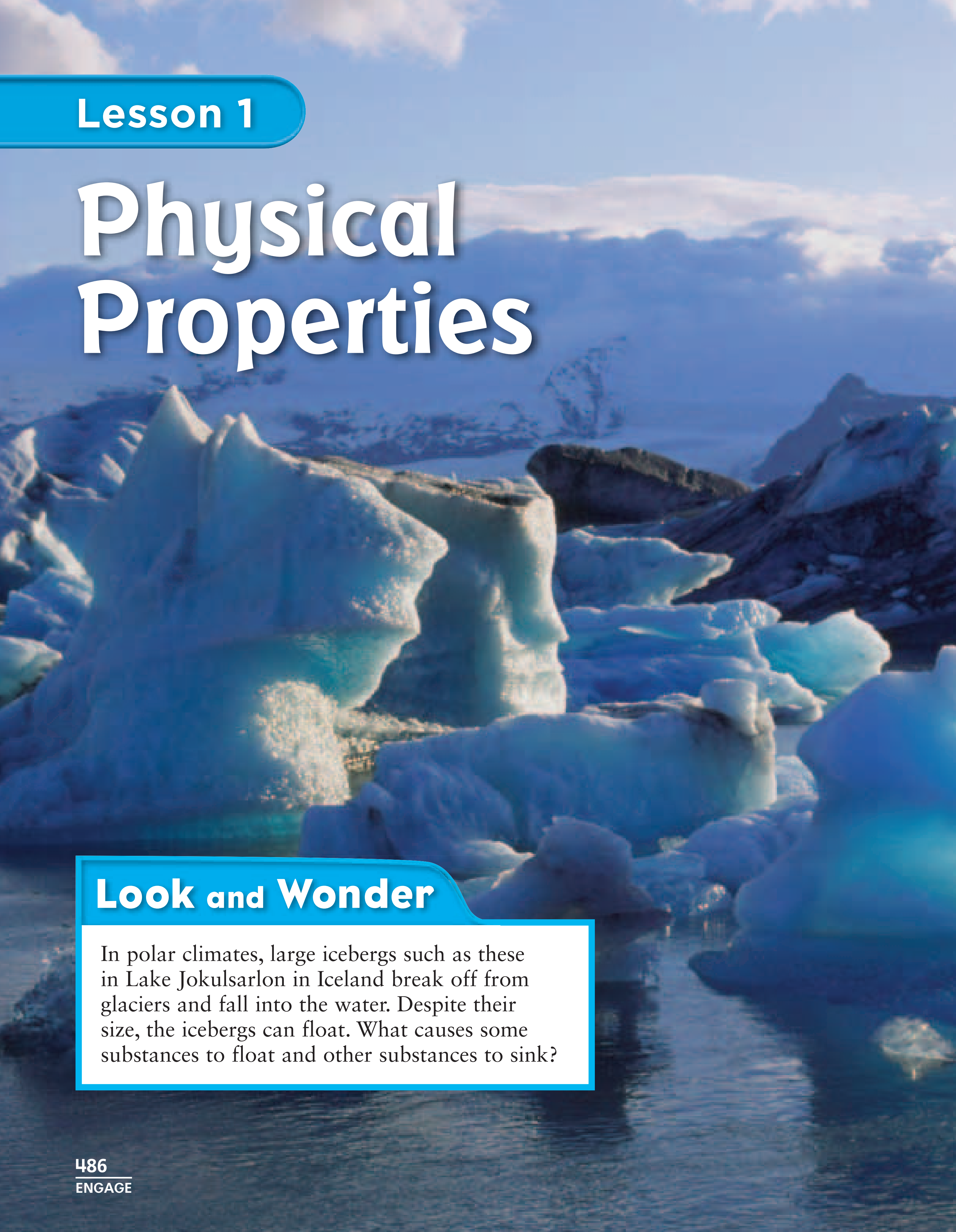
boiling point, p. 515

pressure, p. 516

physical change, p. 518

suspension, p. 527

solubility, p. 529



Lesson 1

Physical Properties

Look and Wonder

In polar climates, large icebergs such as these in Lake Jokulsarlon in Iceland break off from glaciers and fall into the water. Despite their size, the icebergs can float. What causes some substances to float and other substances to sink?

Explore

Inquiry Activity

What is the density of water?

Form a Hypothesis

Does the density of water depend on the quantity of water? If you change the quantity, does the density change? Write your answer in the form of a hypothesis: "If I change the amount of water, then the density of the water will . . ."

Test Your Hypothesis

1. **Measure** Record the mass of a dry, clear container. Add 25 mL of water to the graduated cylinder. To measure the water properly, view the cylinder at eye level. The bottom of the water's curved surface, the meniscus, should be at the 25 mL mark. Pour the water into the container.
2. **Record Data** Record the mass of the container and water together.
3. **Use Numbers** Determine the mass of the water by subtracting the mass of the clear container from the total mass. Record your measurement.
4. **Use Numbers** Determine the water's density. The density of a substance is the amount of mass in a given volume. Divide the mass of the water in grams by the volume in milliliters. Round to the nearest tenth.
5. Repeat steps 1–4 three times, using 50 mL, 75 mL, and 100 mL of water.
6. **Communicate** Plot the results from the four samples on a graph, with volume on the *x*-axis (horizontal) and mass on the *y*-axis (vertical).

Draw Conclusions

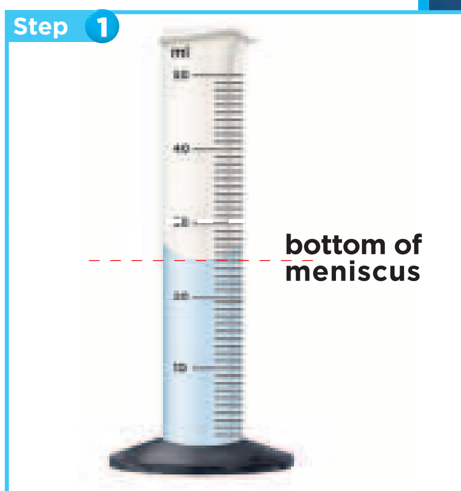
7. **Interpret Data** Does the density of water change as the amount of water changes?

Explore More

Is this relationship true for other liquids? Repeat the investigation using oil. Would it be true for solids?

Materials

- balance
- gram masses
- clear container (such as a pitcher)
- water
- graduated cylinder



Read and Learn

Main Idea

The properties of objects affect how they function and interact with other objects.

Vocabulary

mass, p. 488
weight, p. 488
volume, p. 488
solid, p. 489
liquid, p. 489
gas, p. 489
density, p. 490
physical property, p. 492

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Reading Skill

Infer

Clues	What I Know	What I Infer

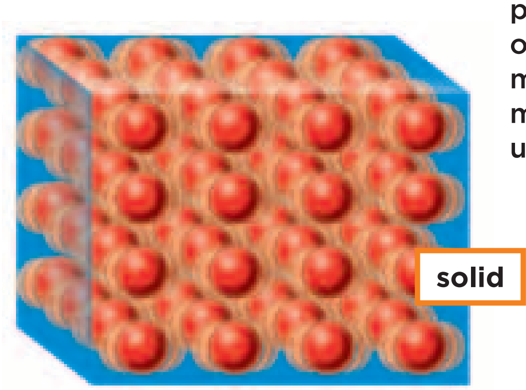
What is matter?

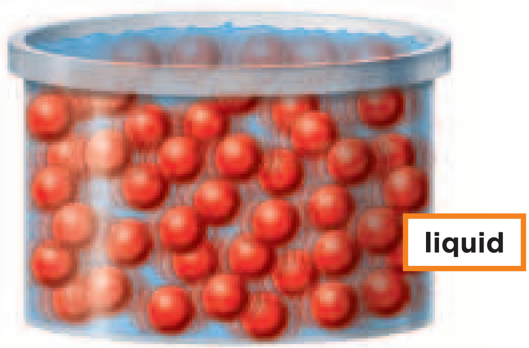
Diamonds, water, and air are all matter. *Matter* is anything that has mass and volume. The amount of matter in an object is called **mass**. Scientists use a balance to measure the mass of an object by comparing it to standard masses. Mass is usually measured in milligrams, grams, or kilograms. The mass of an object never changes. **Weight** is the measurement of the pull of gravity on an object. You would weigh much less on the Moon than you do on Earth. The pull of gravity is lower on the Moon than it is on Earth, because the Moon has much less mass. Spring scales measure the weights of objects. Weight is measured in newtons (N) or pounds.

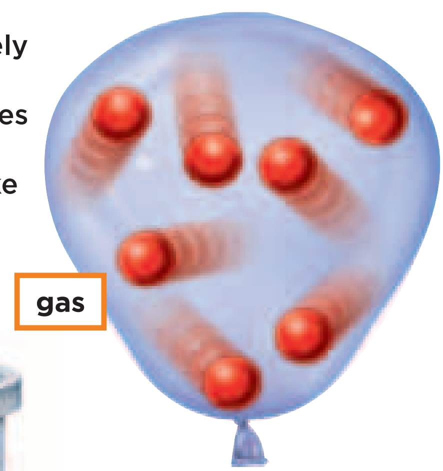
The amount of space that matter takes up is its **volume**. The volume of a liquid can be measured in milliliters by pouring the liquid into a graduated cylinder. Solids are often measured in units called cubic centimeters (cm^3). A cubic centimeter is equal to the volume of a cube that is 1 centimeter long, 1 centimeter wide, and 1 centimeter high. A milliliter and a cubic centimeter both represent the same volume.

Molecules in a Solid, a Liquid, and a Gas

The molecules in solids are closely packed together. As the amount of energy increases, the molecules move more and separate. As molecules spread apart, they take up more space.



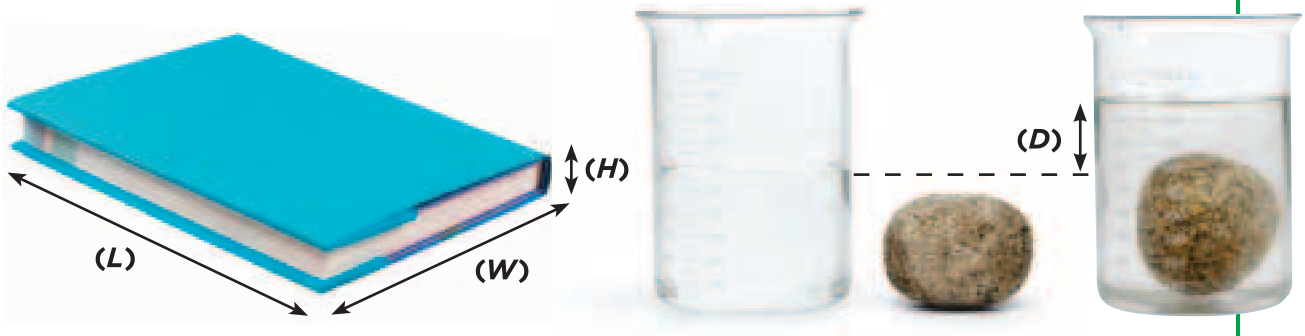




Calculating Volume

volume (V) =
length (L) × width (W) × height (H)

The volume of an object (V) is equal to the amount of water it displaces (D).



Calculating Volume

You can easily calculate the volume of a regularly shaped object, such as a rectangular solid. Measure the object, and then multiply its length (L) by its width (W) by its height (H): $L \times W \times H$. However, some objects have irregular shapes and cannot be measured easily with a ruler. You can find the volume of such objects by using water displacement.

To do this, you measure the amount of water that is moved out of the way, or displaced, when the object is placed in water. An irregularly shaped object may be put into a graduated cylinder that contains water. The amount that the water rises in milliliters indicates the volume of the object in cubic centimeters. For this to work properly, the object needs to be completely underwater.

States of Matter

Most of the world's matter exists in one of three states: solid, liquid, or gas. **Solids** have a definite shape and occupy a definite amount of space. **Liquids** take up a definite amount of space but do not have a definite shape. The molecules in most liquids are spread out more than those in solids but not nearly as much as those in gases. This is because the molecules in liquids have a little more energy than those in solids. The molecules in gases have much more energy than those in liquids. **Gases** do not take up a definite amount of space and have no definite shape. Molecules in gases constantly move around and spread out.

Quick Check

Infer If you drop an object into 5 mL of water and the water level rises to 8 mL, what is the volume of the object?

Critical Thinking What is the difference between mass and weight?

What are density and buoyancy?

Density is the measurement of how much mass fits within a certain volume. Density is measured in grams per cubic centimeter (g/cm^3). For example, the density of water is 1 gram per cubic centimeter. To find the density of a solid object, divide its mass in grams by its volume in cubic centimeters.

Two objects with the same volume can have different densities. Suppose you have two boxes of the same size: one filled with steel and the other filled with feathers. Which would have the greater overall density? The box filled with steel would be denser, because it would have much more mass in the same amount of space than the box filled with feathers.

An object will float if it is less dense than the gas or liquid in which it is placed. It will sink if it is denser than the gas or liquid in which it is placed. Even though steel has a higher density than water, heavy steel ships can float, because their hulls and cabins are filled with large volumes of air. The air, which is less dense than water, makes the steel ship's average overall density less than that of water. This lower density enables the ship to float on water.

Densities of Some Common Substances

Substance	Density (g/cm^3)
helium	0.000175
air	0.0013
feathers	0.0025
ice	0.92
water	1.00
steel	7.80

How Heavy Ships Float

Read a Photo

How does the air inside this steel ship help it float on water?

Clue: Which substance—air or water—appears to have a lower density?

▲ Helium balloons float because helium gas is less dense than air.

Buoyant Force

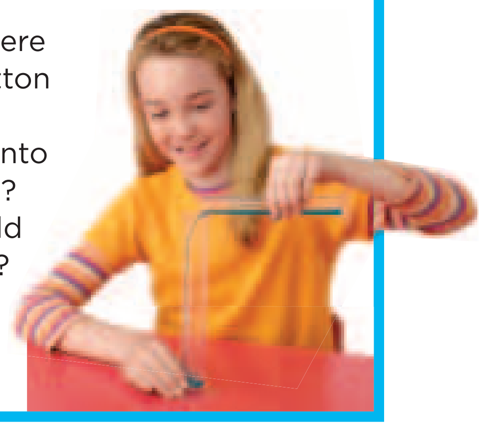
Buoyancy describes the ability of an object to float in a fluid, which is a liquid or gas. When an object is submerged in, or pushed down into, a fluid of greater density, the fluid's buoyant force pushes the object back toward the surface.

Archimedes' principle states that buoyant force is equal to the weight of the fluid that is displaced. The size of the fluid's buoyant force determines whether an object sinks or floats. If the buoyant force exceeds the object's weight, the object floats. For example, buoyant force pushes an ice cube back toward the surface of the water in a glass. Since the buoyant force is greater than the weight of the ice cube, the ice cube floats. Archimedes' principle explains why ships can float on water and balloons can float in the air.

Quick Lab

Density in Action

1. **Predict** What will water, corn oil, baby oil, and corn syrup do if you pour them into a graduated cylinder and do not mix them?
2. **Measure** Add blue food coloring to 20 mL of water. Pour the water into a 100 mL graduated cylinder.
3. **Observe** Slowly pour 20 mL of corn oil into the graduated cylinder. Then slowly add 20 mL of baby oil, followed by 20 mL of corn syrup. Describe what happens as each substance is poured into the graduated cylinder.
4. **Communicate** Make a diagram that shows the graduated cylinder with all of the substances added. Label each of the substances.
5. **Infer** What does your illustration show about the density of each substance?
6. **Predict** Where would a button float if you dropped it into the cylinder? Where would a cork float? A penny?



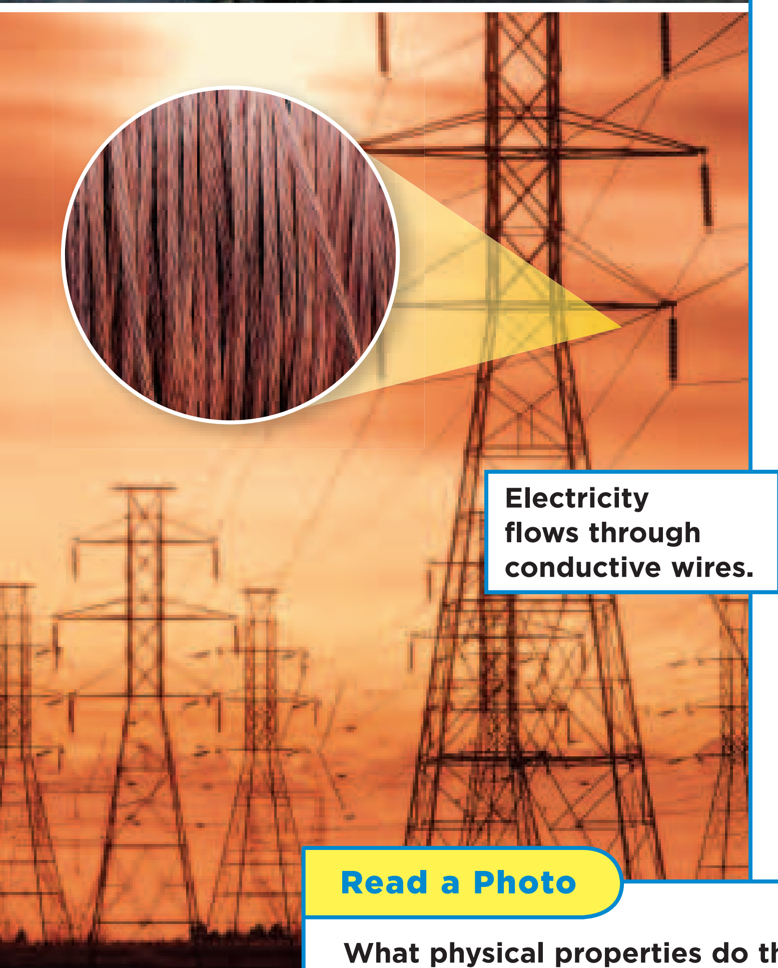
Quick Check

Infer How does density affect an object's ability to float?

Critical Thinking How can an object with little mass be denser than an object with more mass?

Physical Properties

Diamonds are used to cut through rock.



Electricity flows through conductive wires.

What are physical properties?

The **physical properties** of a substance are properties that can be observed without changing the identity of the substance. These properties help us tell substances apart. Density, color, hardness, odor, magnetism, boiling point, and texture are some physical properties.

Conductors and Insulators

Conductivity, the ability of a material to conduct heat and electricity, is also a physical property. The flow of heat and electricity in conductors is different from that in insulators. *Conductors*, including metals such as aluminum, copper, gold, and silver, allow both heat and electricity to flow easily. Copper is a very good conductor, and it is often used in electrical circuits and connections. Materials such as glass, rubber, and plastic are all *insulators*, which restrict the flow of heat and electricity.

Quick Check

Infer How has the production of new types of plastic helped encourage new inventions and innovations?

Critical Thinking Explain the types of protective materials people should wear if their jobs involve heat and electricity.

Read a Photo

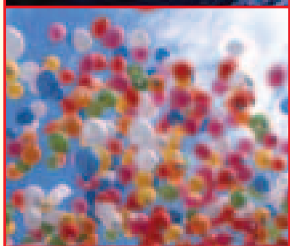
What physical properties do the objects shown here illustrate?

Clue: Look for properties that help identify the objects.

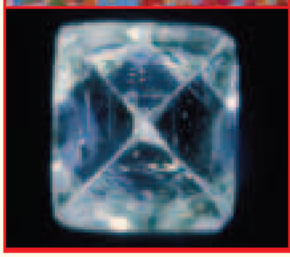
Lesson Review

Visual Summary

Matter can be measured by **mass**, **weight**, or **volume**.



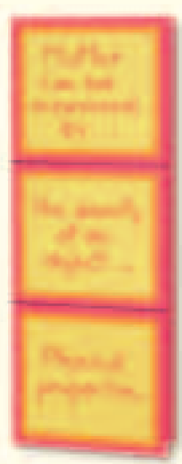
The **density** of an object measures how much mass can fit within a certain amount of space.



Physical properties such as density, hardness, odor, magnetism, and conductivity help us identify different substances.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add other details about physical properties.



Think, Talk, and Write

1. **Main Idea** Anything that has mass and volume is ________.
2. **Vocabulary** Density can be calculated using an object's ________ and ________.
3. **Infer** How does heating the air in a hot-air balloon enable it to float?

Clues	What I Know	What I Infer

4. **Critical Thinking** What kind of experiment could determine whether an object was made of pure gold?
5. **Test Prep** **Which of the following is NOT a physical property?**
   - **A** hardness
   - **B** strength
   - **C** density
   - **D** beauty
6. **Test Prep** **The ability of an object to float in a liquid or gas is called**
   - **A** weight.
   - **B** buoyancy.
   - **C** mass.
   - **D** volume.

Writing Link

Explanatory Writing

A submarine rises to the ocean's surface to take on passengers and then sinks back underwater. Explain how you think the submarine works.

Math Link

Measure Density

A 22 g piece of clay is placed in a graduated cylinder that contains water. The water level rises from 40 mL to 55 mL. What is the density of the clay?

Focus on Skills

Inquiry Skill: Measure

As you know, matter is the "stuff" that makes up all things. There are millions of different things in this world. How do scientists distinguish one thing from another? One way is to **measure** and compare the objects' common physical properties.

You can use water to find the volume of some objects.

Learn It

To **measure** is to find the size, distance, time, volume, area, mass, or temperature of an object. It is important to record measurements. If you use a chart to record information, you will be able to see your data at a glance.

Density is one physical property that can be measured. Density is the ratio of mass to volume. To find the density of an object, divide its mass by its volume. Mass can be measured in grams, and volume can be measured in cubic centimeters, so density can be stated in grams per cubic centimeter.

Try It

Of the objects listed in the chart on the next page, which do you think matches the "mystery matter" described in this box?

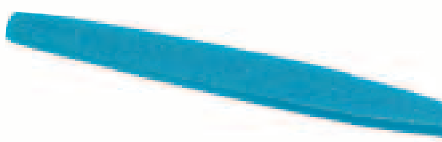
Mystery Matter
color: white
texture: smooth
density: 2.6 g/cm^3

Find out whether you are right. Here's how.

The displaced water equals the object's volume.

Materials **wooden block, sugar cube, golf ball, table-tennis ball, sheet of $8\frac{1}{2}$-by-11-inch paper, piece of chalk, plastic spoon, balance, gram weights, ruler, graduated cylinder, water, pencil**

1. Observe the color and texture of each object.
2. Record the information on a chart like the one shown on the next page.
3. **Measure** and record each object's mass in grams using the balance and a standard mass set.
4. Find the volume of regularly shaped rectangular objects using this formula: *volume* = *length* × *width* × *height*. Record the results on your chart.



5 Find the volume of the irregularly shaped objects. For each object, partially fill a graduated cylinder with water, and measure the volume. Put the object into the cylinder. If the object floats, use a pencil point to push it under the water. Measure the new volume. Then subtract the volume of the water alone from the volume of the water with the object in it. Record this as the object's volume on your chart.

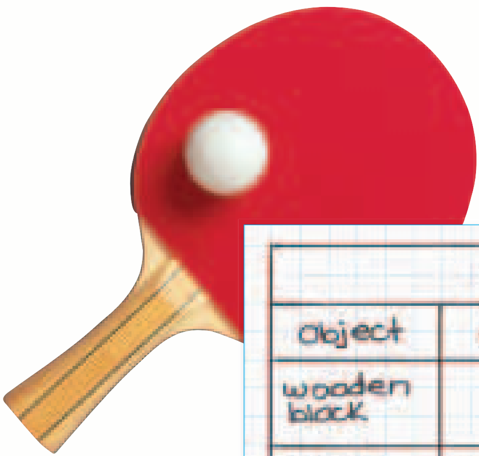
6 Calculate the density of each object by using this formula: *density = mass/ volume*. Record the data on your chart.

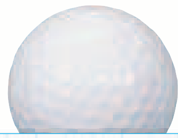
▶ Apply It

1 Now use the data from your chart to answer these questions. Which object had the lowest density? Which was the "mystery matter"? Will a smaller object always be lighter than a larger one?

2 Make a bar graph to display your density measurements. Draw a picture of each item, and then color in bars to compare at a glance the actual densities of the objects, from least to greatest density.

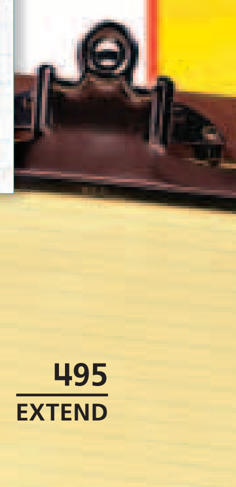
3 Choose some items from your classroom. Predict which of them will have the lowest density. **Measure** the mass and volume of each object, and then calculate its density. Was your prediction correct?

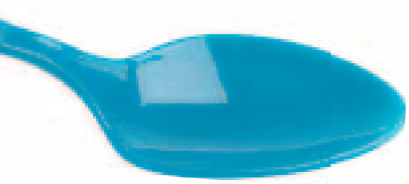


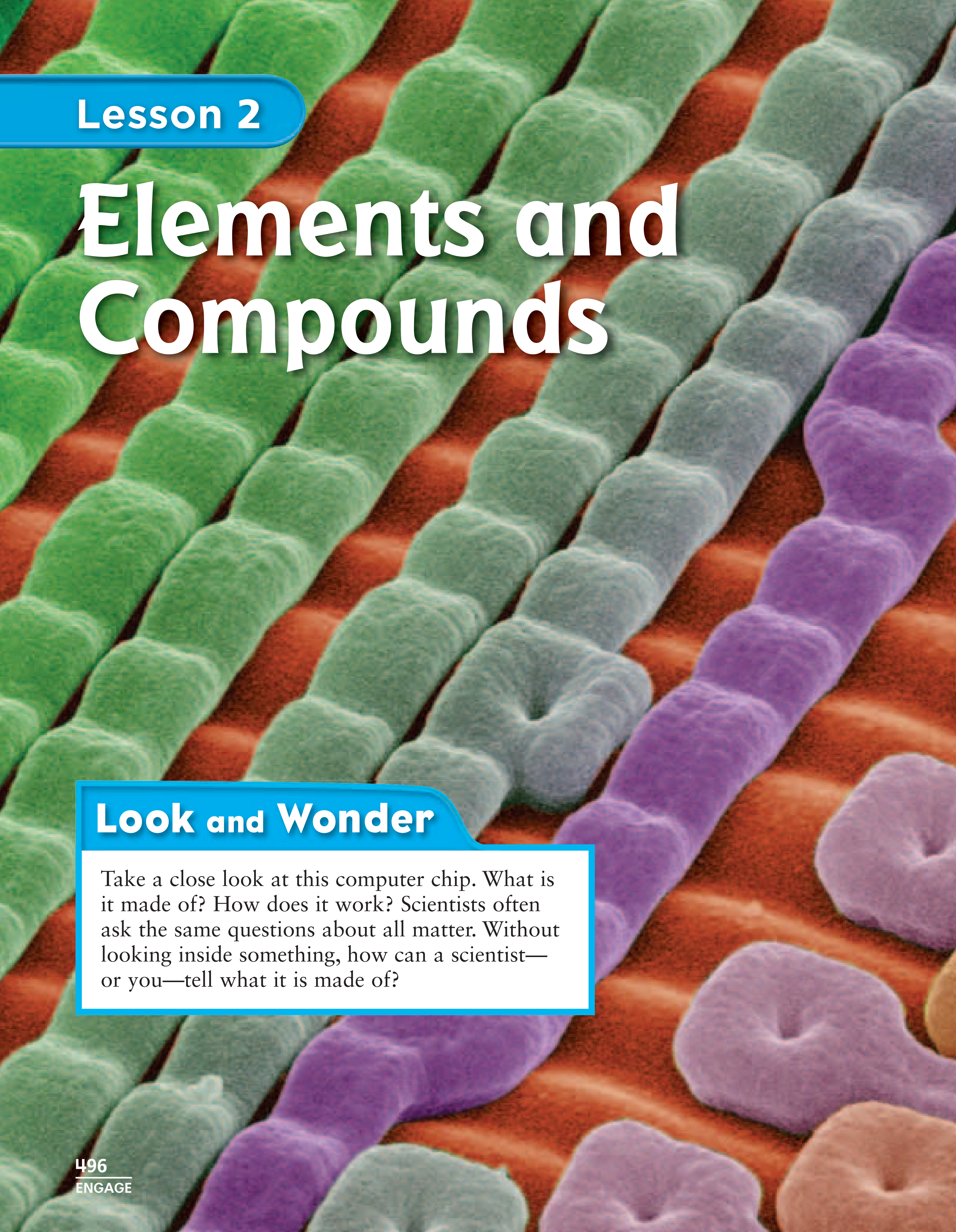


Physical Properties of Objects

Object	Color	Texture	Mass (g)	Volume (cm^3)	Density (g/cm^3)
wooden block					
sugar cube					
golf ball					
table-tennis ball					
sheet of 8½-by-11-inch paper					
piece of chalk					
plastic spoon					







Lesson 2

Elements and Compounds

Look and Wonder

Take a close look at this computer chip. What is it made of? How does it work? Scientists often ask the same questions about all matter. Without looking inside something, how can a scientist—or you—tell what it is made of?

Explore | **Inquiry Activity**

Can you always cut a substance in half?

Make a Prediction

Throughout history people have wondered what the smallest possible piece of a substance might be that still has all the qualities of that substance. For example, what is the smallest possible piece of gold that still has all the qualities of gold? In this case, you will predict how small or large the smallest possible piece of graph paper might be. Write your answer in the form "The smallest possible piece of graph paper that still has all the qualities of graph paper will be . . ."

Test Your Prediction

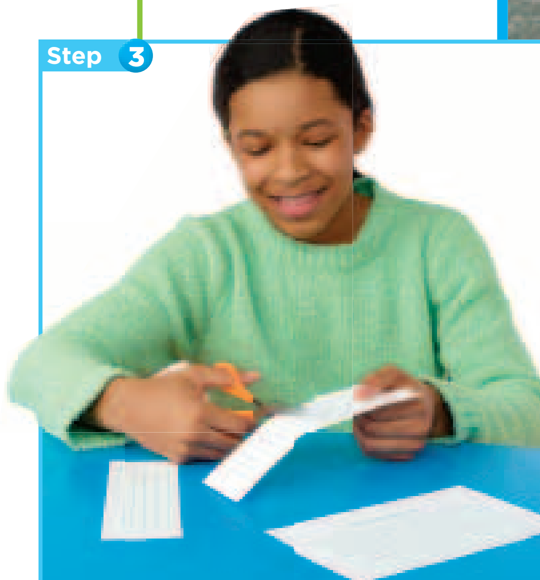
1. **Classify** What qualities distinguish graph paper from regular paper? In other words, what qualities must paper have in order to be considered graph paper?
2. **Measure** What is the measurement (length and width) of a single box on your sheet of graph paper?
3. **Observe** Cut your sheet of graph paper in half. ⚠ **Be Careful.** Can the paper still be considered graph paper? Explain.
4. **Experiment** Continue cutting the graph paper in half. Keep going until you think you have the smallest piece that can still be identified as graph paper. How big is the piece left after you have finished cutting?

Draw Conclusions

5. **Infer** Why did you stop cutting the paper at that size? State the reasons for the size at which you stopped cutting.

Materials

- sheet of graph paper
- scissors



Step 3

Explore More

Try this activity using a material other than graph paper. What difficulties will you have in representing the smallest possible piece of that material? What tools will you need in order to be successful?

Read and Learn

Main Idea

Atoms combine to make all the things that surround us.

Vocabulary

atom, p. 500
nucleus, p. 501
neutron, p. 501
proton, p. 501
atomic number, p. 501
electron, p. 501
periodic table, p. 502
molecule, p. 506

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Reading Skill

Classify

What is matter made of?

Everything around you is made of elements, or pure substances that cannot be broken down into any simpler substances. Elements can be solids, liquids, or gases. The "lead" in a pencil is actually composed of the element carbon. Water is composed of the elements hydrogen and oxygen. Have you heard people call water H_2O? H is the symbol for hydrogen, and O is the symbol for oxygen. The number 2 indicates that there are two hydrogen particles for each oxygen particle in water.

Every element has a symbol that is one or two letters long. Hydrogen (H) and oxygen (O) have one-letter symbols. Some elements have two-letter symbols. For example, the symbol for copper is Cu.

Elements usually do not exist by themselves. Most combine to form compounds. A compound is a substance formed from the chemical combination of two or more elements that then act as a unique substance. Water is a compound. When elements react with one another, the new combination has different properties than the elements of which it is made. For example, hydrogen and oxygen are gases.

Every drop of water is made of billions of oxygen and hydrogen atoms.

How We Use Elements						
gold Au	iron Fe	sulfur S	copper Cu	carbon C	aluminum Al	helium He

They combine to form water, which has properties that are quite different from those of either element.

Particles of Matter

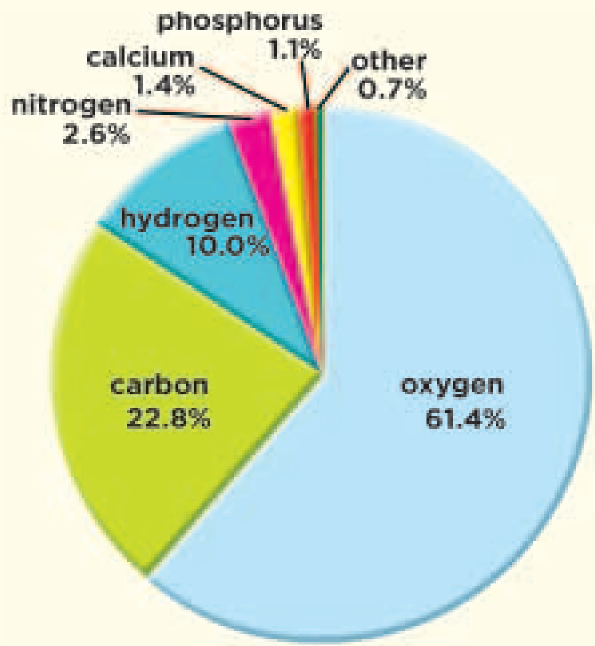
Aristotle, an ancient Greek philosopher, believed that all things on Earth were made of four "elements": air, earth, fire, and water. Later, scientists conducted experiments and found that Aristotle's "elements" were not really elements at all. The air that we breathe, for example, is made up of different elements, including nitrogen and oxygen. Since those early findings, scientists have discovered more than 100 elements.

Quick Check

Classify Why are only about 100 of the millions of known substances identified as elements?

Critical Thinking If a compound is made of two elements that are liquids, is it certain that the compound will also be a liquid?

Elements in the Human Body



Six elements—oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus—make up about 99 percent of the mass of the human body.

Read a Graph

How much more oxygen than hydrogen is there in a typical human body?

Clue: What are the percents given for oxygen and hydrogen?

What are atoms made of?

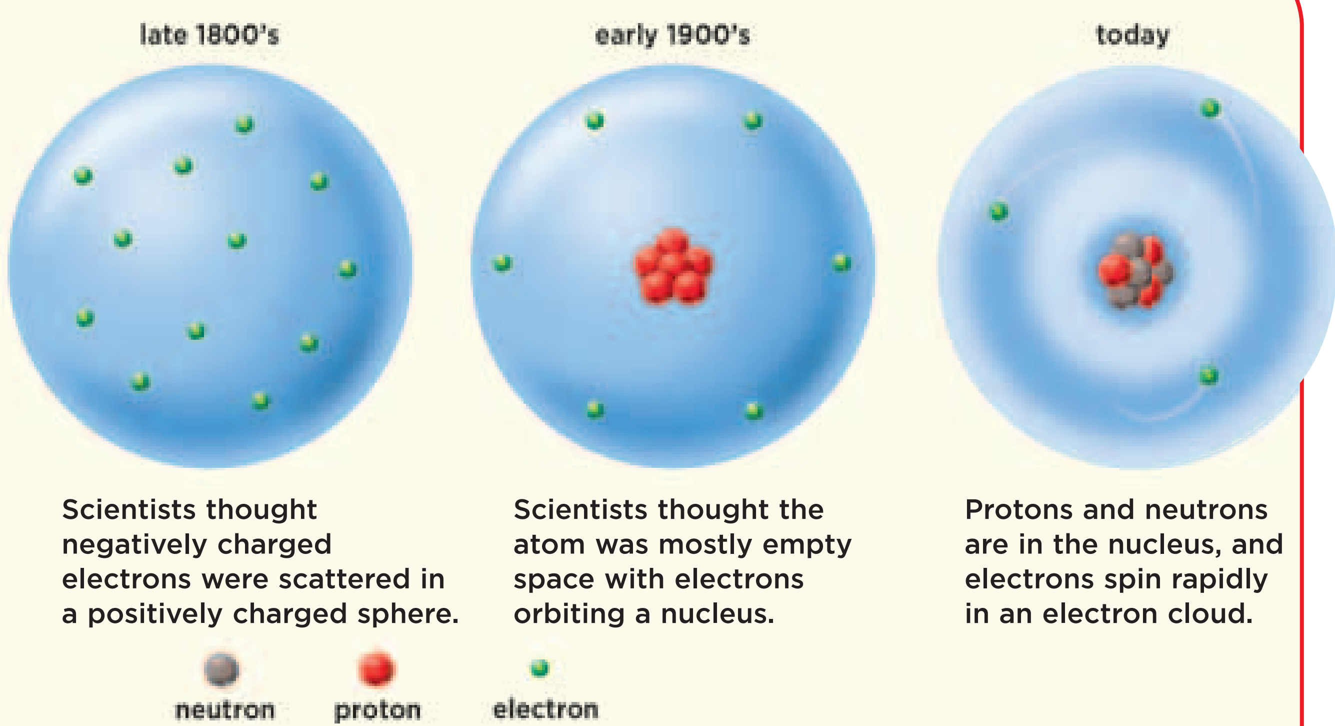
Did you know that your pencil "lead" and a diamond are both made of carbon? How do these forms of carbon differ? The way the atoms join together determines whether carbon forms graphite or diamonds. An **atom** is the smallest particle of an element that still has the same chemical properties of the element. The number and arrangement of atoms in an element determine its properties.

Atoms are tiny. Millions of atoms can fit in a space as small as the dot of this letter *i*. The ancient Greek philosopher Democritus believed that matter could be cut into smaller and smaller pieces only up to a certain point, which he called an atom. In the early 1800s, a teacher named John Dalton formulated the atomic theory. Dalton's experiments indicated that matter must be made of tiny particles (atoms) with spaces between them. We now have more evidence that supports and confirms this theory. The scanning tunneling microscope, developed in 1981, first enabled scientists to "see" single atoms of an element.

Exploring the Atom

Atoms are too small to see without a high-powered microscope. However, scientists have discovered many things about the structure of atoms. In the early 1900s, the British scientist Ernest Rutherford and his student assistant conducted experiments to study the atom. They fired helium atoms at gold foil and found that most of them went right through the gold. From this evidence Rutherford inferred that atoms were mostly empty space.

Models of Atoms over the Past 100 Years



Scientists thought negatively charged electrons were scattered in a positively charged sphere.

Scientists thought the atom was mostly empty space with electrons orbiting a nucleus.

Protons and neutrons are in the nucleus, and electrons spin rapidly in an electron cloud.

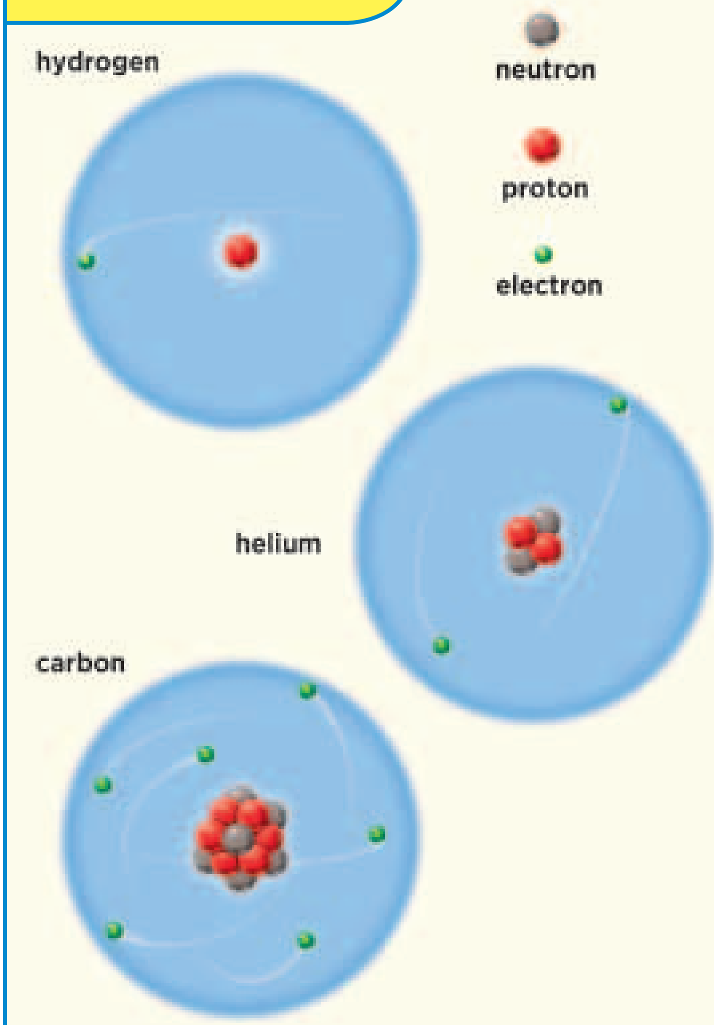
The researchers also noticed that a few of the atoms bounced back. Rutherford inferred that some of the small helium atoms had hit a tiny but dense part of the larger gold atom. He called this part the nucleus. The **nucleus** is at the center of an atom and contains most of its mass.

The nucleus contains two types of particles: neutrons and protons. Both kinds of particles have about the same mass. **Neutrons** have no electrical charge; they are neutral. **Protons** have a positive electrical charge. An element is identified by the number of protons contained in each of its atoms. Every element has a unique number of protons. The number of protons in an atom of an element is its **atomic number**.

The *atomic mass* of an element is the number of protons added to the number of neutrons. Atoms of the same element may have different numbers of neutrons. This changes the atomic mass. Atoms of the same element that have different atomic masses are called *isotopes*. An isotope's atomic mass is listed beside its name or symbol.

Atoms also contain **electrons**, which each have a very small mass and a negative electrical charge. The number of electrons in an atom does not change its atomic number. Electrons also are not counted in atomic mass, because they are so small that they add almost no mass. An electron's negative charge is attracted to a proton's positive charge. Electrons move around the nucleus. Atoms normally have the same number of electrons as protons. If there are more or fewer electrons than protons, an atom has an overall positive or negative charge and is called an *ion*.

The Composition of Atoms



Read a Diagram

Which element shown here has the highest atomic number?

Clue: Identify the number of protons in the nucleus of each atom.

Quick Check

Classify How are the atomic number and the atomic mass of an element calculated?

Critical Thinking Which particles in an atom can increase or decrease in number without changing the identity of the element?

What is the periodic table?

As scientists discovered more elements, they tried to organize them. In 1869, Russian scientist Dmitri Mendeleev originally arranged the elements in the order of their atomic masses. He noticed that elements with certain properties aligned in repeating patterns. These properties included an element's metallic character and the way in which it reacted with other elements. Mendeleev used the patterns to correctly predict the properties of some elements that had not yet been discovered.

Later, scientists arranged the elements by atomic number rather than atomic mass. All the elements fit exactly into the repeating patterns.

The **periodic table** is a chart that shows the elements in order of increasing atomic number. The word *periodic* refers to a repeating pattern. The periodic table is arranged in vertical columns, called groups or families, and horizontal rows, called periods. The elements in the columns have similar chemical properties.

Periodic Table

Sodium — element name
Na — element symbol
11 — atomic number

metal
nonmetal
metalloid
artificial

state at room temperature (20°C):
black: solid
red: liquid
orange: gas

1	2	3	4	5	6	7	8	9	10	11	12
Hydrogen H 1											
Lithium Li 3	Beryllium Be 4										
Sodium Na 11	Magnesium Mg 12										
Potassium K 19	Calcium Ca 20	Scandium Sc 21	Titanium Ti 22	Vandium V 23	Chromium Cr 24	Manganese Mn 25	Iron Fe 26	Cobalt Co 27	Nickel Ni 28	Copper Cu 29	Zinc Zn 30
Rubidium Rb 37	Strontium Sr 38	Yttrium Y 39	Zirconium Zr 40	Niobium Nb 41	Molybdenum Mo 42	Technetium Tc 43	Ruthenium Ru 44	Rhodium Rh 45	Palladium Pd 46	Silver Ag 47	Cadmium Cd 48
Cesium Cs 55	Barium Ba 56	Lanthanum La 57	Hafnium Hf 72	Tantalum Ta 73	Tungsten W 74	Rhenium Re 75	Osmium Os 76	Iridium Ir 77	Platinum Pt 78	Gold Au 79	Mercury Hg 80
Francium Fr 87	Radium Ra 88	Actinium Ac 89	Rutherfordium Rf 104	Dubnium Db 105	Seaborgium Sg 106	Bohrium Bh 107	Hassium Hs 108	Meitnerium Mt 109	Darmstadtium Ds 110	Roentgenium Rg 111	Ununbium Uub 112
				Cerium Ce 58	Praseodymium Pr 59	Neodymium Nd 60	Promethium Pm 61	Samarium Sm 62	Europium Eu 63	Gadolinium Gd 64	Terbium Tb 65
				Thorium Th 90	Protactinium Pa 91	Uranium U 92	Neptunium Np 93	Plutonium Pu 94	Americum Am 95	Curium Cm 96	Berkelium Bk 97

Elements belong to one of three groups—metals, nonmetals, and metalloids—according to their properties. *Metals* conduct heat and electricity, become shiny when polished, melt at high temperatures, and can be easily reshaped. *Nonmetals* have a dull surface, melt at lower temperatures, and tend to break when bent. *Metalloids* have some properties of metals and some of nonmetals. For example, metalloids can be shiny or dull. They usually conduct heat and electricity better than nonmetals but not as well as metals.

13	14	15	16	17	18
					Helium He 2
Boron B 5	Carbon C 6	Nitrogen N 7	Oxygen O 8	Fluorine F 9	Neon Ne 10
Aluminum Al 13	Silicon Si 14	Phosphorus P 15	Sulphur S 16	Chlorine Cl 17	Argon Ar 18
Gallium Ga 31	Germanium Ge 32	Arsenic As 33	Selenium Se 34	Bromine Br 35	Krypton Kr 36
Indium In 49	Tin Sn 50	Antimony Sb 51	Tellurium Te 52	Iodine I 53	Xenon Xe 54
Thallium Tl 81	Lead Pb 82	Bismuth Bi 83	Polonium Po 84	Astatine At 85	Radon Rn 86
Dysprosium Dy 66	Holmium Ho 67	Erbium Er 68	Thulium Tm 69	Ytterbium Yb 70	Lutetium Lu 71
Californium Cf 98	Einsteinium Es 99	Fermium Fm 100	Mendelevium Md 101	Nobelium No 102	Lawrencium Lr 103

Quick Lab

Classifying Elements

1. **Classify** How could you classify elements into groups? What characteristics would you compare and contrast?

2. **Observe** Look at samples of iron, copper, carbon, and aluminum. Use a hand lens to look closely at each sample. Note any similarities and differences.
3. **Experiment** Rub each sample with sandpaper. How does this help you tell how the samples differ?
4. **Classify** How could you classify these four elements into groups? Record, compare, and contrast their characteristics.
5. **Draw Conclusions** Which of the four samples is most different from the others? Explain your reasoning.

Quick Check

Classify How are the elements arranged in the periodic table?

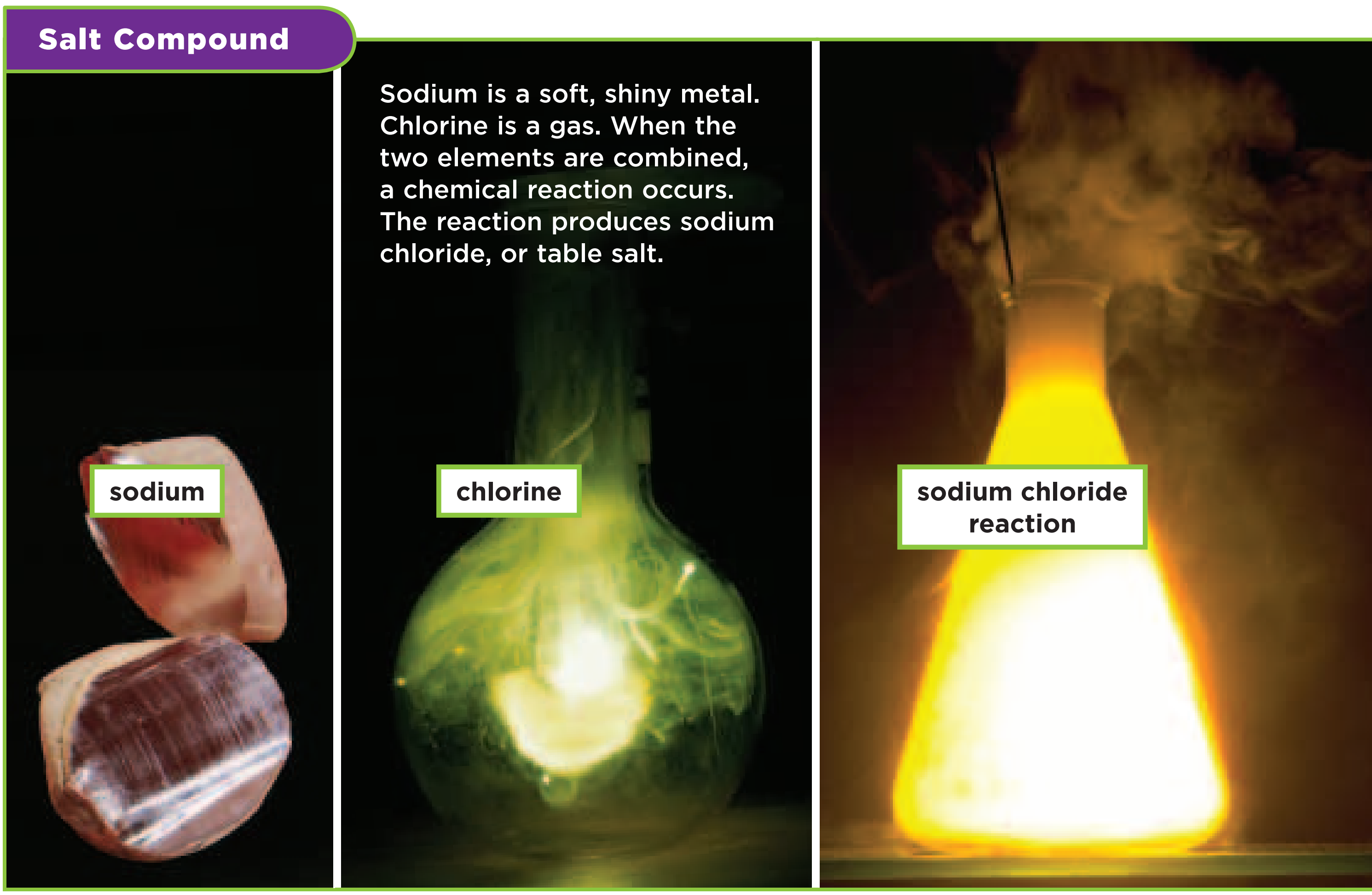
Critical Thinking How could you test a piece of an unknown solid to determine whether it was a metal, a nonmetal, or a metalloid?

What are compounds?

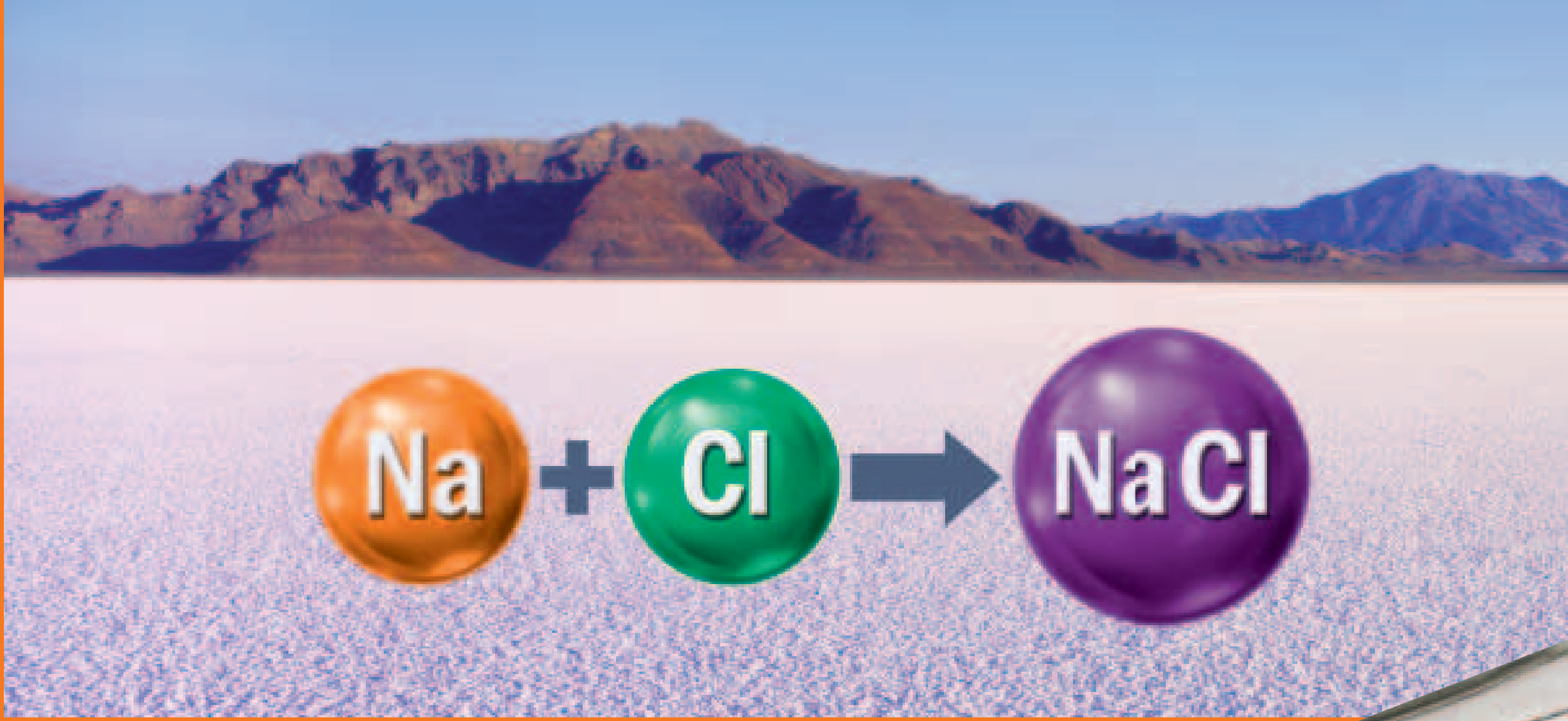
Few elements exist by themselves. Most elements are found as combinations of one or more elements. These groups of elements combine to form compounds. For example, the shells of birds' eggs are made of a compound containing the elements calcium (Ca), carbon (C), and oxygen (O). Citric acid, which is found in oranges, lemons, and other citrus fruits, is a compound made up of the elements carbon (C), hydrogen (H), and oxygen (O).

One common compound that people around the world use every day is table salt. This compound is composed of the elements sodium (Na) and chlorine (Cl). The properties of table salt are quite different from the properties of the elements that are part of it. Sodium is a soft, silvery, and highly reactive metal. Chlorine is a poisonous green gas. When these two elements combine, they form sodium chloride, which is a white, brittle, crystalline solid. Sodium chloride is the table salt often used to flavor food.

Salt Compound



Sodium is a soft, shiny metal. Chlorine is a gas. When the two elements are combined, a chemical reaction occurs. The reaction produces sodium chloride, or table salt.



▲ Table salt is a compound (NaCl) made of sodium (Na) and chlorine (Cl).

Chemical Formulas

A *chemical formula* is a simple way to indicate the composition of elements in a compound. It shows the number and types of atoms in a compound. Formulas help scientists categorize and label chemicals. For example, the chemical formula for sodium chloride is written as NaCl. This means that it is a compound made from sodium (Na) and chlorine (Cl). This formula also states that for every sodium atom there is one chlorine atom. The two elements exist in a 1-to-1 ratio.

Another common chemical formula is CO_2. This is the formula for carbon dioxide. Carbon dioxide is composed of carbon (C) and oxygen (O) atoms. However, there are two oxygen atoms for every carbon atom. That is why the number 2 is written after the O representing oxygen.

Quick Check

Classify Of carbon dioxide, hydrogen oxide (water), and sodium chloride (table salt), which has a 1-to-1 ratio of atoms?

Critical Thinking How many atoms are in the formula for the compound glucose ($C_6H_{12}O_6$)?

table salt

What are molecules?

When two or more atoms join together and share electrons, they can form a molecule. A **molecule** is the smallest particle of a compound that still has all the qualities of that compound. The atoms of a molecule are so tightly bonded that they act like a single particle.

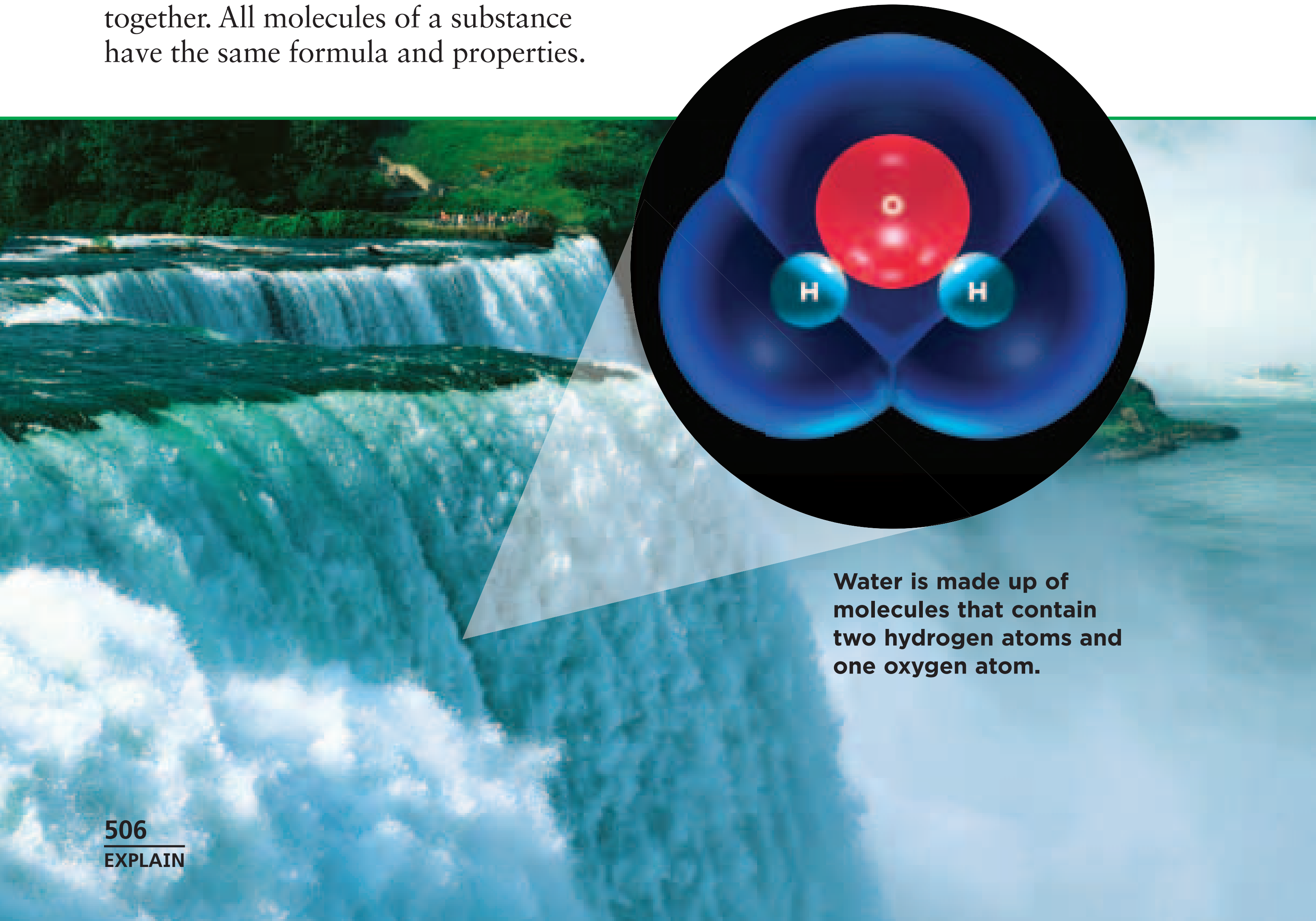
Some molecules are composed of atoms of the same nonmetallic element. For example, hydrogen gas exists as H_2 molecules, which are each two hydrogen atoms joined together. Other molecules are made up of the atoms of two or more nonmetallic elements. Water is a compound written as H_2O. In water molecules, oxygen shares its electrons with hydrogen, and this joins the atoms together. All molecules of a substance have the same formula and properties.

Some compounds are not made of molecules. Instead, they are collections of atoms that are held together by their opposite charges. An example of a compound held together in this way is sodium chloride (NaCl). In this substance, sodium and chlorine atoms cluster together.

Quick Check

Classify Name one substance that is made up of molecules and one that is not.

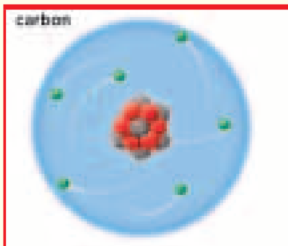
Critical Thinking Potassium (K) is in the same family as sodium (Na). What would be the formula if potassium combined with chlorine?



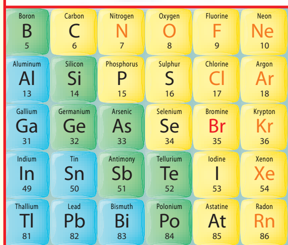
Water is made up of molecules that contain two hydrogen atoms and one oxygen atom.

Lesson Review

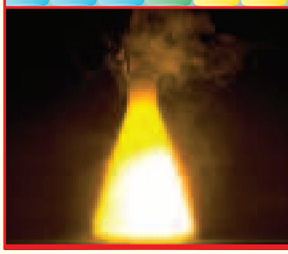
Visual Summary



Matter can be broken down into **molecules**, elements, and **atoms**.



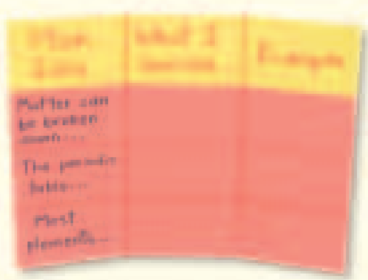
The **periodic table** organizes elements by physical properties and number of **protons**.



Most elements combine to form compounds and **molecules**.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the phrases showing what you learned, and include examples.



Think, Talk, and Write

1. **Main Idea** Atoms can combine to make ________.
2. **Vocabulary** The number of protons in an atom's nucleus is the same as its ________.
3. **Classify** The element indium has the symbol In. Based on its placement on the periodic table, what properties do you expect it to have?
4. **Critical Thinking** The ingredients listed on a cookie box tell what was used to make the cookies. Why might it still be difficult to make the cookies yourself?
5. **Test Prep** **According to the periodic table, which of the following elements has the LEAST atomic mass?**
   A oxygen (O)
   B carbon (C)
   C nitrogen (N)
   D helium (He)
6. **Test Prep** **Which of the following has a negative charge?**
   A a proton
   B an electron
   C a neutron
   D sodium

Writing Link

Explanatory Writing

Write a brief paragraph about how the periodic table organizes elements. In your paragraph, explain why elements are listed in particular places.

Art Link

Draw Compounds

Research carbon monoxide and carbon dioxide. Make a drawing of each to show the difference between the two molecules.

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A WORLD WITHOUT PLASTIC

Fictional Narrative

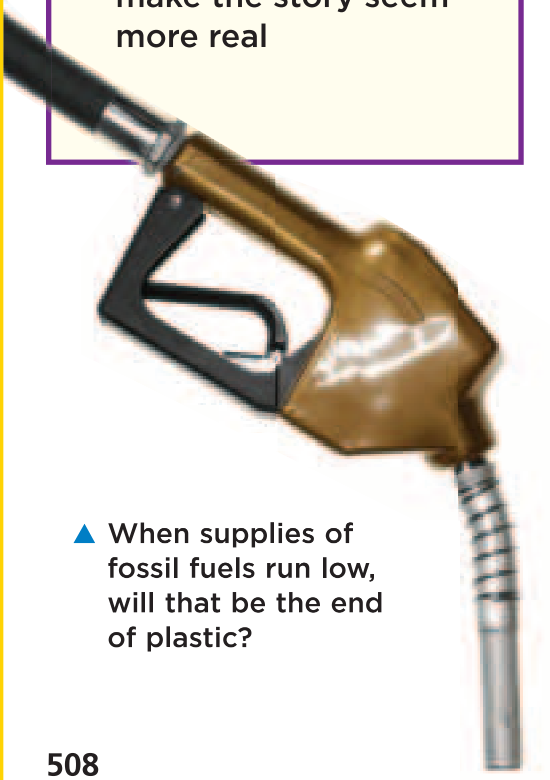
A good story, or fictional narrative,

- describes a setting, telling when and where the story takes place
- has characters that move the action along
- has a plot with a problem that is solved at the end
- uses dialogue to make the story seem more real

Plastic is usually made from petroleum, a fossil fuel. Someday our supply of petroleum will run low. Then perhaps we will not have plastic in our lives anymore. What would life be like without plastic?

With no plastic, all bottles for food and medicine might have to be made of glass, which is dangerous when it breaks. Your clothes would have to be made from cotton, wool, or other natural fibers. Having no synthetic fibers made from plastic would mean more expensive clothes that might be harder to care for or that some people might be allergic to. Foods would no longer be sealed in plastic to keep them fresh and clean. Paper and cloth bags would replace plastic bags.

Our world would be very different without plastic. We need to conserve petroleum and other fossil fuels. These fuels are nonrenewable resources. When they are gone, we will not be able to replace them.



▲ When supplies of fossil fuels run low, will that be the end of plastic?

Write About It

Fictional Narrative Write a science-fiction story about a future time when a substance we use now, such as plastic, is scarce. Describe the setting and the way the main character in your story tries to solve the problem. You can use the information from "A World Without Plastic" as well as information you find online. Use an appropriate point of view, and include dialogue to help your story come alive.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Math in Science

Changing the Density of Water

If you went swimming in the Dead Sea in the Middle East, you would float very easily. This is because the water there contains much more salt than any of the world's oceans. This high level of salt means that the water has a much greater density than fresh water. If you add salt to water, you are adding mass. However, doing this does not change the volume, because the salt dissolves in the water. Study the equation for finding density:

density (g/mL) = mass (g) ÷ volume (mL)

Use this equation to understand how the density of a glass of water changes as salt is dissolved in it.

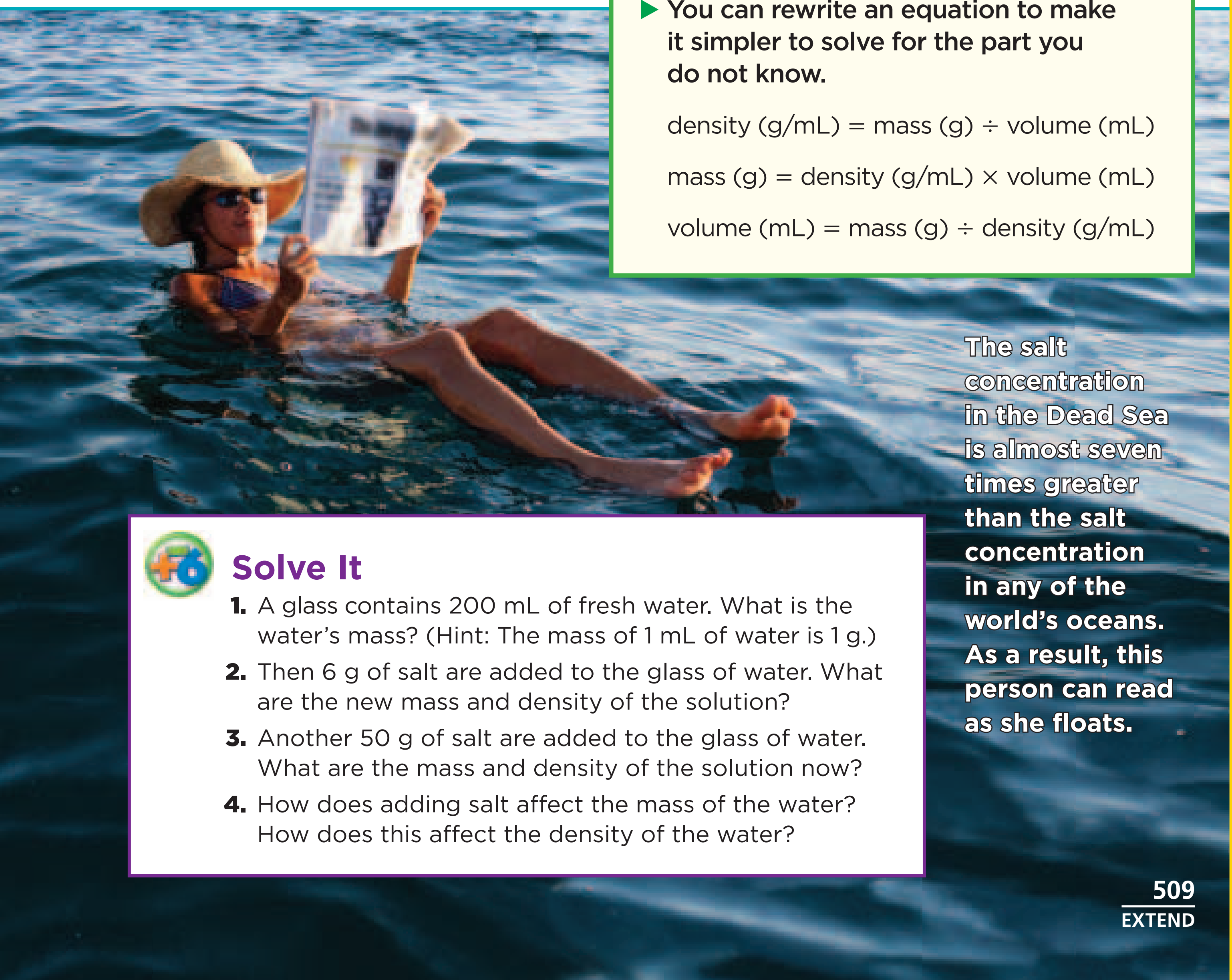
Rewrite the Equation

- **Remember, the density of fresh water is 1 g/mL. Before you add any salt, put this number and the volume given into the equation to find the water's mass.**
- **You can rewrite an equation to make it simpler to solve for the part you do not know.**

density (g/mL) = mass (g) ÷ volume (mL)

mass (g) = density (g/mL) × volume (mL)

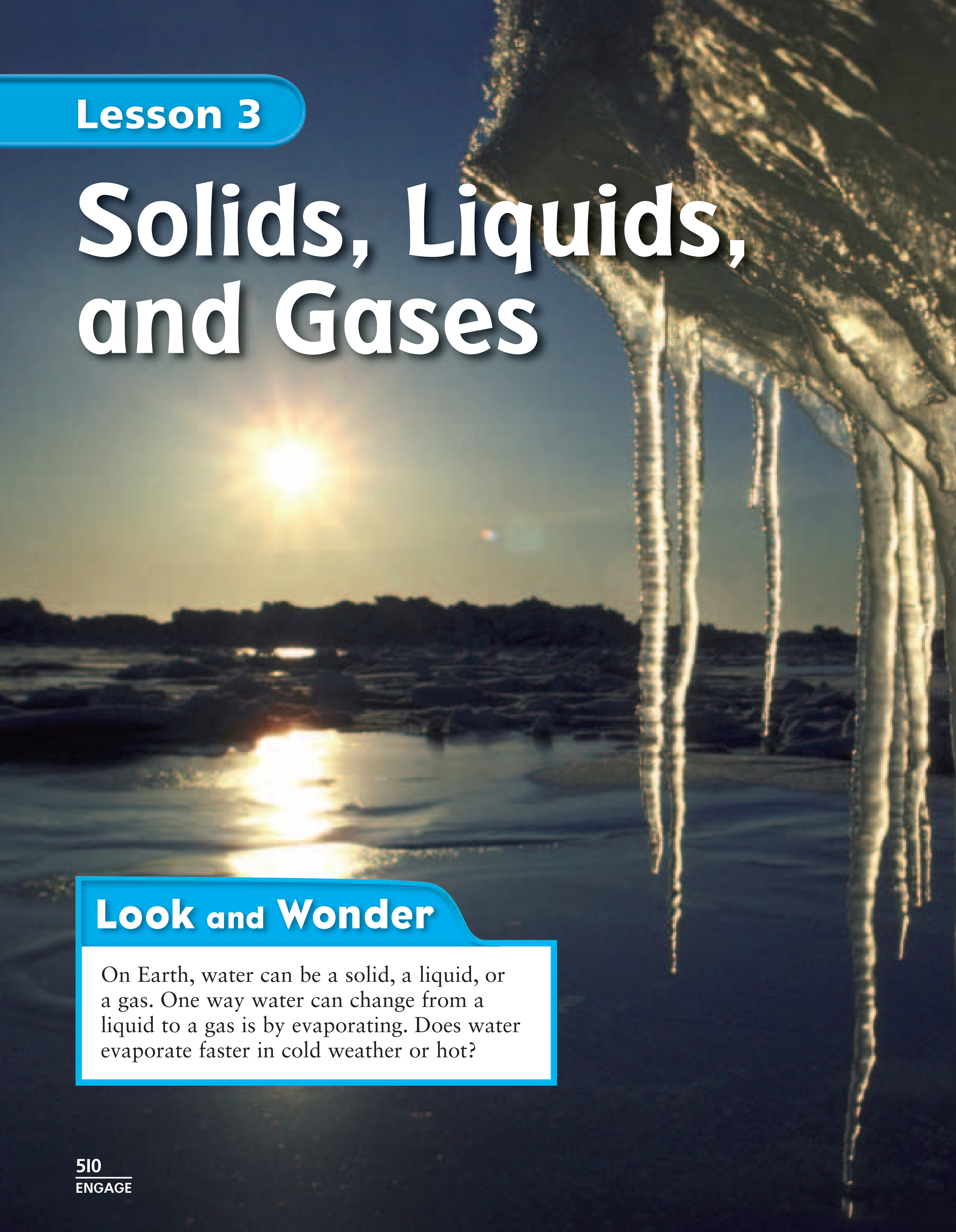
volume (mL) = mass (g) ÷ density (g/mL)



The salt concentration in the Dead Sea is almost seven times greater than the salt concentration in any of the world's oceans. As a result, this person can read as she floats.

Solve It

1. A glass contains 200 mL of fresh water. What is the water's mass? (Hint: The mass of 1 mL of water is 1 g.)
2. Then 6 g of salt are added to the glass of water. What are the new mass and density of the solution?
3. Another 50 g of salt are added to the glass of water. What are the mass and density of the solution now?
4. How does adding salt affect the mass of the water? How does this affect the density of the water?



Lesson 3

Solids, Liquids, and Gases

Look and Wonder

On Earth, water can be a solid, a liquid, or a gas. One way water can change from a liquid to a gas is by evaporating. Does water evaporate faster in cold weather or hot?

Explore

Inquiry Activity

Does temperature affect the rate at which water evaporates?

Form a Hypothesis

Will water evaporate at a different rate if the temperature of the water is changed? Write your answer in the form of a hypothesis: "If the same amount of water is used, then a higher temperature will cause the evaporation of water to . . ."

Test Your Hypothesis

1. **Measure** Using the graduated cylinder, pour 20 mL of water into each of the beakers. Place one beaker under the heat lamp and the other nearby but away from the heat.
2. **Predict** Which water sample do you think will evaporate first? Explain.
3. **Experiment** Check the beakers every 30 minutes. Indicate the total amount of time it took for the water to evaporate from the beakers.
4. **Use Numbers** What is the rate of evaporation for the water in each beaker?

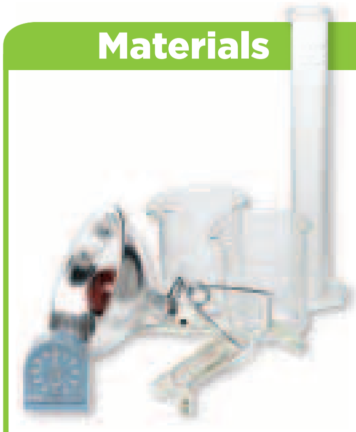
Draw Conclusions

5. **Interpret Data** Compare the data collected for the two beakers. Did your observations support your hypothesis? Does temperature affect the rate of evaporation? Explain.

Explore More

Do some substances evaporate faster or slower than others? What might happen if you used a substance other than water in this same experiment? Make a prediction, and test it. Then present your results to the class.

Materials



- graduated cylinder
- water
- 2 beakers
- heat lamp
- timer or clock

Step 1

Step 3

Read and Learn

Main Idea
Heat and pressure affect the properties of matter.

Vocabulary
temperature, p. 512
sublimation, p. 513
melting point, p. 514
freezing point, p. 514
boiling point, p. 515
vaporization, p. 515
pressure, p. 516
physical change, p. 518

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Reading Skill
Sequence

First → Next → Last

Technology
SCIENCE QUEST

Explore the power of convection currents with a chef.

Molten silver takes the shape of the mold in which it cools and hardens.

How does heat affect the state of matter?

Most matter can be a solid, a liquid, or a gas, depending on its temperature. **Temperature** is a measurement of how hot or cold something is. It is a measure of the average amount of kinetic energy of the atoms and molecules in a material.

Changing the state of matter involves energy changes. When a substance changes from a solid to a liquid to a gas, it absorbs energy. The additional energy causes the particles to move faster and, thus, farther apart. When faster-moving particles collide with one another, they bounce away farther.

When clothes dry, liquid water evaporates into water vapor, a gas. Energy is required for that evaporation to take place. The energy is absorbed by the liquid water.

◀ A foglike vapor spills off a beaker of dry ice.

An example of evaporation is what occurs when you perspire. Energy is required for the perspiration to evaporate. The energy that is used comes from the heat energy in your skin, leaving you cooler as a result.

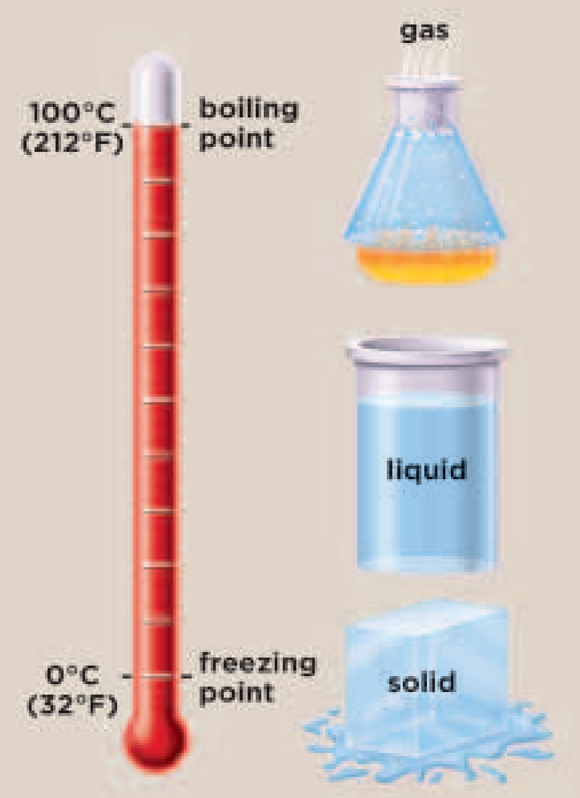
During evaporation, the water molecules absorb energy. The molecules move faster and farther apart and escape from the liquid. In contrast, when water vapor condenses into liquid water, energy is released. When energy is removed, the molecules slow down and move closer together to become liquid again.

Changes of State

The state of matter can change in other ways. **Sublimation** occurs when a substance changes directly from a solid to a gas without going through a liquid state. Ice cubes left in your freezer for a long period of time will become smaller. Eventually, the ice cubes will "disappear." This is because the ice cubes' water molecules change directly from the solid state (ice) to the gaseous state (water vapor).

Most matter on Earth exists as a solid, a liquid, or a gas. However, matter can also reach another state that has even more energy. The Sun and other stars contain elements that exist in a fourth state known as plasma. Plasma is a state of matter with so much energy that some or even all of the electrons have separated from the nuclei of most atoms. Plasma is rare on Earth, because it requires such a high temperature.

Changes of State



Read a Diagram

Describe the changes of state for water from 0°C (32°F) to 100°C (212°F).

Clue: Look at the marks on the thermometer.

LOG ON *Science in Motion* Watch changes of state at www.macmillanmh.com

Quick Check

Sequence Contrast the structures and speeds of water molecules when water is a solid, a liquid, and a gas.

Critical Thinking What will happen to a sealed balloon that contains dry ice if the balloon is left at room temperature?

FACT Dry ice, which is solid carbon dioxide, changes directly from a solid to a gas at room temperature.

What is a melting point?

Suppose you see a pile of table salt and a pile of sugar. How can you determine which pile is which without tasting them? One way is to know the temperatures at which the crystals melt. *Melting* is the process by which a solid changes to a liquid.

A solid that is a pure substance has a characteristic **melting point**, the temperature at which the solid melts to become a liquid. The melting point of sugar (sucrose) is 186°C (295°F), and the melting point of table salt is 801°C (1,474°F). Knowing the temperatures at which the crystals of the two substances melt can help you identify which substance is table salt and which is sugar.

States of Matter (in degrees Celsius)

Substance	State at 20°C	Melting Point	Boiling Point
ammonia	gas	-77.7	-33.4
chlorine	gas	-103	-34.6
carbon (diamond)	solid	3,550	4,827
mercury	liquid	-38.9	356

When a gas changes to a liquid, we say the particles have condensed. *Condensation* is the changing of a gas to a liquid as heat is removed and the particles lose energy. Liquids also have a characteristic temperature at which they change to solids, or *freeze*. The temperature at which a liquid freezes is its **freezing point**. A substance's melting point and freezing point are the same temperature.

Water Changing State

Water is not like most substances when it freezes. Liquids usually shrink and take up a smaller volume when they freeze. However, water expands when it changes to a solid. Water molecules bond in a kind of crystal arrangement that causes the molecules to take up more room when water is a solid than they do when water is a liquid.

The melting point of steel varies, but iron melts at 1,535°C (2,795°F).

Boiling Point and Evaporation

If a liquid continues to be heated, its molecules continue to move apart as they gain more energy. Soon, bubbles of vapor form within the liquid. The bubbles are the gaseous form of the substance. The temperature at which a liquid becomes a gas is its **boiling point**. Boiling occurs when a liquid reaches a temperature at which bubbles of gas form rapidly throughout the liquid. Once a liquid starts to boil, the temperature remains constant until all of the liquid has been converted to a gas.

Vaporization is the process by which a liquid changes to a gas. Reaching the boiling point of a liquid causes vaporization to occur. Evaporation happens on the surface of a liquid at any temperature below the liquid's boiling point. During evaporation, some molecules at the surface have enough energy to escape.

Quick Lab

Molecular Movement

1. **Predict** Does temperature affect the movement of molecules?
2. **Measure** Label one beaker *W* and the other *C*. Fill beaker W with very warm water. Fill beaker C with the same amount of very cold water. Place the beakers near each other.
3. **Experiment** At exactly the same time, place one large drop of food coloring into each beaker. Watch carefully, and take notes on what you observe in each beaker.
4. **Record Data** Did the food coloring look the same in each beaker? What was different?
5. **Interpret Data** What caused the differences? Would molecular movement explain your observations?
6. **Infer** Explain how temperature and its relation to the movement of molecules applies to cooking.

Quick Check

Sequence What does a solid turn into when enough heat is added?

Critical Thinking Would water evaporate faster in a wide glass than in a narrower glass?

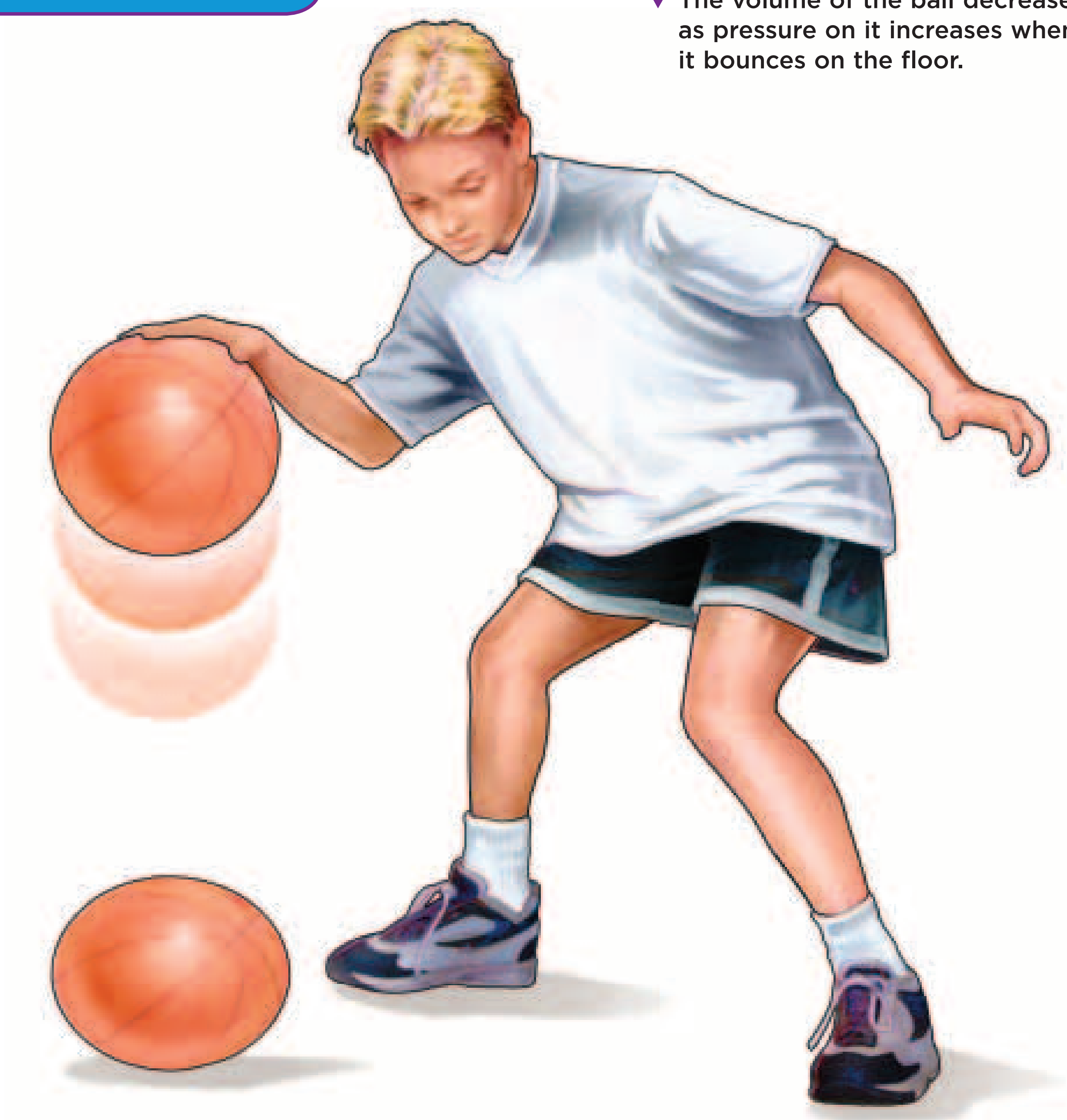
What is pressure?

How does a balloon retain its shape? The gas particles inside the balloon move around rapidly and hit the inner surface of the balloon. These "hits" produce **pressure**, which is the force exerted by the gas. Have you ever tried to squeeze an inflated balloon? You may have noticed that the harder you push it, the harder the balloon seems to push back.

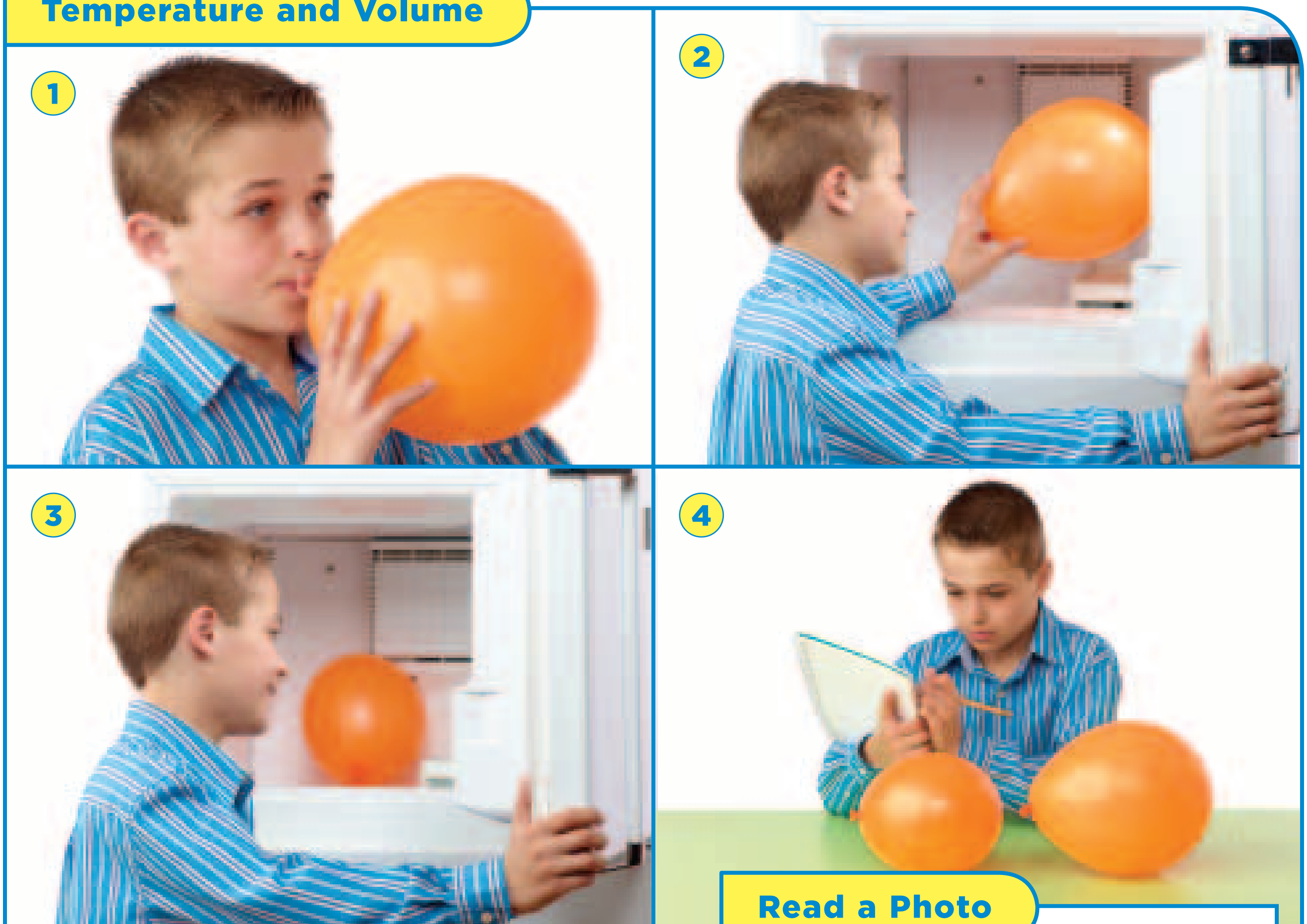
Increasing pressure on a gas decreases its volume. If you push down on a balloon, its volume decreases. The particles inside are crowded into a smaller space, so they hit the balloon's inner surface more frequently. This movement increases the pressure, and this causes the balloon to push back more as you press down on it.

Pressure and Volume

▼ The volume of the ball decreases as pressure on it increases when it bounces on the floor.



Temperature and Volume



Read a Photo

What happened to the air inside the balloon that was in the freezer?

Clue: Compare the sizes of the two balloons.

Temperature and Volume

If you put a balloon into very cold water, it shrinks. The number of air molecules inside the balloon has not changed. Temperature has caused the volume of the gas inside the balloon to change. Because the balloon is now much colder, the molecules move more slowly. The spaces between the molecules decrease, and the air inside the balloon has a smaller volume.

Gases contract when they cool and expand when they heat. As the temperature of a sample of gas at constant pressure increases, the volume increases. As the temperature decreases, the volume decreases.

Quick Check

Sequence What factors can cause the pressure of a gas to change?

Critical Thinking A tightly inflated balloon pops when brought outside on a hot day. What can you infer about the temperature at which the balloon was originally filled? What made the balloon pop?

What are other physical changes of matter?

A substance can change without becoming a different substance. For example, a piece of paper that is cut in half is still paper. If you mold a piece of clay into a different shape, it continues to be clay. Altering the size, shape, or state of a substance without forming a new substance is a **physical change**. Physical changes mean that substances have not linked together chemically.

Physical Changes

Does putting sugar into water cause a physical change to occur? Does freezing water cause a physical change to occur? One way to determine whether a physical change occurred is to test whether the original substances can be brought back to their original state using physical means.

With a mixture of sugar and water, you could evaporate the water and collect the vapor. The sugar would be left behind in the original container. If you froze water, it would become ice. Then you could melt the ice and have the water you started with. In each case, the change that occurred could be reversed using physical methods. Mixing sugar with water and freezing water are both physical changes.

When sugar is mixed with water, the sugar dissolves in the water. *Dissolving* is the process that occurs when the molecules of a solid move apart and are separated by the molecules of a liquid. Heat usually speeds up this process. Heat causes the different molecules to move around faster, so they mix more rapidly.

▲ Dissolving matter and changing the shape of a substance are both physical changes that do not alter the chemical properties of matter.

Quick Check

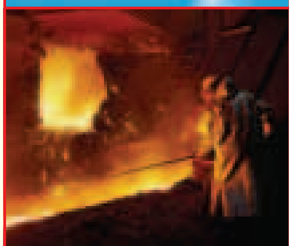
Sequence What happens to the process of dissolving if heat is decreased?

Critical Thinking Explain why baking cookie dough is or is not a physical change.

Lesson Review

Visual Summary

Matter can exist as a **solid**, a **liquid**, or a **gas**, depending on temperature.



Melting points and **boiling points** can help identify unknown substances.

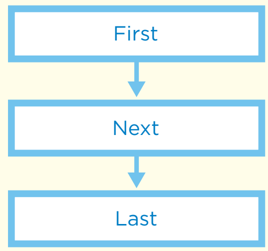
The **volume** of a gas is affected by temperature and pressure.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the phrase, and provide additional details.

Think, Talk, and Write

1. **Main Idea** How do heating and cooling change the state of matter?
2. **Vocabulary** The force exerted by a gas is ________.
3. **Sequence** When a liquid forms gas bubbles below its surface, the liquid has reached its ________.



4. **Critical Thinking** A balloon is brought outside. It quickly shrinks by 15 percent. Is the temperature outside warmer or cooler than the temperature inside?
5. **Test Prep** **Heat energy is absorbed during which of these changes of state?**
   A liquid to solid
   B solid to gas
   C gas to liquid
   D gas to solid
6. **Test Prep** **The change of state from gas to liquid is called**
   A condensation.
   B melting.
   C pressure.
   D boiling.

Writing Link

Explanatory Writing

Design an experiment to investigate the effect of salt or sugar on the rate at which water melts and boils. Write out a hypothesis and steps. Share it with your teacher for comments.

Health Link

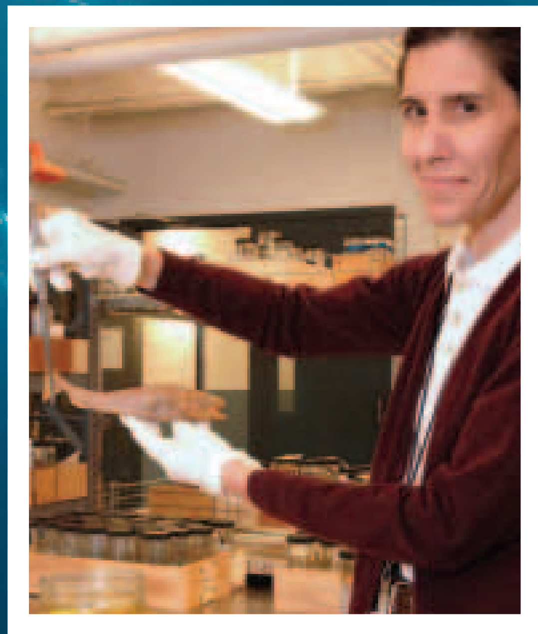
Diving and Pressure

As divers come back to the surface of a deep body of water, the pressure on their bodies decreases. Research why divers must return to the surface gradually when coming back from great depths.

Meet Adriana Aquino

Water covers about two thirds of Earth's surface, and fish live in almost every area of it. In tropical seas where coral reefs are found, the water is warm. In oceans near the poles, the water is below freezing. How do fish survive in these different conditions?

Adriana Aquino is a scientist at the American Museum of Natural History. She studies several fish species from around the world. The fish she studies are from many different environments. Adriana specializes in their body structure and form. Some of the fish she is interested in have developed amazing adaptations in their circulatory systems that allow them to live in these different environments.



▲ Adriana is an ichthyologist. (That's a scientist who studies fish.)

One of these adaptations allows the fish to live in some of the coldest places on Earth, such as the icy-cold waters of the Arctic and Antarctic oceans. You might think that fish swimming in water below freezing—0°C (32°F)—would freeze solid, but they do not. What stops them from freezing?

The Antarctic notothenioid iives in one of Earth's coldest oceans. It has special "antifreeze" proteins in its circulatory system to keep from freezing.

Antarctic dragonfish

These fish have special proteins in their blood. These "antifreeze" proteins in the circulatory systems of these fish stop the blood from freezing. Even a single ice crystal can be deadly to a fish. Once one crystal grows, others can cluster around it, eventually freezing the blood. If the blood freezes, the circulatory system fails. The frozen blood stops circulating and no longer carries oxygen and nutrients to cells. The antifreeze proteins stop this from happening by surrounding any ice crystals and binding to their sides. This stops the crystals from clustering. That is how these fish can survive in the coldest waters of the world.

Write About It

Main Idea and Details

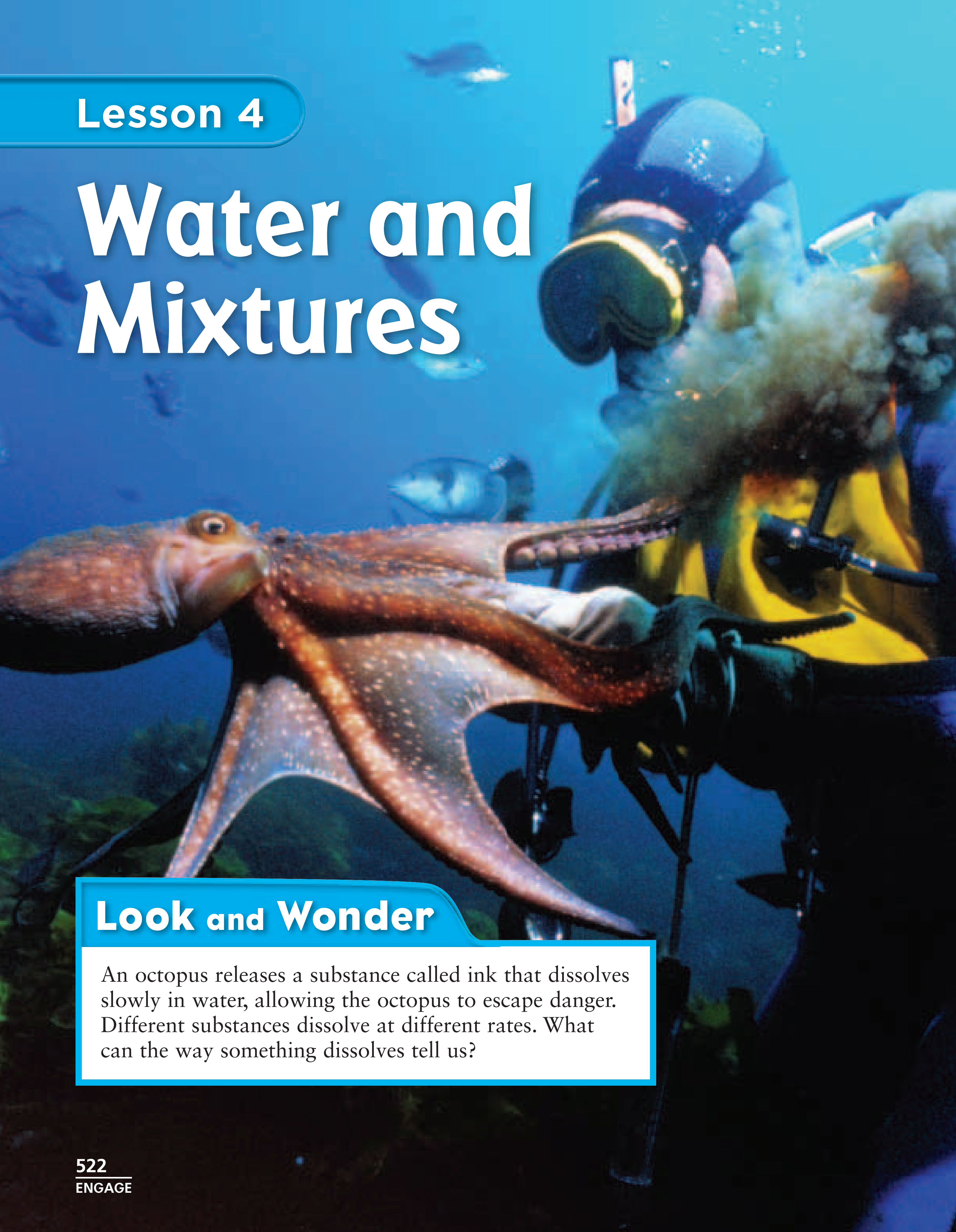
1. Tell how the fish that live in the Arctic and Antarctic oceans are able to keep from freezing.
2. Explain what would happen if one of these fish did not have this adaptation to the cold water.
3. Research and explain other adaptations that fish in cold environments use to survive.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Main Idea and Details

- Look for the central point of a selection to find the main idea.
- Details are important parts of the selection that support the main idea.

American Museum of Natural History



Lesson 4

Water and Mixtures

Look and Wonder

An octopus releases a substance called ink that dissolves slowly in water, allowing the octopus to escape danger. Different substances dissolve at different rates. What can the way something dissolves tell us?

Explore

Inquiry Activity

Can marker ink be separated?

Make a Prediction

Picture accidentally getting an ink stain from a marker on your clothing. What is the first thing you might do to help lighten or remove the stain? If you soak an ink stain with water, what do you think will happen? Write your answer in the form of a prediction: "If different ink stains are soaked in water, then they will . . ."

Test Your Prediction

1. **Measure** Cut out three strips of filter paper, each 5 cm by 10 cm. ⚠ **Be Careful.**
2. **Use Variables** Make a small (0.5 cm) dark spot on each strip, using a different black marker each time. Each spot should be about 2 cm from the bottom edge of the piece of filter paper.
3. **Experiment** Using a paper clip, secure the first piece of filter paper to the cup as shown. Add enough water to just touch the filter paper. The water level must be below the spot of ink.
4. **Observe** After 10 minutes, remove the filter paper, and place it on paper towels. Look closely at the filter paper, and observe it as it dries. Repeat this process with the other strips.
5. **Interpret Data** What happened to the ink spots and water? Did the ink from each marker respond in the same way?

Draw Conclusions

6. **Infer** Why do you think some colors traveled farther on the paper than others?

Explore More

Make changes to your test. Try using rubbing alcohol instead of water. Is the pattern the same each time for each marker? Could you use this as a reliable method for identifying a particular marker?

Materials

- scissors
- filter paper
- ruler
- 3 washable black markers
- paper clip
- plastic cup
- water
- paper towels

Step 2

Step 3

Read and Learn

Main Idea

Substances can combine to form mixtures. Each substance in a mixture keeps its own properties.

Vocabulary

mixture, p. 524
suspension, p. 527
emulsion, p. 527
colloid, p. 527
solution, p. 528
alloy, p. 528
solubility, p. 529
distillation, p. 532

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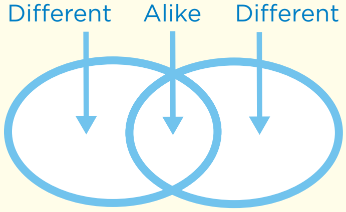
Reading Skill

Compare and Contrast



What are mixtures?

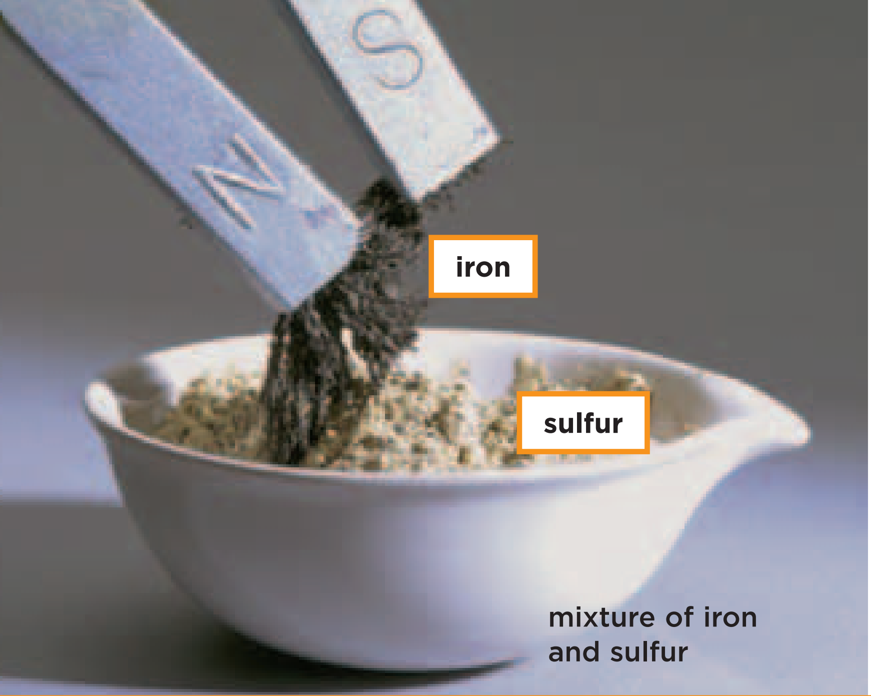
At first glance a tossed salad, a brass tuba, and fog seem to have little in common. However, each is a **mixture**, a physical combination of two or more substances that blend together without forming new substances.

The characteristics of the substances in a mixture do not change when they are mixed. For example, a tossed salad may contain lettuce, carrots, celery, and tomatoes. When the ingredients are mixed together, the tomato keeps its color, shape, and flavor, and so does the lettuce. Mixtures can usually be "unmixed," or separated. Just as the salad was put together, it can be separated into its original ingredients.

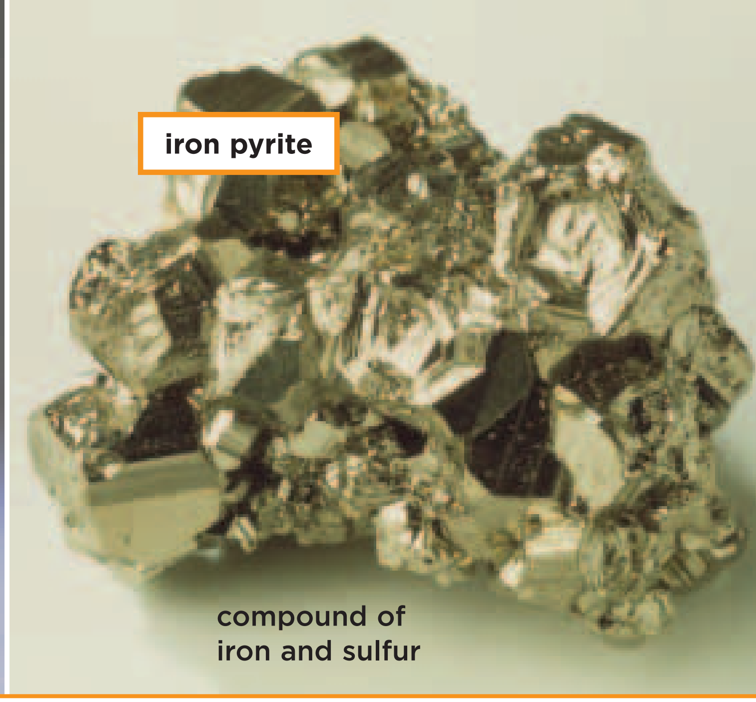
Mixtures and Compounds

When mixed together, iron filings and sulfur keep their individual properties. Iron filings are magnetic. Sulfur is a yellow powder. The iron can be separated from the sulfur with a magnet.

Fog is a mixture of water and air.



mixture of iron and sulfur



compound of iron and sulfur

However, iron and sulfur also can combine chemically to form the compound iron sulfide. Iron sulfide has different physical properties from either iron or sulfur. It is not magnetic like iron. It is not a yellowish powder like sulfur. It is a brightly colored rock that looks much like gold. For this reason iron sulfide, also known as iron pyrite, is sometimes called "fool's gold."

Heterogeneous Mixtures

A tossed salad is a heterogeneous mixture, or a mixture that contains distinct substances. Mixtures can have different combinations. In the tossed salad, there can be many tomatoes or only a few. There are no mixing rules, and there can be more of one ingredient in some parts than in others. The sulfur and iron filings also make a heterogeneous mixture. Look at a mixture of salt and white sand. The parts look similar at first, but a hand lens shows that the parts are different. How could you separate them?

Liquids and gases also can form heterogeneous mixtures. For example, fresh milk has a layer of cream on top. On a cloudy day, the sky contains a heterogeneous mixture of clouds and air. In fact, air itself is a mixture of different gases.

Conservation of Mass

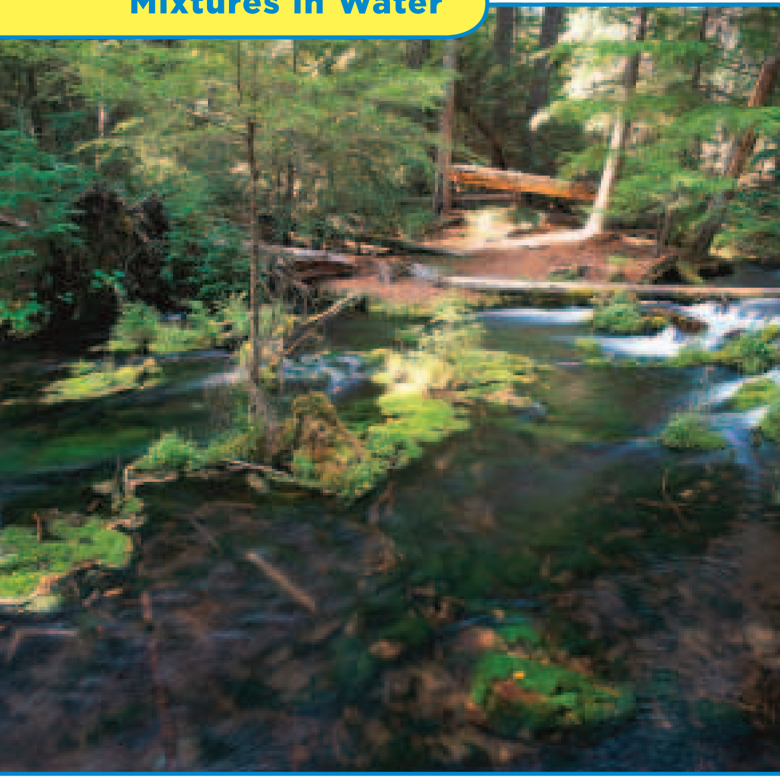
If you added 100 grams of salt to 100 grams of sand, the total mass would be 200 grams. The mass of each part always adds up to the mass of the whole. Mass is never added or lost in the process of making a mixture.

✔ Quick Check

Compare and Contrast How is a mixture of iron filings and sulfur like iron pyrite? How is it different?

Critical Thinking List three examples of heterogeneous mixtures that can be found in your school or classroom. Explain why they are heterogeneous mixtures.

Mixtures in Water



Read a Photo

What mixed with the water in the right-hand photograph and caused it to turn brown?

Clue: Compare the two photographs.

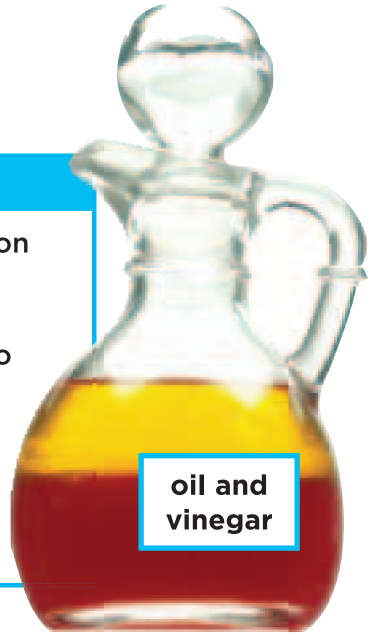
What are some kinds of mixtures?

There are several types of mixtures. Even though the substances in a mixture keep their own properties, you may not always recognize these properties. For example, perfumes are mixtures. If you separated the substances found in perfumes, you might find that some parts have foul odors. However, when these substances are mixed together in perfumes, their odors blend to make a pleasing fragrance. Additionally, some mixtures are homogeneous. This means that the mixture is the same throughout. Many food products are processed to make them homogeneous.

This milk has been homogenized to make it the same throughout. ▶

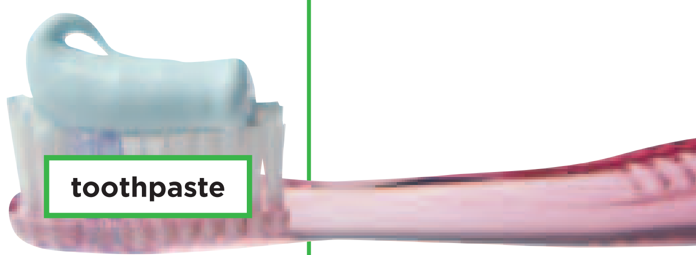
Suspensions

A suspension is a mixture made of parts that separate upon standing. Products that are suspensions, such as certain types of sauces and dressings, are often marked, “Shake well before using.” To make a suspension, add fine sand to a bottle of water. Shake it, and watch the particles move. Soon, the sand particles will separate from the water and settle to the bottom of the bottle. Very fine particles, however, often remain suspended for a long time. You can also separate fine particles by using a filter.



Emulsions

An emulsion (i•MUL•shuhn) is a suspension of two liquids that usually do not mix together. Emulsions are stable homogeneous mixtures of very small droplets suspended, rather than dissolved, in a liquid. Many food products and toothpastes are emulsions.



Colloids

A colloid (KOL•oyd) is a stable homogeneous mixture in which very small, fine particles of one material are scattered throughout another material, blocking the passage of light without settling out. Fog is a colloid, because it is a mixture of fine water droplets with other air molecules. In a colloid, undissolved particles or droplets stay mixed in another substance. Fog is a liquid-in-gas colloid. Smoke is a solid-in-gas colloid. Nonfat milk is a solid-in-liquid colloid.

Quick Check

Compare and Contrast How are colloids different from heterogeneous mixtures?

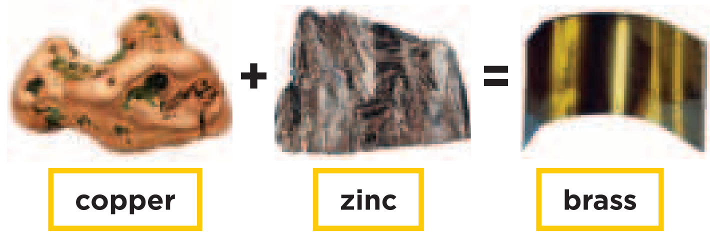
Critical Thinking Describe the kind of suspension that would take the longest to settle out.

Are solutions homogeneous mixtures?

Have you ever mixed salt in water? What happened? The salt may have seemed to disappear, but it was still there. The salt dissolved, or separated into tiny particles. Salt water is a **solution**, a mixture of one substance dissolved in another. The properties of a solution are the same throughout the mixture. Solutions are similar to colloids. Both are homogeneous mixtures, but the particles in solutions are smaller than those in colloids.

Solutions have two parts. The *solute* (SOL•yewt) is the substance that dissolves. The *solvent* (SOL•vuhnt) is what the solute dissolves in.

Many metals form substances called alloys. **Alloys** are mixtures of one or more metals with other solids. Most alloys are solutions. Alloys are made by heating, melting, and mixing the parts together. The solution then cools and hardens, but the parts remain dissolved.



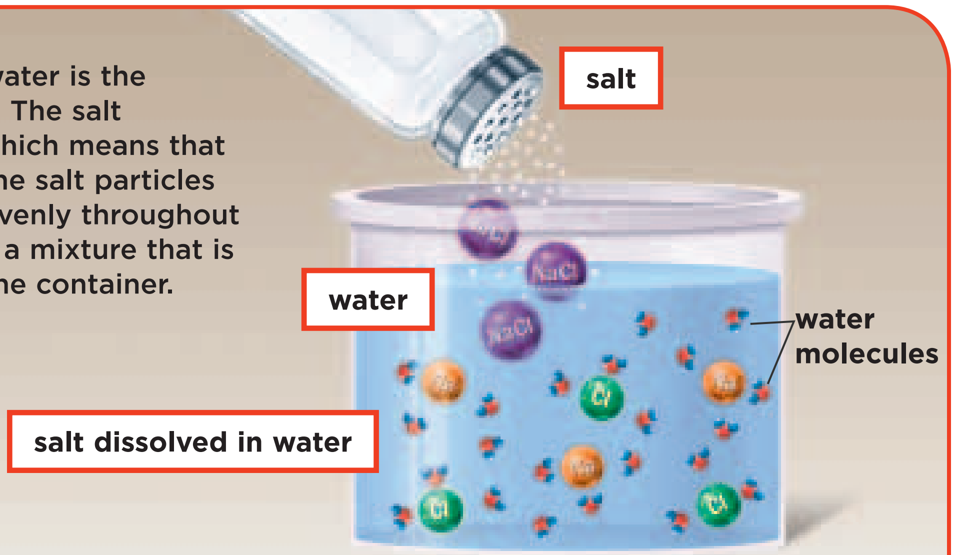
Steel is an alloy made mostly of iron and carbon. It is very strong, so it is used in building construction. Bronze and brass are both alloys that contain copper. Bronze consists of copper and tin, and brass is a mixture of copper and zinc.

Solubility in Solutions

When you mix cocoa powder with water, you make a solution. If you put only a few specks of cocoa powder in the water, the solution is diluted, which means that there are not many particles dissolved in it. If you add two spoonfuls of powder to the water, the cocoa becomes concentrated, which means that more particles are dissolved in it.

Salt Solution

Salt is the solute and water is the solvent in this solution. The salt particles are soluble, which means that they can dissolve. As the salt particles dissolve, they spread evenly throughout the water. The result is a mixture that is the same throughout the container.



Brass is a mixture of copper and zinc.

If you pour the entire box of cocoa mix into the water, the powder will not all dissolve. Some of it will settle to the bottom of the cup. When this happens the solution is saturated; no more solute will dissolve. **Solubility** is a physical property of solutes in different solvents. It describes the amount of a substance that can dissolve in a solvent.

Stirring a solution or breaking the solute into smaller pieces can help a substance dissolve more quickly. Heat may also affect the solubility of a solid. Heating a solution can allow more solute to dissolve. Heat may also speed up the process of dissolving.

Solutions and Safety

Some solutions are toxic, or poisonous. Combining solutions can produce new compounds, some of which can be dangerous. For this reason, household cleaners should never be mixed together. Always read warning labels on bottles of chemicals.

Quick Lab

Make a Saturated Solution

1. **Predict** How much salt do you think will dissolve in 100 mL of water?
2. **Measure** Weigh out 10 g of table salt using a balance scale.
3. **Experiment** Add the salt to 100 mL of water in a beaker. Stir until the salt has dissolved completely and the solution is clear.
4. Repeat steps 2 and 3 until no more salt will dissolve.
5. **Use Numbers** How much salt dissolved in the water? Was your prediction correct?
6. **Infer** Why can you no longer see the salt once it has dissolved?
7. **Predict** Based on your data, estimate the amount of salt that will dissolve in 1 L of water.

Quick Check

Compare and Contrast What is the difference between a diluted solution and a saturated solution?

Critical Thinking A sugar solution appears to be saturated. How could you increase its solubility?

How can mixtures be separated?

The parts of mixtures can be separated using physical methods. Physical methods separate the parts of a mixture without changing their properties or identities. For example, the ink in most pens is a mixture of different pigments. They can be separated by a filter because the different pigments soak through the filter paper at different rates.

The different properties of matter are helpful in separating mixtures. Density, magnetism, boiling point, and melting point are all properties that are used to separate mixtures.

A magnet separates iron filings from nonmagnetic materials.

A sieve separates materials of different sizes.

When water is added to salt and sand, salt dissolves, but sand does not. A filter separates the sand from the salt water.

The wood chips float to the top of the water, and the rocks settle at the bottom. The wood chips can be skimmed off and allowed to dry.

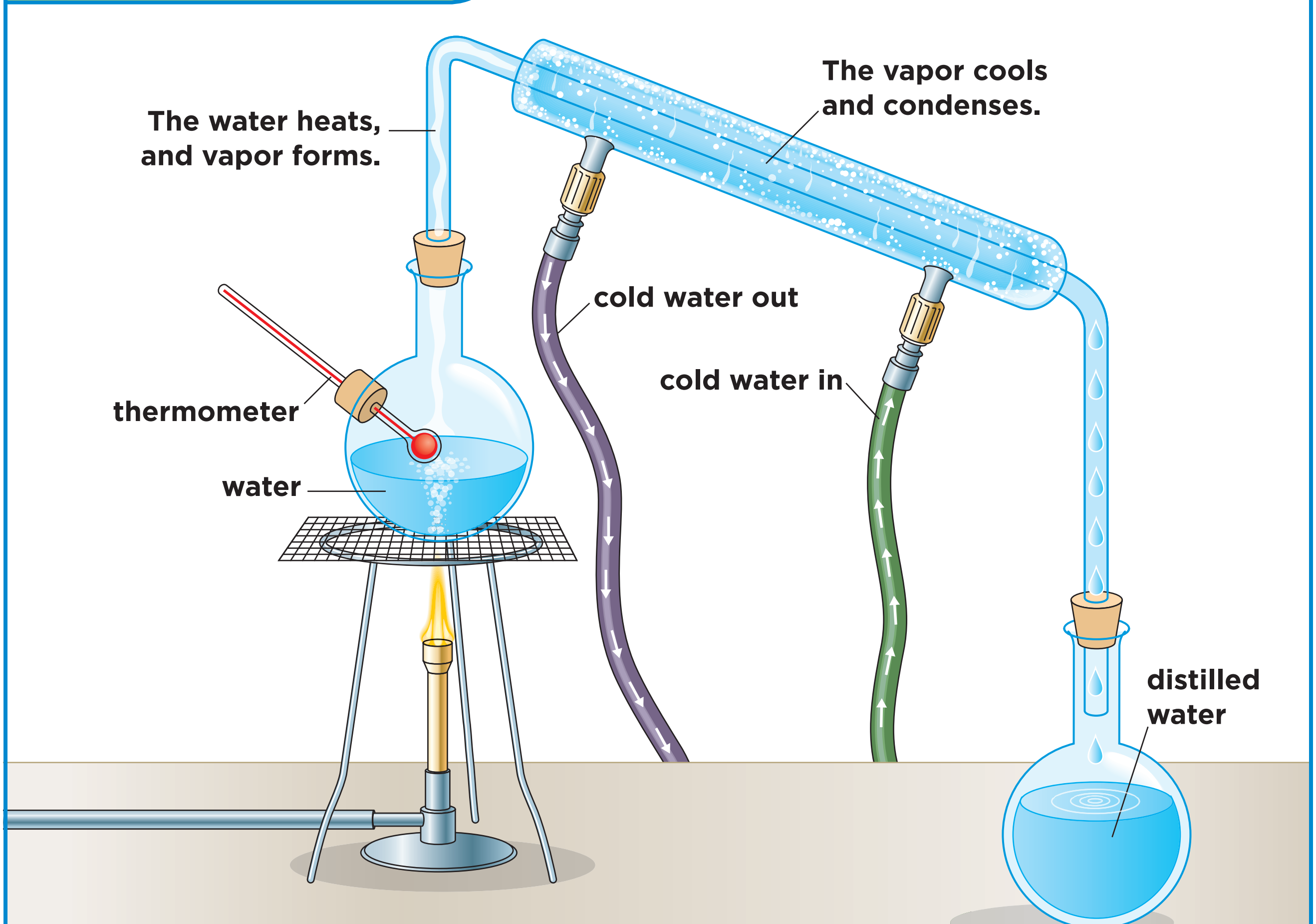
Water evaporates from salt water, leaving the salt behind.

Quick Check

Compare and Contrast What is the difference between sifting and filtration?

Critical Thinking You need to separate a mixture of several kinds of dried beans. How could you accomplish this?

Making Distilled Water



You could distill water by heating and collecting it as shown here.

Read a Diagram

What happens to the water after it is heated?

Clue: Follow the water's path through the process.

What is distillation?

Distillation separates the parts of a mixture by vaporization and condensation. This can be done by heating for a solution of water and salt, which have very different boiling points. The water, which has the lower boiling point, will boil, change to a gas, and leave the container first. The salt will remain in the container, as it will not have reached its boiling point. The gas can then be condensed in a cooling tube and can flow to another container. At that point, the two parts of the mixture will be completely separated.

Quick Check

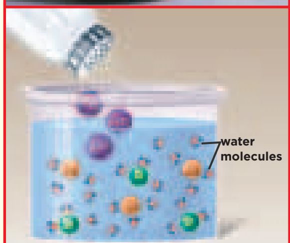
Compare and Contrast How does vaporization differ from condensation?

Critical Thinking Saudi Arabia has a large number of distillation plants. Why do you think they are so important there?

Lesson Review

Visual Summary

A **mixture** combines two or more substances without forming a new substance.



A **solution** is a mixture of one substance dissolved in another so that the properties are the same throughout.

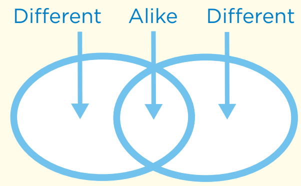
Mixtures can be separated using the **physical properties** of the substances that make up the mixture.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the phrases showing what you learned, and include examples.

Think, Talk, and Write

1. **Main Idea** How is a mixture different from a compound?
2. **Vocabulary** A mixture that contains one or more metals and other solids is called a(n) ________.
3. **Compare and Contrast** How is a solute different from a solvent?



4. **Critical Thinking** How can you use the boiling point and solubility properties of a substance to separate it from a mixture?
5. **Test Prep** **Which of the following would MOST LIKELY slow the process of dissolving?**
   - **A** using larger pieces of solute
   - **B** stirring the solute
   - **C** using smaller pieces of solute
   - **D** using less solute
6. **Test Prep** **What type of mixture is salt water?**
   - **A** a heterogeneous mixture
   - **B** a homogeneous mixture
   - **C** an alloy
   - **D** a colloid

Writing Link

Explanatory Writing

Write a paragraph that explains each of the steps you would take in order to separate a mixture of iron filings, sulfur, and marbles.

Social Studies Link

Research Metals

Read about the following alloys: brass, bronze, and steel. How have these mixtures been used in music, art, and architecture?

Be a Scientist

Materials


spoon

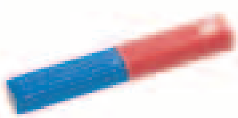

mixture items


plastic cup


sieve


bowl

plastic bag


magnet


funnel with filter paper

Structured Inquiry

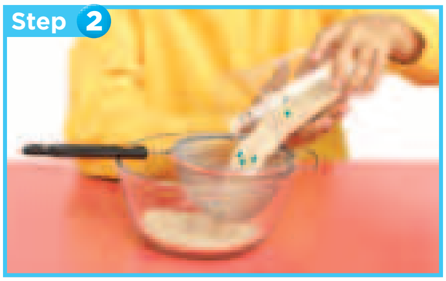
How can you separate a mixture?

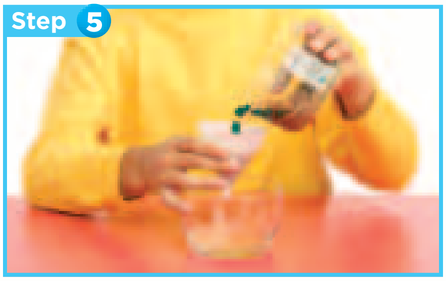
Form a Hypothesis

How can physical properties be used to separate a mixture? Write your answer in the form of a hypothesis: "If salt, sand, gravel, iron filings, and plastic beads are mixed together, then the following physical properties can be used to separate the parts of the mixture: ________ can separate the salt, ________ can separate the sand, ________ can separate the gravel, ________ can separate the iron filings, and ________ can separate the beads."

Test Your Hypothesis

1. Combine a spoonful each of salt, sand, gravel, plastic beads, and iron filings in a plastic cup. This forms the mixture you will use in this experiment. Record your observations after each step.
2. **Experiment** Over a bowl, pour your mixture into the sieve. Shake it until no more particles fall into the bowl. Transfer the items left in the sieve to another pan.
3. Turn a plastic bag inside out, and place a magnet inside the bag. Pass the magnet through the mixture. Turn bag right-side out to collect materials attracted by the magnet.
4. Add water until the water level is 2 cm of water above the remaining materials. Use the spoon to collect any of the materials that float, and put them aside.
5. Stir the mixture. Place filter paper in a funnel, and pour the mixture into the funnel. Use the plastic cup to catch the water.
6. **Observe** Leave this cup of water in a warm, dry place for 2 days.





Draw Conclusions

7. **Infer** What process was responsible for separating the water from the salt?

8. **Communicate** Share with the class how each part of the mixture was separated. Compare your results with your original hypothesis, and revise your hypothesis if necessary.

Guided Inquiry

How can you design your own method for separating mixtures?

Form a Hypothesis

Could you design your own procedure to separate a mixture of different materials? With the help of your teacher, gather a mixture of tea leaves, sugar, marbles, and plastic-foam peanuts. Then write your answer in the form of a hypothesis: "If I have a mixture of tea leaves, sugar, marbles, and plastic-foam peanuts, then . . ."

Test Your Hypothesis

Design an experiment to test your hypothesis. Write out the materials you will need and the steps you will follow. Record your results and observations as you carry out your experiment.

Draw Conclusions

Did you follow the steps you used to separate the first mixture, or did you change the steps? Why or why not?

Open Inquiry

What else can you learn about mixtures? For example, how do stirring and shaking affect different mixtures? Design an experiment to answer your question. Write your experiment so that another group could repeat the experiment by following your instructions.

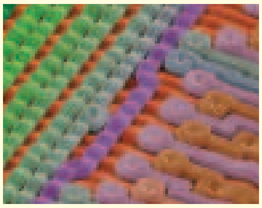
Remember to follow the steps of the scientific process.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions

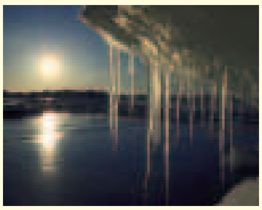
CHAPTER 9 Review

Visual Summary

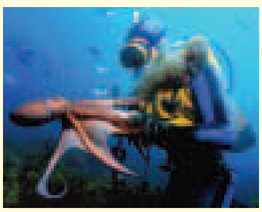
Lesson 1 The properties of objects affect how they function and interact with other objects.



Lesson 2 Atoms combine to make all the things that surround us.



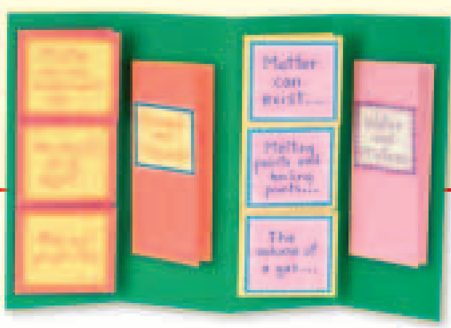
Lesson 3 Heat and pressure affect the properties of matter.



Lesson 4 Substances can combine to form mixtures. Each substance in a mixture keeps its own properties.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

alloy, p. 528

mixture, p. 524

molecule, p. 506

nucleus, p. 501

physical change, p. 518

physical property, p. 492

vaporization, p. 515

weight, p. 488

1. Altering the size, shape, or state of a substance without forming a new substance is a(n) ________.

2. The measurement of the pull of gravity on an object is called ________.

3. A mixture of one or more metals with other solids is a(n) ________.

4. The process by which a liquid becomes a gas is called ________.

5. The smallest particle of a compound that still has all the qualities of that compound is a(n) ________.

6. Something that can be observed without changing the identity of a substance is a(n) ________.

7. A combination of two or more substances is called a(n) ________ if no new substances are formed.

8. The part of an atom that contains protons and neutrons is the ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. Infer You know that the atomic number of silver is 47. What can you infer about this element?

10. Fictional Narrative Suppose you are a superhero. You have been captured and placed in a prison made of ice. How can you change the physical properties of the ice to escape? Write a short story explaining your escape.

11. Measure What are two ways to measure a rectangular solid's volume?

12. Critical Thinking Suppose you have made hot chocolate and want to keep it warm for as long as possible. What kind of cup should you use? Explain.

13. Interpret Data Which of the materials in the table below would float in water? Which would sink? Why?

Densities of Some Common Substances

Substance	Density (g/cm^3)
feathers	0.0025
water	1.00
steel	7.80

14. What are the properties of different types of matter?

Performance Assessment

The Volume Mystery

Your goal is to determine whether volume changes when two substances are mixed.

What to Do

1. To make a drink from a powdered mix, how much water do you need? How much of the mix? Make a prediction about the final volume of the drink.
2. Measure the powder and water separately. Stir the powder into the water. Measure the volume of the finished mixture. Record your measurements and observations in a data table.

Analyze Your Results

- Did your experiment confirm your prediction? Why or why not?
- What do you think happened when the powder and water were mixed together?

Test Prep

1. The photo below shows a change of state happening to dry ice.

What change of state is shown here?

A A gas becomes a plasma.

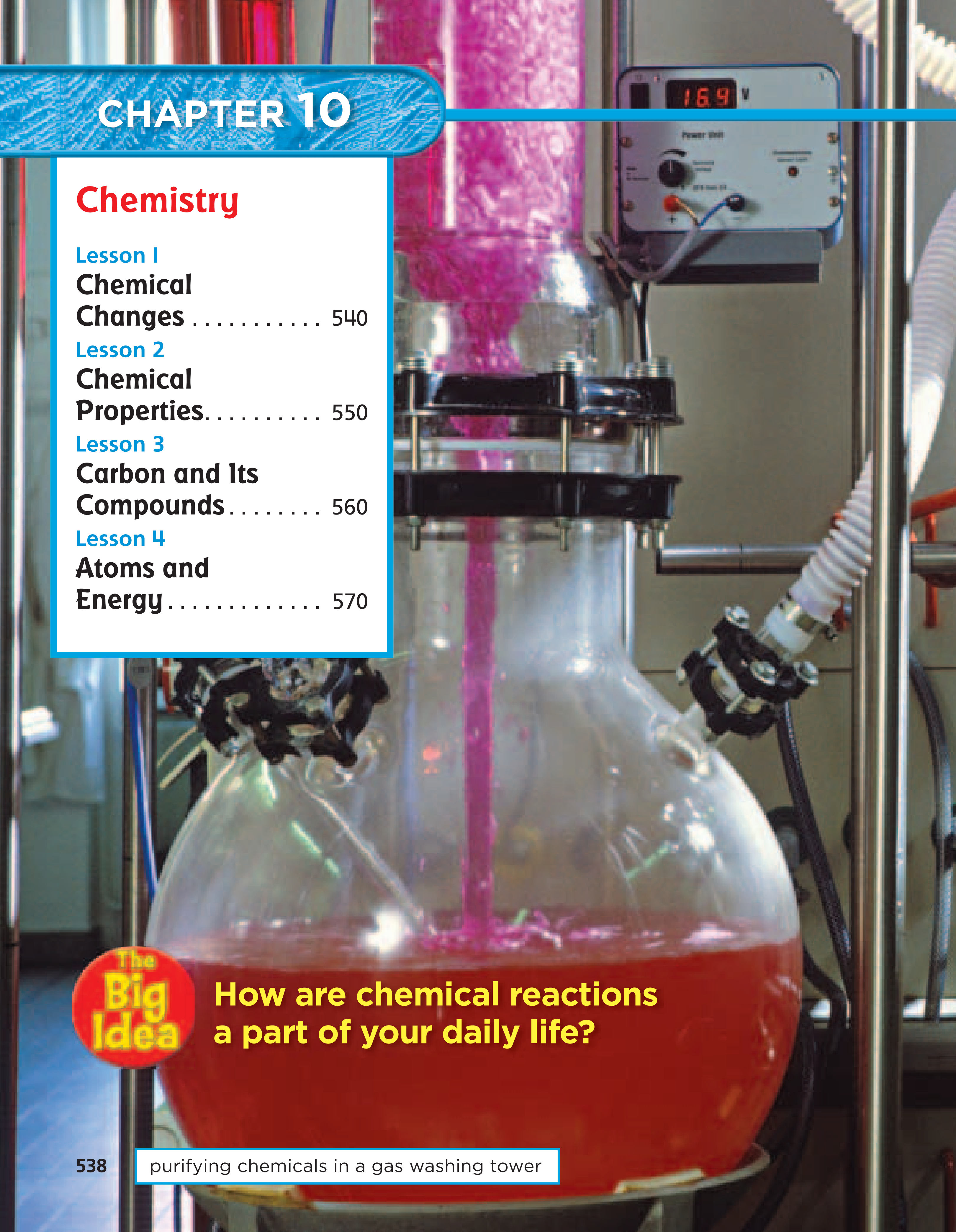
B A liquid becomes a solid.

C A solid becomes a gas.

D A plasma becomes a liquid.

CHAPTER 10

Chemistry



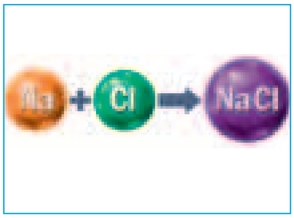
The Big Idea

How are chemical reactions a part of your daily life?

purifying chemicals in a gas washing tower

Key Vocabulary

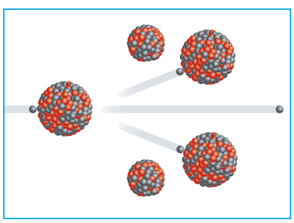
chemical change
A change in matter that produces a new substance with different properties from the original. (p. 542)



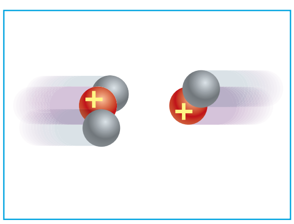
chemical equation
A way to represent a chemical change by using symbols for the amounts of reactants and products in the change. (p. 543)

exothermic
A chemical reaction that gives off heat energy. (p. 546)

plastic
A molded material that can retain its shape. (p. 566)



nuclear fission
The splitting of a nucleus into two or more pieces when struck with a slow-moving neutron. (p. 574)



nuclear fusion
The merging of nuclei with small masses to form a nucleus with a larger mass. (p. 574)

More Vocabulary

chemical bond, p. 542

reactant, p. 543

product, p. 543

endothermic, p. 546

chemical property, p. 552

indicator, p. 554

acid, p. 554

base, p. 554

salt, p. 556

neutralization, p. 556

organic compound, p. 562

synthetic, p. 566

radioactive, p. 573

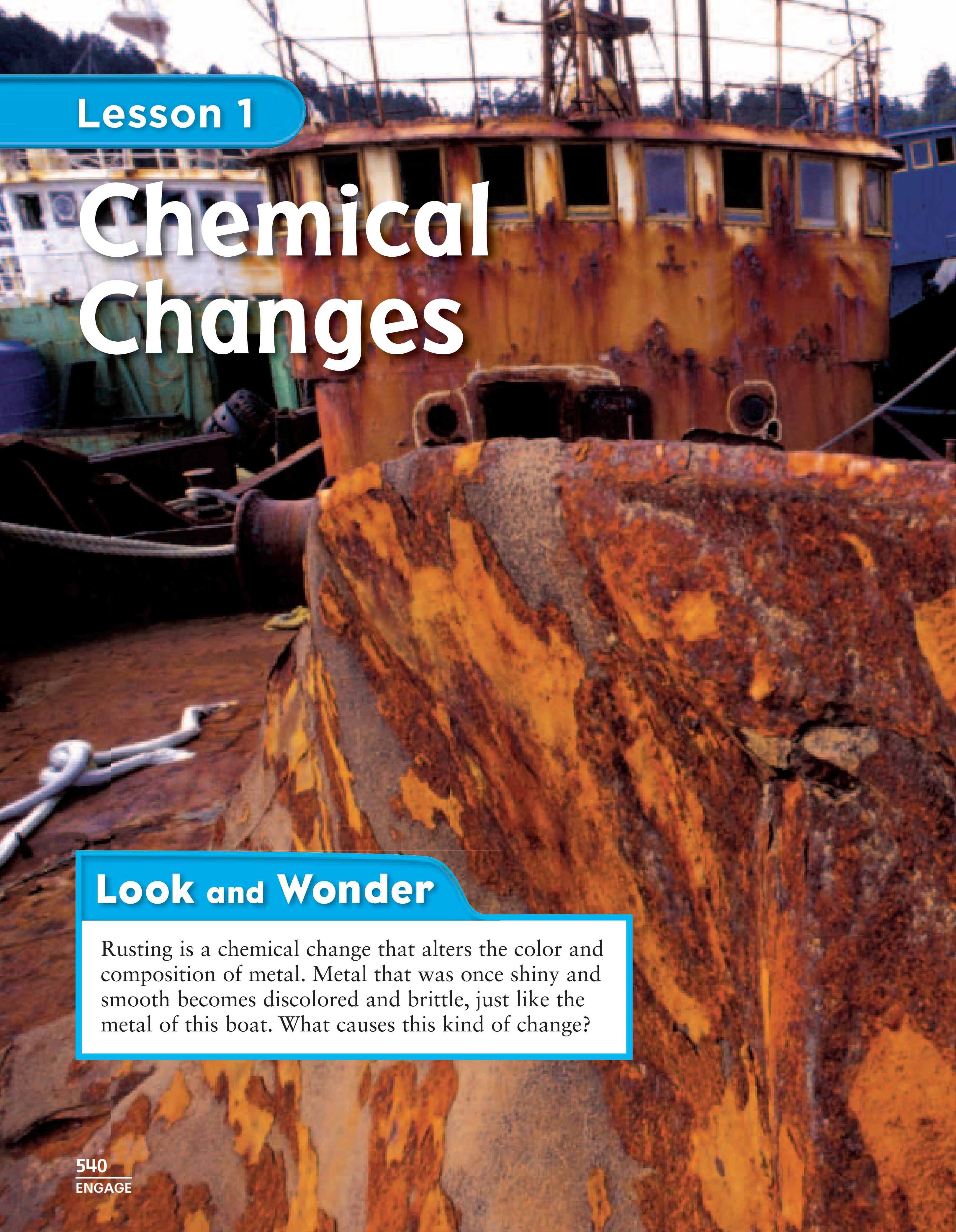
radiation, p. 573

half-life, p. 573

chain reaction, p. 574

Lesson 1

Chemical Changes



Look and Wonder

Rusting is a chemical change that alters the color and composition of metal. Metal that was once shiny and smooth becomes discolored and brittle, just like the metal of this boat. What causes this kind of change?

Explore

Inquiry Activity

What happens when metal rusts?

Make a Prediction

What do you think happens when metal rusts? If you find the mass before a metal rusts, what do you think will happen to that mass after it rusts? Write your answer in the form of a prediction: "When steel wool rusts in air, the total mass will . . ."

Test Your Prediction

1. **Observe** Look closely at the steel wool with your hand lens. Describe its properties.
2. Soak the steel wool in a beaker of vinegar for 2 minutes. Remove the steel wool, and squeeze out the vinegar. ⚠ **Be Careful.** Dip the steel wool into water, and squeeze out the water. Place the damp steel wool in a sealable plastic bag. Trap air in the bag before sealing it.
3. **Measure** Use the balance to find the mass of the filled bag. List all the contents of the bag.
4. **Experiment** Put aside the sealed bag for the length of time your teacher has determined.
5. **Record Data** Leave the bag closed until otherwise instructed. Find the mass of the filled bag.

Draw Conclusions

6. **Interpret Data** Did the mass of the bag and its contents change? Why was it important to leave the bag sealed until after your measurements?
7. **Infer** Now open the bag, and use your hand lens to look carefully inside. ⚠ **Be Careful.** Do the contents seem to have the same properties that you listed earlier?
8. **Interpret Data** Draw conclusions based on your experiment. Consider the amount of mass in the bag and the properties of the substances in the bag before and after the experiment. What can you conclude about the substances in the bag?

Materials

- steel-wool pad
- hand lens
- beaker
- vinegar
- water
- sealable plastic bag
- balance
- gram masses
- protective gloves
- safety goggles

Step 2

Explore More

Would mass change during other experiments in which new compounds were formed? Experiment using another metal to test your prediction. Share your results with the class.

Read and Learn

Main Idea

Chemical changes come from breaking and forming chemical bonds.

Vocabulary

chemical bond, p. 542
chemical change, p. 542
reactant, p. 543
product, p. 543
chemical equation, p. 543
exothermic, p. 546
endothermic, p. 546

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Reading Skill

Cause and Effect

Cause → Effect
→
→
→
→

What are chemical changes?

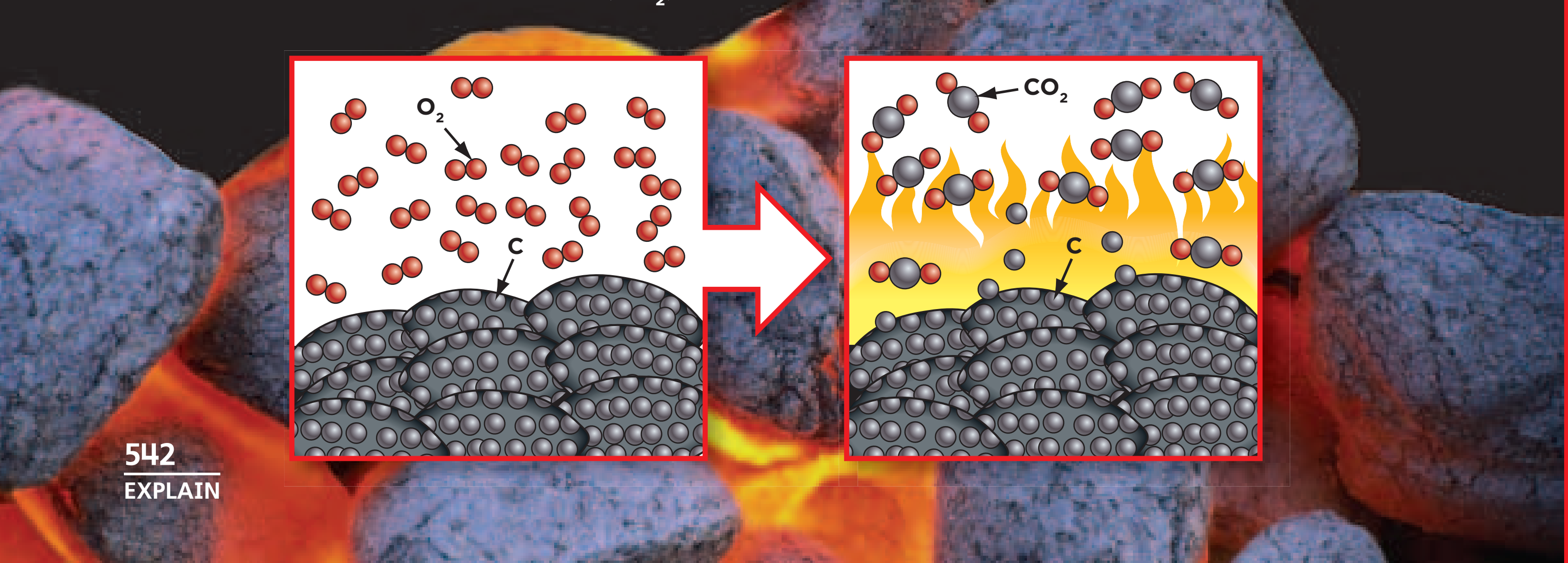
Physical changes, such as tearing paper or making mixtures, do not result in new substances. For example, mixing sugar and water changes some of the physical properties of the two materials. However, no new substance forms when they are mixed. Where do new substances come from?

When atoms attach to other atoms, they form chemical bonds. **Chemical bonds** are forces that hold atoms together. Forming or breaking these bonds changes the chemical properties of a substance. For example, carbon atoms can link to form charcoal. When the charcoal burns, molecules of oxygen from the air bond with the carbon in the coal, producing new molecules of carbon dioxide. This is an example of a chemical change. **Chemical changes** produce new substances with chemical properties that are different from those of the original substances.

The signs of a chemical change may include color change, the formation of gases, and the release of light or heat. However, some of these signs can also appear without a chemical change taking place. Food coloring appears to change the color of water, but no chemical change occurs. Food coloring and water are a mixture that can be separated by evaporation.

Chemical Change

When charcoal burns, new bonds form between atoms of carbon and oxygen. The result is molecules of carbon dioxide (CO_2).



Describing Chemical Changes

Chemical changes power vehicles, change the visible colors in leaves, and enable our bodies to function. Baking bread, frying an egg, and digesting food all involve chemical changes.

Another term for a chemical change is *chemical reaction*. Chemical reactions have two parts. A substance present before a chemical change is a **reactant**. A substance produced by a chemical change is a **product**. A **chemical equation** uses letters and numbers to represent the amounts of reactants and products involved in a chemical change. An arrow separates the reactants on the left from the products on the right. The same atoms are present on both sides of the arrow.

Chemical Reaction

Read a Photo

What are some signs of a chemical change in this picture?

Clue: What signs do you see that indicate the formation of a new substance?

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

2 sodium + 2 water ⟶ 2 sodium hydroxide + hydrogen

The reactants and the products are made of the same elements, but the elements are rearranged. There are equal numbers of each atom on both sides of the arrow. This means that the chemical equation is balanced. A chemical reaction does not create new matter. Instead, it forms new bonds among existing atoms. Scientists call this the *law of conservation of mass*. According to this law, matter is not created or destroyed during a chemical reaction. All the atoms present before a reaction will also be there after the reaction ends. However, the atoms may bond with other atoms in different ways to form different substances.

Bonds among atoms form in particular ratios. When hydrogen and oxygen bond to form water (H_2O), two hydrogen atoms bond with one oxygen atom in a ratio of 2 to 1. What is the ratio of carbon atoms to oxygen atoms in a molecule of carbon dioxide (CO_2)?

Quick Check

Cause and Effect In a chemical equation, what appears to the left of the arrow? To the right?

Critical Thinking If the reactants in a chemical change include three elements, what can you predict about the products?

What are chemical reactions?

There are three major types of chemical reactions. A *synthesis reaction* occurs when elements or compounds combine to form a new, more complex compound. Manufacturing, especially chemical manufacturing, often involves synthesis reactions.

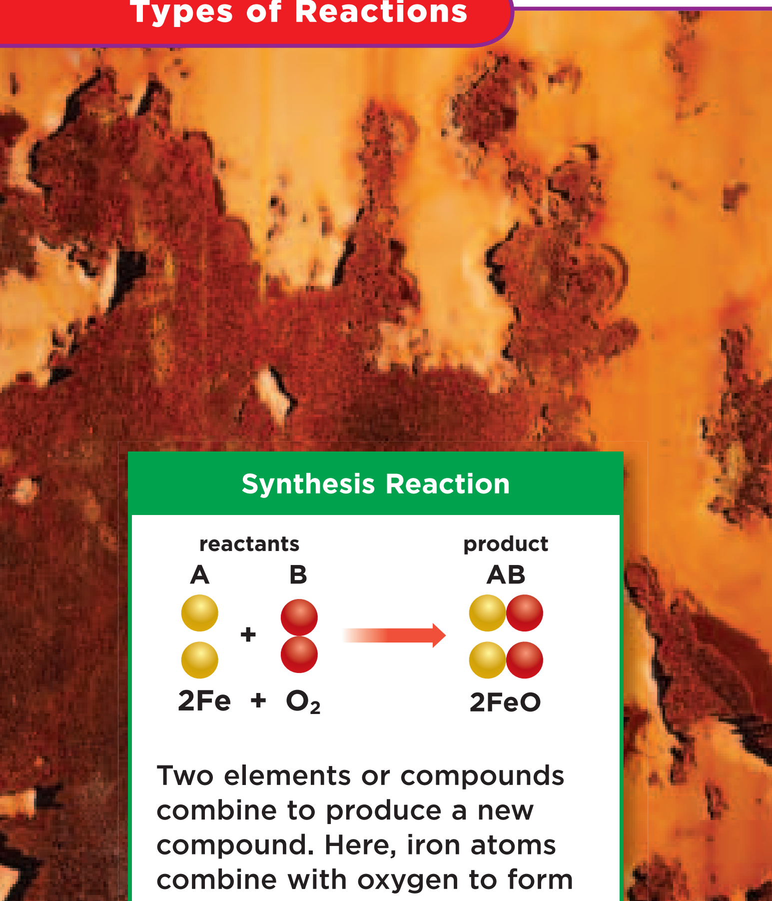
A *decomposition reaction* is the opposite of a synthesis reaction. In this case a more complex compound breaks down into simpler substances. Decomposition reactions happen in your body every day. When your cells break apart food, they perform decomposition reactions.

Replacement reactions occur when elements or molecules switch places. One element or molecule takes the place of another, forming a different compound. An example of this is the reaction of hydrochloric acid and sodium hydroxide to form water and sodium chloride (table salt). The chemical equation is written this way: $HCl + NaOH \longrightarrow H_2O + NaCl$.

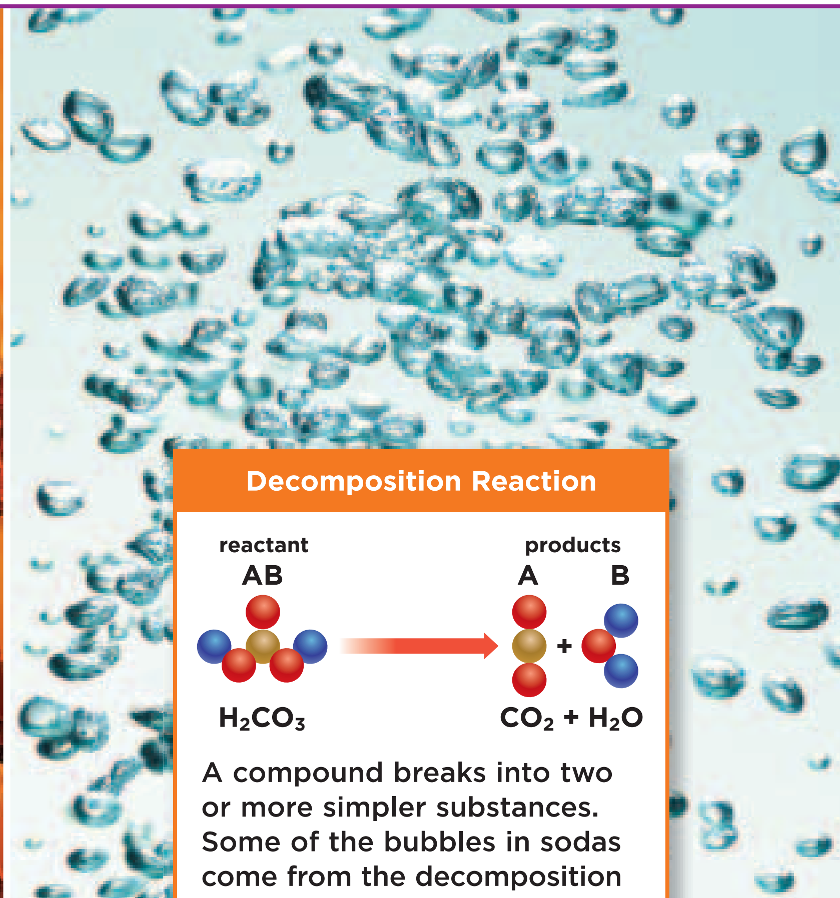
Speed of Chemical Reactions

The rate, or speed, of a chemical reaction depends on many factors. Some of the most important factors include temperature, concentration, and pressure. Increasing temperature causes the particles to move faster.

Types of Reactions



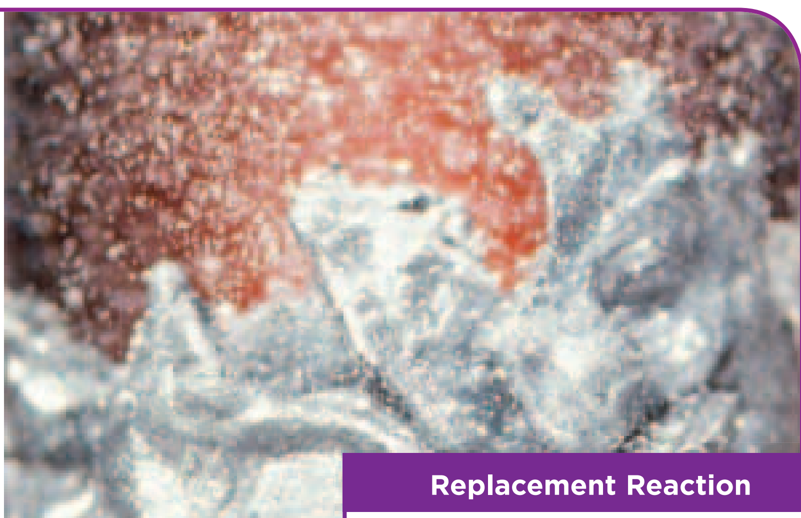
Two elements or compounds combine to produce a new compound. Here, iron atoms combine with oxygen to form iron oxide, or rust.



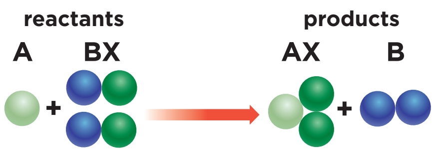
A compound breaks into two or more simpler substances. Some of the bubbles in sodas come from the decomposition reaction of carbonic acid here.

Because of this increase in movement, the atoms in the reactants are more likely to come into contact with each other and form chemical bonds. The particles also have more energy to use to break existing chemical bonds.

Increasing the concentration of a reactant in a solution also means that particles are more likely to come into contact and form chemical bonds. Increasing the pressure forces a greater number of particles into a smaller area, so this, too, increases the rate at which the particles contact one another. The amount of surface area of solid reactants is another factor that increases the rate of a chemical reaction. The larger the area that is exposed, the faster the reaction takes place.



Replacement Reaction



$Zn + 2HCl$ → $ZnCl_2 + H_2$

One element replaces another in a compound. Here, zinc in hydrochloric acid forms zinc chloride and hydrogen gas.

Quick Lab

Rate of Reaction

1. Will a whole or crushed antacid tablet react faster with water? Test this using two effervescent antacid tablets and two similar containers labeled *Whole* and *Crushed*.
2. **Use Variables** Pour equal amounts of water of the same temperature into the two containers. Crush one tablet on paper. Do not lose any of the pieces.
3. **Experiment** At the same time, add the whole antacid tablet to the *Whole* container and the crushed tablet to the *Crushed* container.
4. **Observe** In which container did the reaction start first? Finish first? In which container was the reaction stronger?
5. **Infer** What variable did you test? How did this variable affect the rate of the chemical reaction?

Quick Check

Cause and Effect What causes chemical reactions to speed up?

Critical Thinking When pure silver (Ag) becomes tarnished, silver sulfide (Ag_2S) forms. From this description, what type of reaction could this be? Explain.

What are exothermic and endothermic reactions?

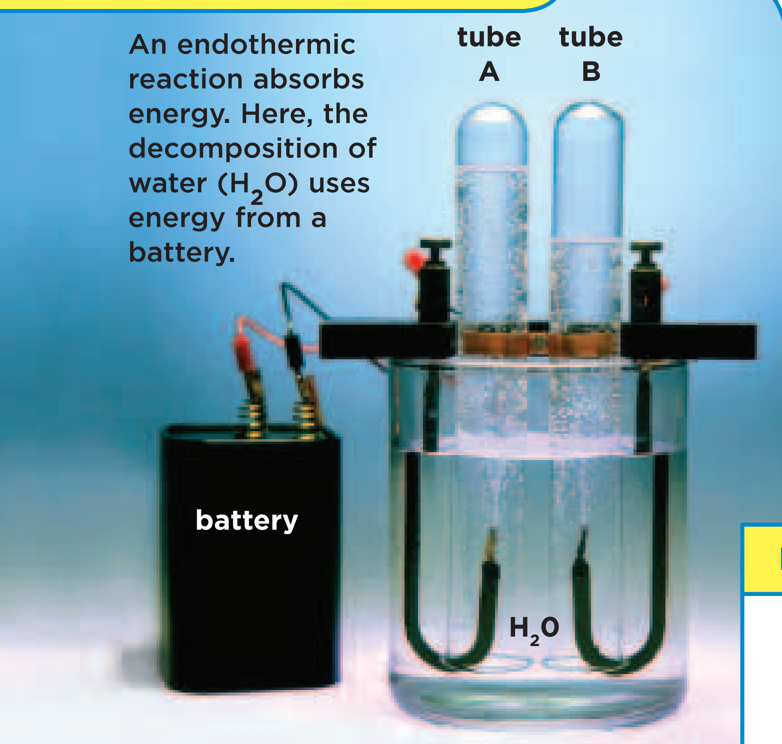
What are some signs that chemical reactions have occurred? The torch held by the welder in the photograph produces a great deal of light and enough heat to cut through metal. The torch's flame is produced when two gases combine. The gases, kept in nearby tanks, react strongly with each other. The reaction between them gives off lots of heat and light in a short amount of time. Reactions that release energy are **exothermic** reactions. These reactions keep going once they have started, and they give off energy until the reaction stops. Some reactions release energy in small amounts over a long period of time. However, rapid exothermic reactions can even produce a flame, as a welder's torch does.

▲ Exothermic reactions release energy, such as the heat of a welder's torch.

There are also reactions that absorb energy. These reactions are **endothermic** reactions. Endothermic reactions require a constant supply of energy for the reaction to continue. As soon as the energy supply stops, the reaction stops as well. Photosynthesis is an example of an endothermic reaction. It does not take place without energy from a source of light.

Endothermic Reaction

An endothermic reaction absorbs energy. Here, the decomposition of water (H_2O) uses energy from a battery.



Quick Check

Cause and Effect What would happen if an endothermic reaction were cooled significantly?

Critical Thinking Two solutions at room temperature are mixed in a beaker. The contents bubble and become hot. What type of reaction, if any, seems to have taken place?

Read a Photo

Water breaks down into two gases. Which tube has oxygen in it?

Clue: Think of the chemical formula of water.

Lesson Review

Visual Summary

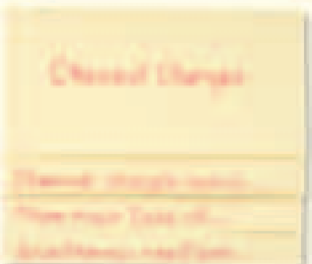
Chemical changes involve breaking and forming chemical bonds.

The three types of chemical reactions are **synthesis**, **decomposition**, and **replacement**.

Exothermic reactions release energy, and **endothermic** reactions absorb energy.

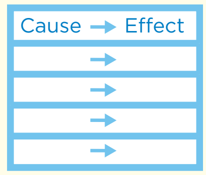
Make a FOLDABLES Study Guide

Make a Layered-Look Book. Use the titles shown. On the inside of each fold, complete the statement with the information you have learned about chemical changes.



Think, Talk, and Write

1. **Main Idea** Chemical changes involve the breaking and forming of ________.
2. **Vocabulary** A substance produced in a chemical change is a(n) ________.
3. **Cause and Effect** When two substances are combined, the temperature increases by 5°C. What may have caused this increase?



4. **Critical Thinking** Why is the rusting of iron an example of a chemical change?
5. **Test Prep** **Which of the following is an example of a decomposition reaction?**
   - **A** Iron and oxygen form iron oxide.
   - **B** Silver chloride and lead form lead chloride and silver.
   - **C** Carbonic acid forms carbon dioxide and water.
   - **D** Water freezes and forms ice.
6. **Test Prep** **Which of the following is NOT a chemical change?**
   - **A** Bread burns in a toaster.
   - **B** An apple slice turns brown.
   - **C** Eggs smell bad when they rot.
   - **D** Sugar mixes with water.

Math Link

Find Ratios

Find the ratios of the atoms of each element in the following compounds: HF, KCl, $MgCl_2$, CCl_4, and H_2S.

Health Link

Physical and Chemical Changes

Food is changed before its energy reaches your body. Write a research report about the physical and chemical changes that take place as an orange goes from your plate to your cells.

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Focus on Skills

Inquiry Skill: Form a Hypothesis

You learned that chemical reactions have reactants, or starting substances, and products, or substances the reactants change into. You also learned that one possible sign of a chemical reaction is a color change.

Scientists use information they read and observe to help them **form a hypothesis**, or make an educated guess, to answer a question. Then they experiment and interpret the result to see whether it supports or disproves their hypothesis.

▶ Learn It

When you **form a hypothesis**, you make a testable statement about what you think is logically true. You might form this hypothesis: "If steel wool soaked in vinegar and exposed to air produces rust, then any other iron or steel item treated that way will also produce rust." Anyone can test this hypothesis with an experiment.

While testing a hypothesis, remember to record all your observations. The data provide evidence of whether the results of your experiment support or disprove your hypothesis.

▶ Try It

Materials **2 saucers, paper towels, vinegar, 2 steel paper clips, copper wire (insulation removed), 2 pennies (1 old and 1 new), timer or clock**

1. Place the two saucers on a table. Fold the paper towels into two squares. Place one square on each saucer.
2. Pour enough vinegar on each saucer to cover the folded paper towel. ⚠ **Be Careful.**
3. **Form a hypothesis** about how paper clips, copper wire, and pennies will react to the vinegar. Record your hypothesis on a chart like the one shown.

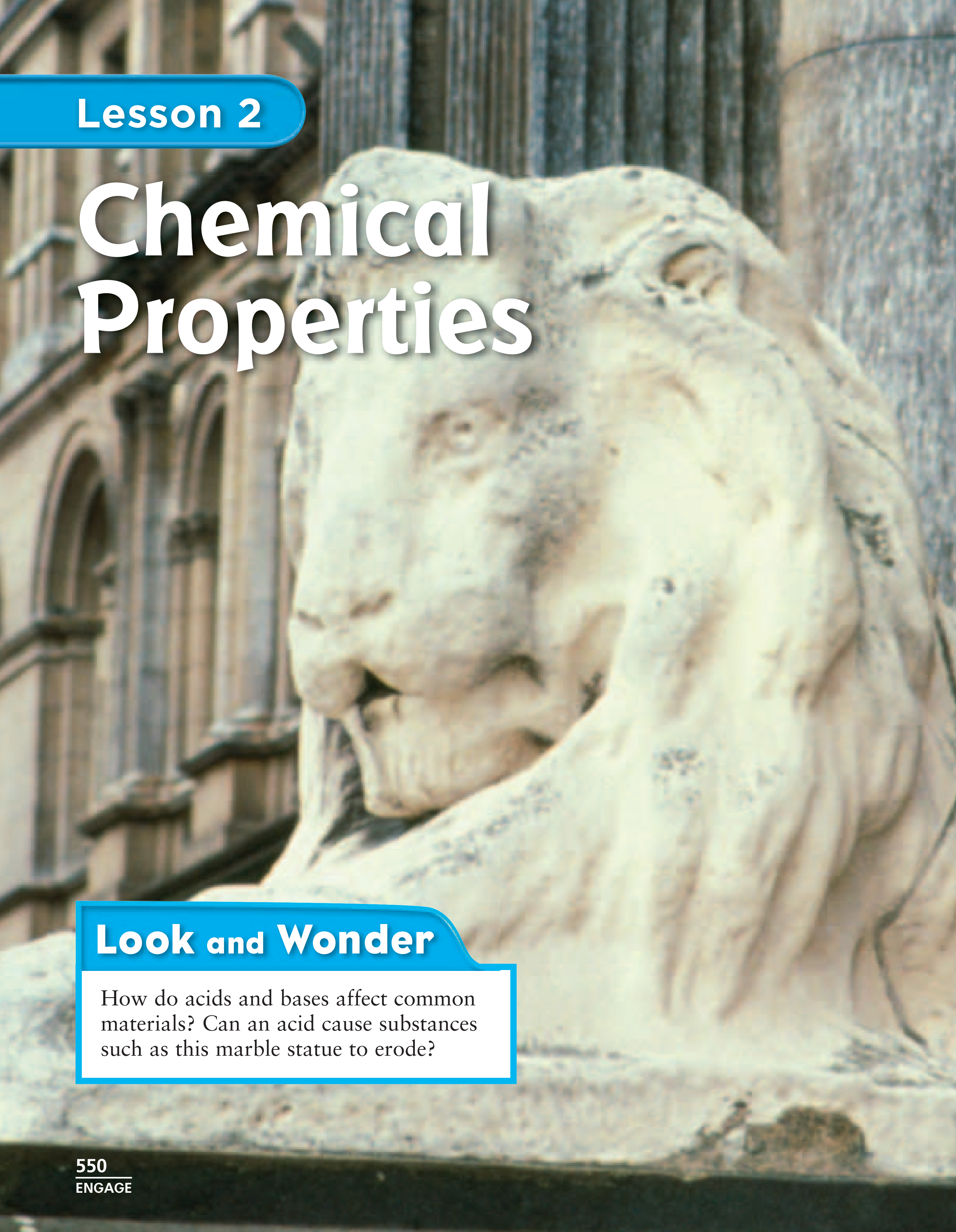
This 45-foot-tall sculpture in Philadelphia combines stainless steel with a special steel that turns reddish-brown as it ages to simulate rust.

4. Place the pennies and copper wire on top of the paper towel in one saucer and the paper clips on top of the paper towel in the other saucer.
5. After 2 minutes, record your observations on your chart. Continue to record your observations at 10-minute intervals.
6. Leave the saucers overnight. The next day check both sides of the pennies, wire, and paper clips. Record your observations.

My Hypothesis		
Time	Paper Clips	Pennies and Wire
2 Minutes		
12 Minutes		
22 Minutes		
32 Minutes		
24 Hours		

▶ Apply It

1. What happened to the paper clips in your experiment? Why?
2. What happened to the pennies and the copper wire? Why?
3. Was there a difference between the changes on the bottoms of the objects and those on the tops? Why or why not?
4. Do your findings in this experiment support your hypothesis?
5. What do you think would happen if you now put the pennies and wire in the bottom of a small cup of vinegar? Would the old penny and the new penny react to the vinegar in the same way? Do you think adding a teaspoon of salt to the vinegar might speed up the chemical process?
6. **Form a hypothesis** about what you think would happen when performing one of the experiments above. Test your idea, record your results, and indicate whether or not the results support your hypothesis.



Lesson 2

Chemical Properties

Look and Wonder

How do acids and bases affect common materials? Can an acid cause substances such as this marble statue to erode?

Explore

Inquiry Activity

What are acids and bases?

Make a Prediction

Red-cabbage juice turns pink in acids and blue-green in bases. The stronger the acid or base, the more the color changes. Neutral substances do not cause a color change in the cabbage juice. Which substances do you think are acidic? Basic? Neutral? Write your predictions in a chart like the one below.

Materials

- small, clear plastic cups
- water
- seltzer
- lemon juice
- baking soda dissolved in water
- white vinegar
- clear, liquid soap
- nonfat milk
- dropper
- red-cabbage juice
- goggles
- apron

Test Your Prediction

1. **Predict** Label a plastic cup for each sample. Pour in a small amount of the sample. Fill in the prediction column on your chart.

Sample	Predict: Acidic, Basic, or Neutral?	Color with Red-Cabbage Juice	Result: Acidic, Basic, or Neutral?
water			
seltzer			
lemon juice			
baking soda dissolved in water			
white vinegar			
clear, liquid soap			
nonfat milk			

2. **Observe** Add drops of red-cabbage juice to your first sample. Record any color changes. Add more juice if needed. Repeat for each substance. **Be Careful.**

Draw Conclusions

3. **Classify** Which samples are acidic? Which are basic? Which are neutral? Record your results.

4. **Interpret Data** Compare your data to the predictions you made. How do they compare?

Explore More

Are common foods or beverages acidic, basic, or neutral? Test your predictions and share your results.

Read and Learn

Main Idea

Different chemical properties help us predict how matter interacts.

Vocabulary

chemical property, p. 552
indicator, p. 554
acid, p. 554
base, p. 554
salt, p. 556
neutralization, p. 556

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Reading Skill

Draw Conclusions

Text Clues	Conclusions

What are the different properties of elements?

Elements have many physical properties, such as density, color, shine, and conductivity. They also have chemical properties. A **chemical property** describes the way a substance reacts with other substances. Elements in the same area of the periodic table have similar properties.

Metals, on the left side of the periodic table, are shiny and bend easily. They conduct electricity and heat. Scientists classify metals into three categories: alkali metals, alkaline earth metals, and transition metals. Alkali metals are located in the far-left column of the periodic table along with hydrogen, which is not a metal. Alkali metals, such as sodium, lithium, and potassium, are soft and extremely reactive. They easily form compounds with other substances and never exist by themselves in nature.

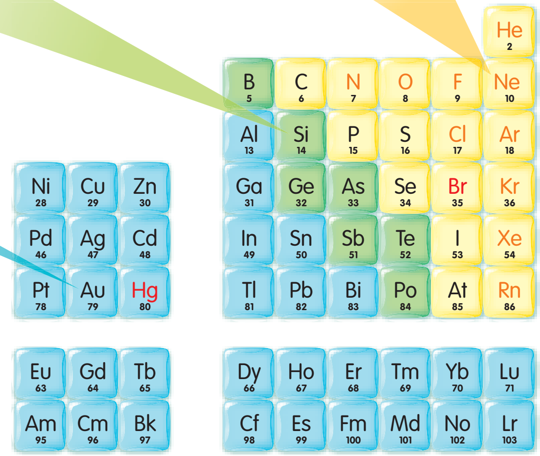
To the right of the alkali elements are the alkaline earth metals. These metals are light and soft, but they are not as reactive as alkali metals. Some alkaline earth metals, such as calcium and magnesium, are essential to many living organisms.

Airships are filled with gases such as helium. In the past, hydrogen, a highly reactive gas, was used.

Silicon (Si) is a metalloid. ▶

Neon (Ne) is a nonmetal. ▶

▲ Gold (Au) is a transition metal.



Transition metals are a large group of elements in the center of the periodic table. They include copper, iron, gold, nickel, and zinc. Most transition metals are hard and shiny. They react slowly with other substances. Transition metals are used to make coins, jewelry, machinery, and many other items.

Metalloids and Nonmetals

On the right side of the periodic table are metalloids and nonmetals. Metalloids, such as silicon, boron, and arsenic, share properties with both metals and nonmetals. Metalloids are *semiconductors*—at high temperatures they conduct electricity, like metals, but at very low temperatures they stop electricity from flowing, like nonmetals. Because of this, silicon and other metalloids are used in machinery, computer chips, and circuits.

Nonmetals, such as oxygen, carbon, and nitrogen, have properties opposite to those of metals. At room temperature, most of them exist as gases or as brittle solids. Nonmetals cannot be rolled into wires or pounded into thin sheets. Most nonmetals are poor conductors of heat and electricity.

Noble gases, in the far-right column of the periodic table, are nonmetals that do not react naturally with other elements. These gases have many uses. Argon is used in electric light bulbs. Neon, when exposed to electricity, produces the bright colors of some signs. Xenon is used in car headlights. Helium is often used in balloons.

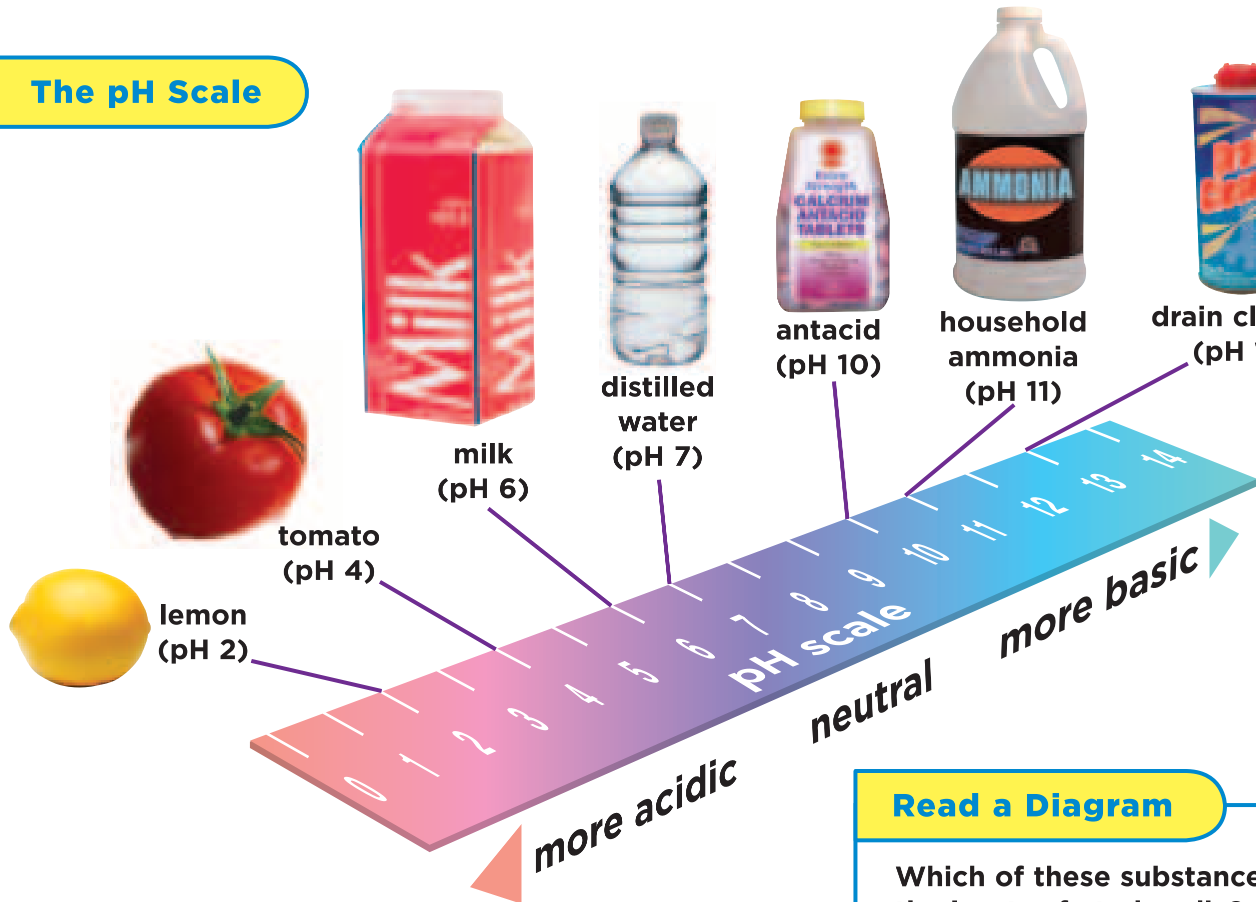
To the left of the noble gases is a column containing the halogens. Halogens, such as fluorine and chlorine, are very reactive nonmetals. Chlorine combines with sodium to form sodium chloride, or table salt.

Quick Check

Draw Conclusions If a gas does not react with any other substances, in what group might it belong?

Critical Thinking Why are alkali metals unsafe to handle?

The pH Scale



Read a Diagram

Which of these substances are the least safe to handle?

Clue: Identify where each substance falls on the pH scale.

What are acids and bases?

What do lemons and vinegar have in common? Both are acids. Acids usually have a sour taste. Taste is one way to determine whether your food is acidic or basic, but it is certainly not a safe way to test unknown substances. Instead, tools such as litmus paper are used to safely determine whether a substance is an acid or a base. Litmus paper and red-cabbage juice are **indicators**, materials that change color in the presence of acids or bases. Some indicators, such as litmus paper, react either to acids or to bases but not to both. Other chemicals, such as pH paper or the flavin in red-cabbage juice, react to both acids and bases.

The pH scale measures the strength of acids and bases. It runs from 0 to 14. A substance with a pH below 7 is acidic, and one with a pH above 7 is basic. A substance with a pH of 7, such as distilled water, is neutral.

Acids taste sour and turn blue litmus paper pink or red. They turn a natural indicator, such as red-cabbage juice, pink. Acids release hydrogen ions (H^+) in solution. The higher the concentration of hydrogen ions, the stronger the acid and the lower its pH.

Bases taste bitter and turn red litmus paper blue. They turn a natural indicator, such as red-cabbage juice, green. Bases, such as soaps, tend to feel slippery. Bases release hydroxide ions (OH^-) in solution. The higher the concentration of hydroxide ions, the stronger the base and the higher its pH.

Uses of Acids and Bases

Both acids and bases have many important uses. Strong acids are used in the production of plastics, explosives, and textiles. Sulfuric acid, nitric acid, and hydrochloric acid are all commonly used acids. Strong bases are used in batteries. Ammonia, a common yet strong base, is used in cleaning and bleaching.

Both acids and bases are used by the body. Hydrochloric acid in your stomach breaks down food during digestion. Your stomach has a mucous lining so that this strong acid does not dissolve and digest the stomach itself.

Bases also break down and dissolve substances. Bases are good cleaning agents, because they are slippery and break down grease and oil. Drain cleaners contain bases that are so strong they can even decompose hair.

Strong acids and bases must be used carefully. People using them must wear protective clothing and eyewear.

Cleaning Copper

Quick Lab

Neutralization

1. In a clear plastic cup, dissolve a small amount of baking soda into 50 mL of distilled water.
2. **Classify** Add red-cabbage juice to the baking-soda solution drop by drop. Red-cabbage juice turns pink in acids and blue-green in bases. What color is the solution? Is this solution an acid or a base?

3. **Observe** Add clear vinegar to the solution drop by drop. Vinegar is an acid solution. How many drops does it take to make the solution the original purple color of the red-cabbage juice?
4. **Infer** What do you think has happened to this solution? What might its pH be now? Use pH paper to check your prediction.

Quick Check

Draw Conclusions If the juice from a fruit tasted sour, what would you predict the pH of the juice to be?

Critical Thinking What types of foods might cause acid buildup in the stomach?

Read a Photo

How do you think ketchup could clean the copper bottom of this pot?

Clue: Ketchup contains vinegar.

What are properties of salts?

There are many kinds of salts. Magnesium sulfate ($MgSO_4$), or Epsom salts, can be used in baths to soothe muscles. Barium sulfate ($BaSO_4$) is a salt used to help view intestinal X rays. Silver bromide (AgBr) is a salt used in the production of photographic film.

Every **salt** is a compound formed by a reaction between an acid and a base. When an acid and a base are mixed, they react. This process, known as **neutralization**, produces water and a salt. The hydrogen ions (H^+) of the acid and the hydroxide ions (OH^-) of the base combine to form water, or H_2O. The other atoms of the acid and the base combine to form a salt.

The sodium and chlorine in table salt are held together by ionic bonds. An *ionic bond* forms when one atom takes an electron from another atom. This bond is what holds the two atoms together. In sodium chloride, a chlorine atom takes an electron from a sodium atom. This gives the chlorine ion a negative charge and the sodium ion a positive charge. The opposite charges are attracted to each other, and this attraction forms the ionic bond of sodium chloride.

Many salts dissolve easily in liquids. Salts are *electrolytes*, meaning that they allow an electric current to flow when dissolved in a liquid such as water.

Quick Check

Draw Conclusions What common characteristic do all salts share?

Critical Thinking Why is electricity conducted by salt water but not by a pile of salt?

Uses of Salts

melting


preserving

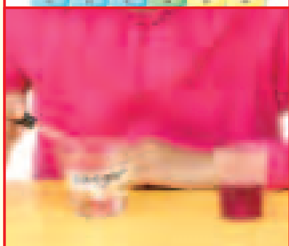

tracing

FACT The United States produces more salt than any other nation.

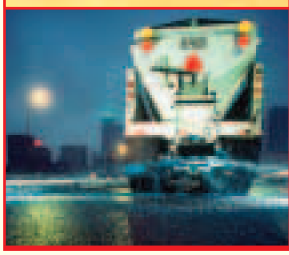
Lesson Review

Visual Summary

The **periodic table** classifies elements as alkali metals, alkaline earth metals, transition metals, metalloids, or nonmetals.



Indicators use color to distinguish substances as **acids** or **bases**.



Salts are formed when acids react with bases.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the statement and add details.

Think, Talk, and Write

1. **Main Idea** What are some differences between acids and bases?
2. **Vocabulary** A substance that changes color in the presence of acids or bases is called a(n) ________.
3. **Draw Conclusions** Why are bases good cleaning agents?

Text Clues	Conclusions

4. **Critical Thinking** Explain why some alkali metals do not exist as stand-alone elements in nature.
5. **Test Prep** **Which of the following is true when an acid mixes with a base?**
   - **A** They do not react.
   - **B** They produce water and a salt.
   - **C** The acid becomes stronger.
   - **D** The base becomes stronger.
6. **Test Prep** **Where does a neutral substance, such as distilled water, fall on the pH scale?**
   - **A** 0
   - **B** 2
   - **C** 7
   - **D** 14

Writing Link

Explanatory Writing

Explain how you could test whether a packet contained crystals of salt or crystals of sugar without tasting the crystals.

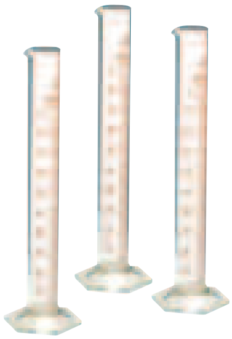
Health Link

Acid Rain

Write a research report about acid rain. What is it? How does it affect lakes, fish, trees, and other parts of the environment? How does acid rain affect buildings?

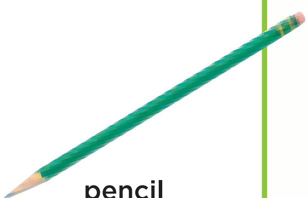
Be a Scientist

Materials

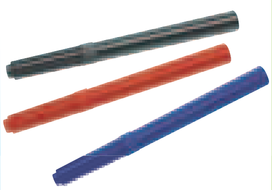


3 graduated cylinders

ocean mix



pencil



3 waterproof markers

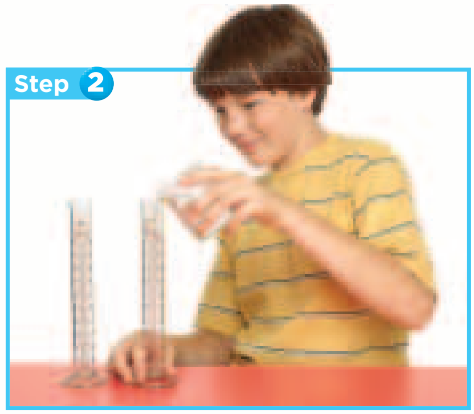
Structured Inquiry

Can differences in salt levels affect water's physical properties?

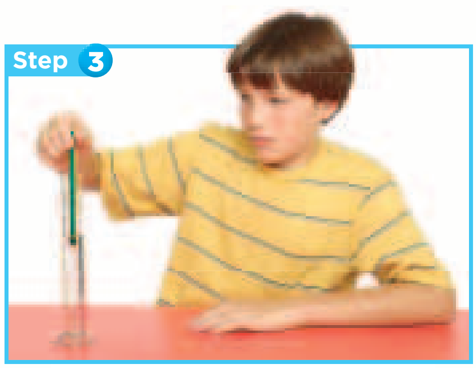
Make a Prediction

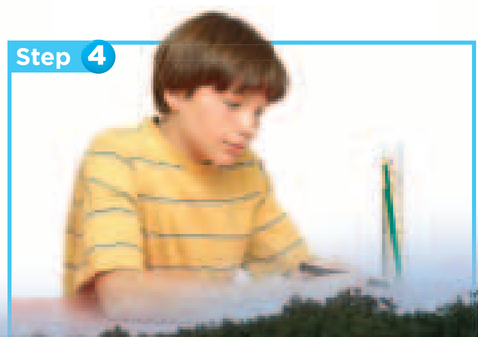
Organisms living in oceans or in freshwater lakes or streams are well suited to the physical conditions of their environments. Estuaries exist where freshwater streams flow into saltwater oceans. Might the water in estuaries have physical properties different from salt or fresh water? Will a pencil placed in all three environments behave in the same way? Write your answer in the form "If fresh, ocean, and estuary water have different physical properties, then a pencil placed in each will . . ."

Test Your Prediction



1. Label three graduated cylinders *Fresh*, *Ocean*, and *Estuary*.
2. **Measure** Pour 200 mL of tap water into the *Fresh* cylinder. Pour 200 mL of water into the plastic cup and make salt water according to the ocean mix directions. Pour 200 mLof salt water into the *Ocean* cylinder.
3. **Experiment** Place the pencil in the *Ocean* cylinder. Use a permanent marker to mark just above where the water level reaches on the pencil.
4. **Use Variables** Repeat step 3 with the *Fresh* cylinder using a different marker.
5. **Measure** Pour 100 mL of water from the *Fresh* cylinder and 100 mL from the *Ocean* cylinder into the *Estuary* cylinder. What happens as they mix?
6. **Use Variables** Repeat step 3 with the *Estuary* cylinder, using a different marker.





Draw Conclusions

7. **Compare** What happened when you placed the pencil in the *Fresh* cylinder? In the *Ocean* cylinder? In the *Estuary* cylinder?

8. **Interpret Data** Based on your experiment, what can you determine about the physical properties of water found in estuaries?

Guided Inquiry

How do ocean salt levels affect living things?

Form a Hypothesis

What do you think might happen to sea life if the ocean's salt levels changed? Write your answer in the form of a hypothesis: "If the ocean's salt levels change, then the organisms in it will . . ."

Test Your Hypothesis

Design an experiment to investigate what effect salt levels have on living organisms, such as yeast or brine shrimp. List the materials you will need and the steps you will follow. As you carry out the experiment, keep careful records of all your data.

Draw Conclusions

Do your results support your hypothesis? Could the rate at which salt levels changed have affected the organisms similarly?

Open Inquiry

What else can you learn about saltwater, freshwater, and estuary ecosystems? For example, what organisms thrive in water with a very high salt content? What types of salt are part of Earth's oceans? Where are estuaries located? Think of a question to investigate, and design an experiment or write a research strategy. Carry out your experiment or research, and then present your results to the rest of your class.

Remember to follow the steps of the scientific process.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions

Lesson 3

Carbon and Its Compounds

Look and Wonder

Carbon bonds with other elements to form many compounds found all around you—in your cells, the tires of a bicycle, many types of fuel, and even the gas you exhale when you breathe. How is one element part of so many different things?

Explore

Inquiry Activity

Can you recognize differences in carbon-compound concentration?

Make a Prediction

Carbon dioxide (CO_2) is colorless and odorless, so how can it be detected? It dissolves slightly in water and forms carbonic acid. The more carbon dioxide there is, the more carbonic acid forms. Will more carbonic acid form in gas from an antacid, from the air, or from your breath? Write your answer in the form "The highest concentration of carbonic acid will form in gas from . . ."

Test Your Prediction

1. Label four test tubes *Antacid*, *Air*, *Breath*, and *Control*. Fill each halfway with red-cabbage juice.
2. **Experiment** Put an antacid tablet and water in the plastic water bottle. Quickly place a balloon over the bottle's mouth, and collect the gas produced. Remove the balloon, and pinch the opening closed.
3. Place a straw in the corresponding test tube. Put the balloon over the end of the straw, and allow the gas to slowly bubble through the juice.
4. **Use Variables** Pump a balloon up to the same size, pinch it closed, and repeat step 3. Then inflate a third balloon yourself, and repeat step 3.

Draw Conclusions

5. **Interpret Data** Compare the colors of the red-cabbage juice in each tube. Estimate the pH of each sample using the table below.

pH	2	4	6	7	8	10	12
Color	red	red-purple	violet	original color	blue	blue-green	green-yellow

Explore More

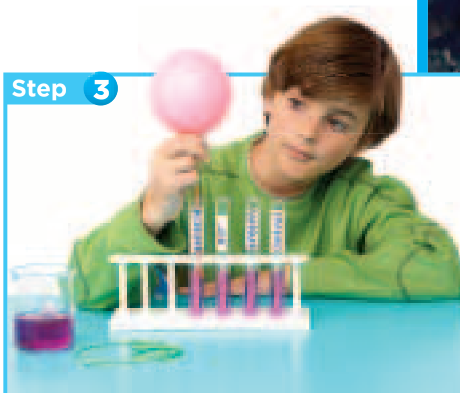
In nature, the water cycle naturally exposes water to carbon dioxide in the air. Does this affect rain's pH? Design and perform an experiment testing rain's acidity, and then share the results with your class.

Materials

- 4 test tubes
- red-cabbage juice
- antacid tablet
- water
- plastic water bottle
- 3 balloons
- straw
- bicycle pump

Step 1

Step 3



Read and Learn

Main Idea

Carbon and its compounds are found in the world around you.

Vocabulary

organic compound, p. 562
plastic, p. 566
synthetic, p. 566

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Reading Skill

Main Idea and Details

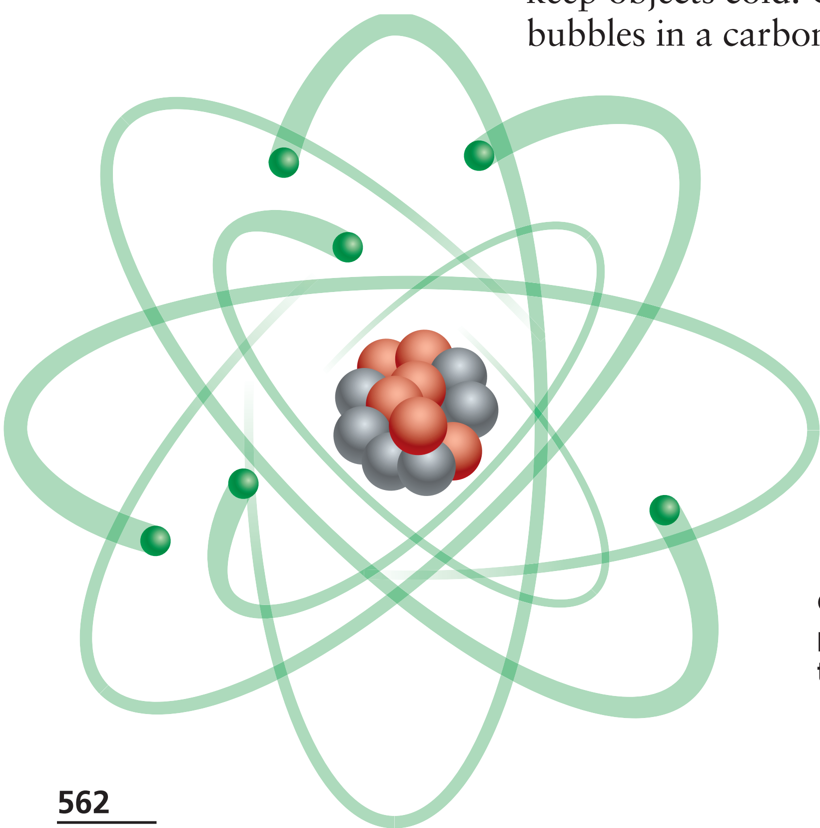
Main Idea	Details

What are some common carbon compounds?

Carbon is found in many of the items you see and use each day. Carbon bonds with itself in different ways, taking on forms as varied as diamonds, coal, and the graphite in your pencil. Carbon also bonds with many other elements and forms many different compounds. Many carbon compounds are **organic compounds**, the chemical building blocks of all known living things. However, carbon is part of many *inorganic compounds* as well.

How We Use Carbon Dioxide

When one carbon atom bonds with two oxygen atoms, the result is a gas called carbon dioxide (CO_2). Carbon dioxide is a clear, odorless gas. Although it is not an organic compound, it is closely involved in the life functions of living things. During photosynthesis plants absorb carbon dioxide from the air. Dead organisms give off carbon dioxide as they decay. You expel carbon dioxide every time you breathe out. Frozen carbon dioxide, called dry ice, is used to keep objects cold. Carbon dioxide is also the gas that bubbles in a carbonated beverage.



KEY
electron
proton
neutron

Carbon is an important part of the compounds that are necessary for life.

At left, carbon dioxide is released from plant decay. At center, carbon monoxide forms from burning fossil fuels. At right, methane forms from biomass decay.

Other Carbon Compounds

Some carbon compounds can be dangerous. For example, when a carbon atom bonds with a single oxygen atom, the product is carbon monoxide (CO). This clear, odorless gas can form when fuel does not burn completely. It is poisonous, and it prevents blood from carrying oxygen to the rest of the body. Poorly vented gas heaters, fireplaces, and furnaces can produce dangerous levels of carbon monoxide inside homes. People should put alarms in their homes to warn of dangerous levels of this poisonous gas.

Carbon also bonds with hydrogen to form methane (CH_4). When methane is formed, each carbon atom bonds with four hydrogen atoms. Methane, or natural gas, is used to heat millions of homes throughout the world. Methane is released in marshes. Methane is also a waste product of digestion and is released by animals as a gas. Fertilizers and rubber tires are made using methane-based products. Methane can also be chemically changed into many other useful compounds.

Quick Check

Main Idea and Details What are some compounds that form when carbon combines with other elements?

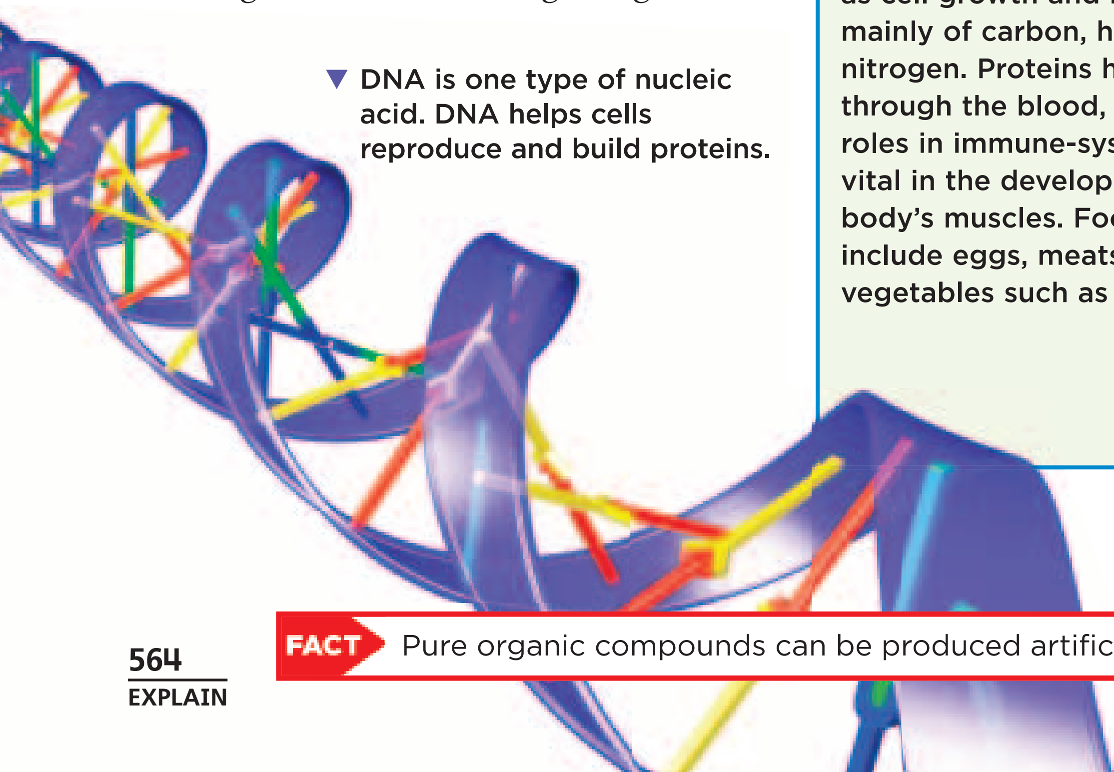
Critical Thinking Why might a carbon monoxide alarm be an important thing to install in a house?

What organic compounds are in your body?

Have you ever heard the saying, "You are what you eat"? It really is true. All the compounds that form the cells and tissues of your body are made of elements found in the foods you eat. You eat food that contains the compounds your body needs in order to grow. Carbon is the most common element of all these compounds, and therefore carbon is essential to the life processes of all known organisms.

Types of Organic Compounds

Nucleic acids are a type of organic compound. They are made mostly of carbon, nitrogen, oxygen, phosphorus, and hydrogen. Nucleic acids are found in cells' chromosomes and in structures throughout the cytoplasm. Nucleic acids store and transfer information on the building of proteins from amino acids, in the form of a genetic code. Nucleic acids, lipids, proteins, and carbohydrates are the chemical building blocks of all living things.



▼ DNA is one type of nucleic acid. DNA helps cells reproduce and build proteins.

Organic Compounds

Carbohydrates are your body's main source of energy. Carbohydrates are organic compounds made of carbon, hydrogen, and oxygen. Grain foods such as bread and pasta, as well as sugars, starches, and fruits, are all made of carbohydrates. During cellular respiration, your body produces the energy it needs by turning glucose and many other carbon-based sugars into carbon dioxide and water. This process releases the energy that powers the cells of your body.

Lipids are organic compounds that have many carbon-hydrogen bonds, but they have fewer oxygen bonds than are found in carbohydrates. Lipids include fats, oils, waxes, and cholesterol. They are rich in energy. Lipids can store and release more energy than other organic compounds. Lipids remain stored in your body as fat.

Proteins are also important organic compounds in the human body. The body uses proteins for important functions such as cell growth and repair. Proteins consist mainly of carbon, hydrogen, oxygen, and nitrogen. Proteins help move oxygen through the blood, play very important roles in immune-system functions, and are vital in the development and use of your body's muscles. Foods rich in proteins include eggs, meats, fish, and some vegetables such as peas and beans.

FACT Pure organic compounds can be produced artificially.

Read a Photo

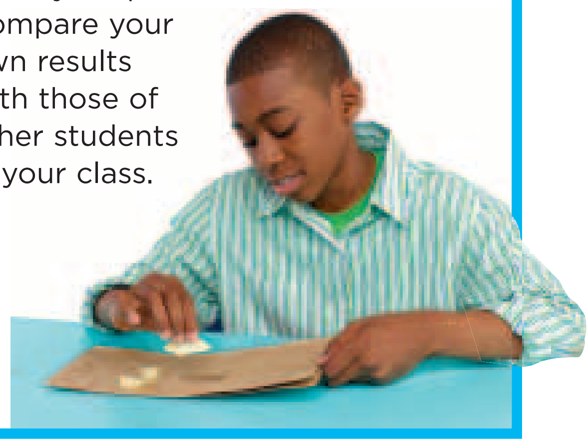
Which foods rich in protein come from plants?

Clue: What color are most plants?

Quick Lab

Looking for Lipids

1. On a large piece of a brown paper bag, lightly pencil in a grid of boxes, each 10 cm by 10 cm.
2. **Predict** Look at the substances that you will be testing, and guess which have a high lipid content. Some you may already know.
3. **Experiment** Rub a substance you are testing in the center of one box on the grid. At the bottom of the box, write the name of the substance being tested. Repeat this for each substance you are testing. Lipids will leave a spot on the paper that seems oily and allows some light to pass through. Allow the paper to dry overnight. Then check the grid again.
4. **Classify** Which substances seem to contain lipids, and which do not? Were your predictions correct? Compare your own results with those of other students in your class.

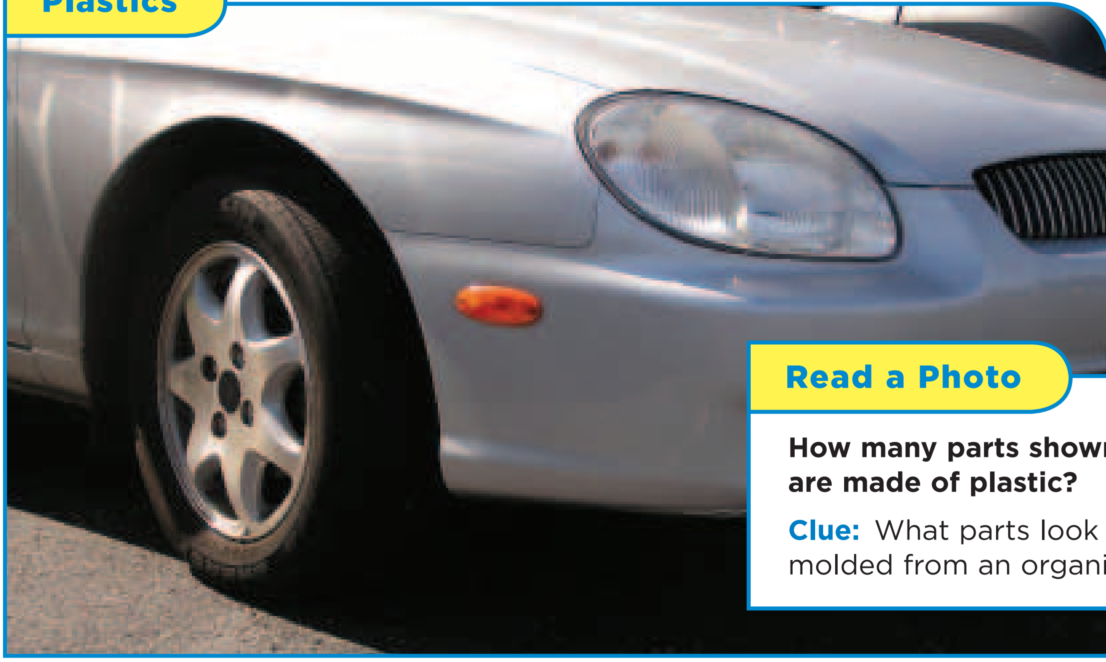


Quick Check

Main Idea and Details What are the most common elements in the organic compounds found in cells?

Critical Thinking Why are organic compounds so important to the functions of the human body?

Plastics



Read a Photo

How many parts shown on this car are made of plastic?

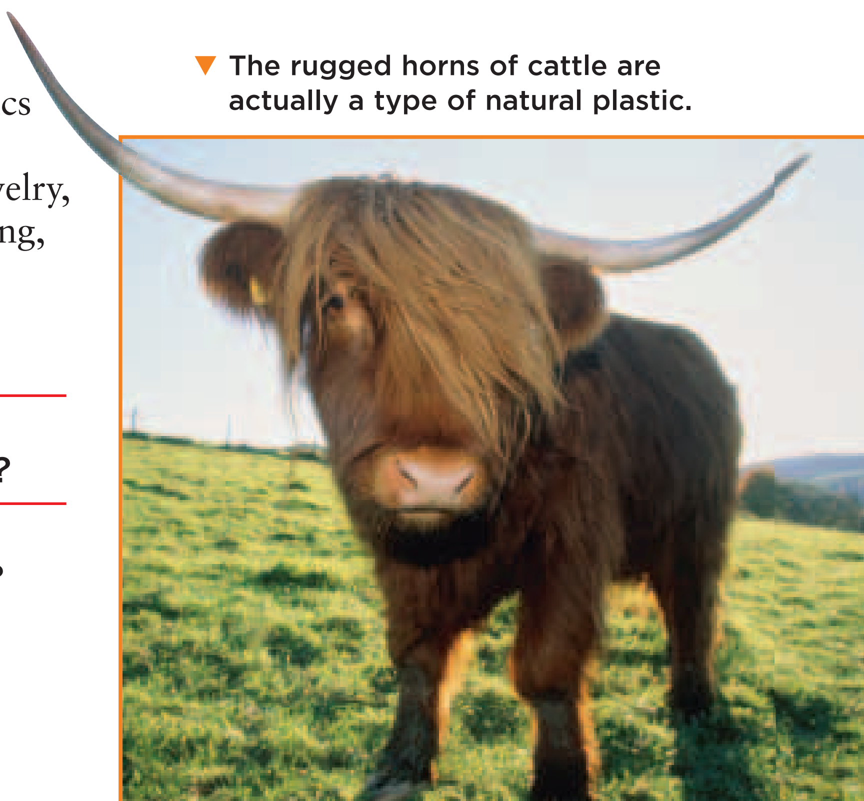
Clue: What parts look as if they were molded from an organic compound?

How do people use organic compounds?

Organic compounds are important components in many of the products that we use every day. Plastic, rubber, soap, fuel, asphalt, and nylon all contain organic compounds.

Plastics have many uses. A **plastic** is a molded material that can retain its shape. The word *plastic* is based on the Greek word *plastikos*, which means "to mold." Plastics are organic compounds made up of carbon, hydrogen, and either oxygen or silicon. A few plastics, such as those found in the horns of some animals, occur naturally. However, most plastics are **synthetic**, or made by people. Plastics are made from chemicals, heated, and molded into things such as costume jewelry, automotive parts, toys, bottles, packaging, nd building materials.

▼ The rugged horns of cattle are actually a type of natural plastic.



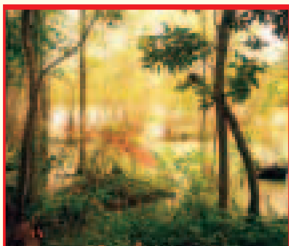
Quick Check

Main Idea and Details Which two elements are common to all plastics?

Critical Thinking Do all organic compounds come from living things? Explain your answer.

Lesson Review

Visual Summary



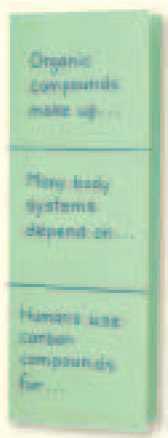
Carbon compounds make up many of the things that surround us.

Organic compounds include nucleic acids, carbohydrates, lipids, and proteins.

Most plastics are **synthetic** organic compounds.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the phrases shown. On the inside of each tab, complete the phrase and provide additional details.



Think, Talk, and Write

1. **Main Idea** Why is carbon essential to life?

2. **Vocabulary** A molded material that can retain its shape is a(n) ________.

3. **Main Idea and Details** The chemical building blocks of all living things are called ________.

Main Idea	Details

4. **Critical Thinking** Explain why carbon monoxide is poisonous.

5. **Test Prep** **Which of the following is NOT an example of an organic compound found in the human body?**
   A protein
   B water
   C carbohydrate
   D lipid

6. **Test Prep** **Proteins are composed of substances called**
   A lipids.
   B carbohydrates.
   C citric acids.
   D amino acids.

Writing Link

Explanatory Writing
Write a paragraph explaining how eating foods that contain proteins helps the cells in your body grow. Include a description of how proteins are broken down.

Health Link

Staying Healthy
In January 2005, the U.S. government made many changes to the Dietary Guidelines for Americans. Research how healthful meals include the carbon compounds that the body needs.

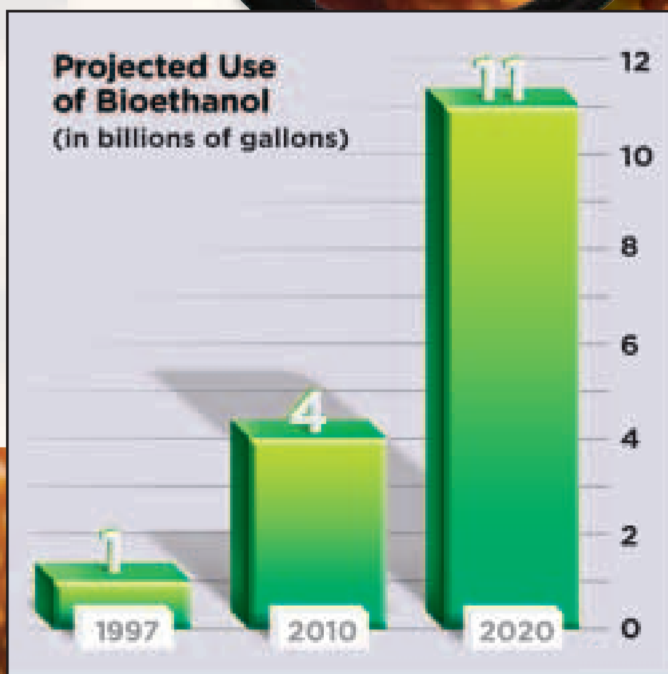
LOG ON e-Review Summaries and quizzes online at www.macmillanmh.com

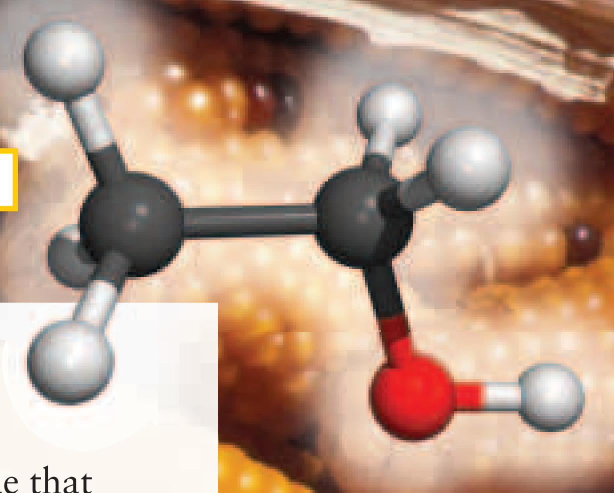
Biofuels

With every energy source come benefits and problems. Many are harmful to the environment, and some are available only in limited amounts. To make sure that we will have energy in the future, scientists are now looking at renewable sources that have a minimal impact on the environment.

Many fuels have organic sources: they are made from the remains of living organisms. Coal, oil, and gas are called fossil fuels because they formed from the remains of prehistoric plants and animals. Fossil fuels are not considered renewable, because they take millions of years to form. Biofuel is another organic energy source. It is fuel made from recently living organisms, and this means that biofuel is renewable.

Burning biofuel releases stored chemical energy in the form of heat. Biofuel has been around since the first campfire. A wood stove uses biofuel. Some countries use biofuel on a large scale to produce heat and electricity for homes and industry.





ethanol molecule

Ethanol is a biofuel used in the United States. It can be made from corn, sugar cane, and other plants. When added to gasoline, ethanol reduces the amount of carbon dioxide that is released into the atmosphere when the mixture is burned. Why don't we use more of it? For one thing, it takes a lot of energy to produce ethanol. Another problem is that most vehicles are not designed to run on ethanol alone. More work is needed to redesign cars to use only ethanol.

Some homes are heated with wood pellets, a biofuel made from recycled wood. The wood is ground into sawdust, compressed into small pellets, and burned in a special stove. Burning these pellets is more efficient than burning oil or wooden logs, and it's cleaner, too.

Why aren't we all using biofuels? Some are not yet widely available, or the fuels are too expensive to produce with current technology. Keep in mind that all biofuels pollute. However, scientists are hard at work in this very promising area.

Write About It

Problem and Solution

1. What problems arise from using fossil fuels?
2. How can using biofuels help solve some of these problems?

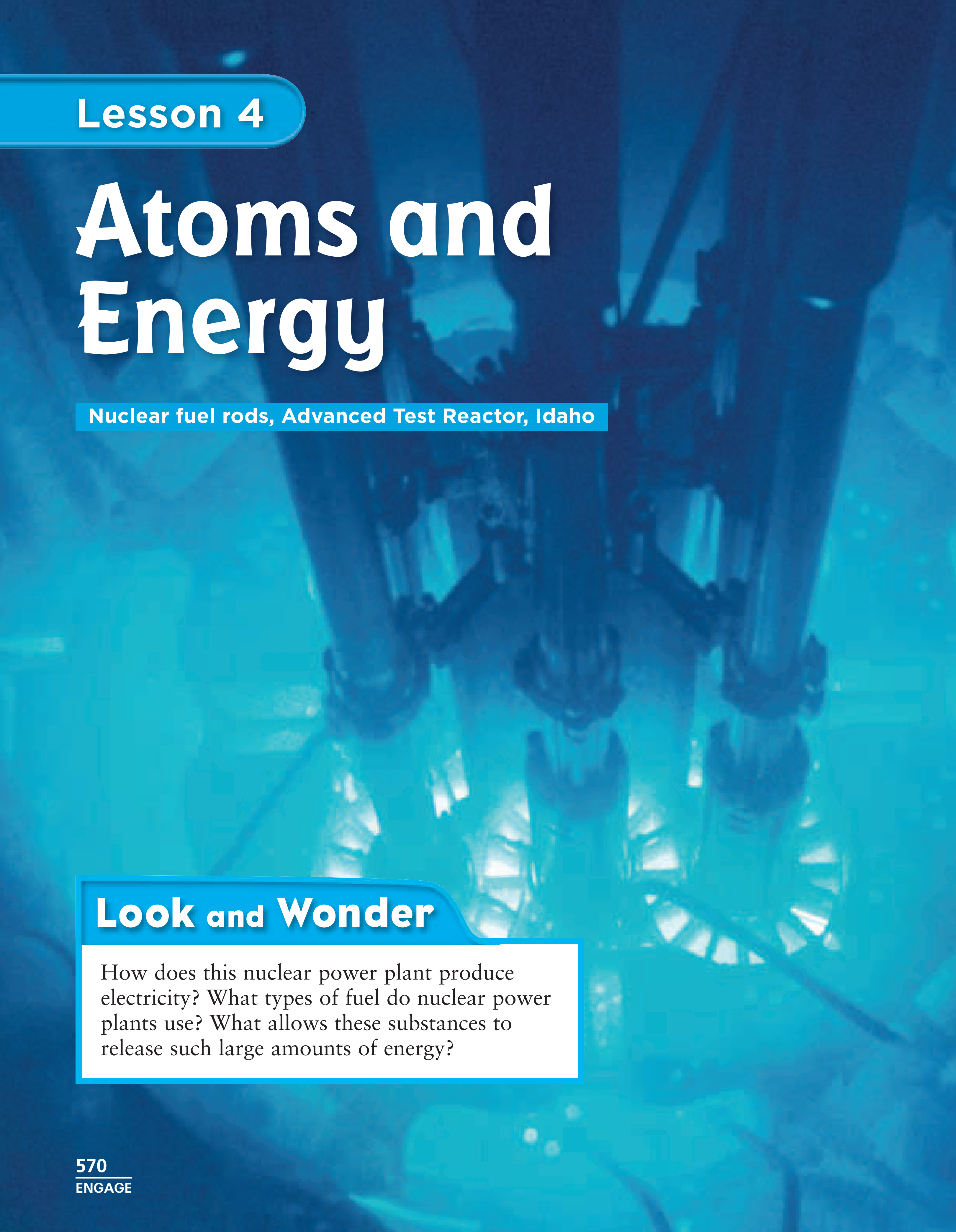
LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Problem and Solution

- Identify the parts of the problem.
- Look for possible solutions.

American Museum of Natural History

Atoms and Energy



Nuclear fuel rods, Advanced Test Reactor, Idaho

Look and Wonder

How does this nuclear power plant produce electricity? What types of fuel do nuclear power plants use? What allows these substances to release such large amounts of energy?

Explore

Inquiry Activity

How can you model radioactive decay?

Make a Prediction

The amount of time it takes for half of a radioactive sample to decay is called its half-life. You will model the radioactive decay of a made-up element called pennium. How many half-lives will it take for your entire sample to decay? Write your answer in the form of a prediction: "It will take ________ half-lives for my entire sample of pennium to decay."

Test Your Prediction

Pennium Atoms

Trial Number	Number at Start	Number That Decayed	Number That Remain	Percent That Decayed
1	100			
2				
3				

1. **Make a Model** Place 100 pennies in a box, making sure that all the tail sides are facing up.
2. **Experiment** Put the cover on the box, and shake it. Open the box, and remove any pennies that now have the head sides facing up. When a penny is head side up, this means the "atom" has "decayed" into a stable form. Write your data on a chart like the one shown.
3. **Record Data** Repeat step 2 until no pennies are left tail side up in the box. Record data for each trial until all pennium atoms have decayed.
4. **Use Numbers** Graph the data you recorded.

Draw Conclusions

5. **Interpret Data** How many trials were needed for the decay of 50 atoms? For the decay of all 100 atoms? Was your prediction correct?

Materials

- 100 pennies
- plastic box with cover
- graph paper

Step 1

Explore More

The half-life of an element can range from a fraction of a second to billions of years. How long would it take for your entire sample of pennium to decay if the half-life were five years? Fifteen years? Fifty?

Read and Learn

Main Idea

Radioactivity releases energy and can be used for detecting and treating diseases.

Vocabulary

radioactive, p. 573
radiation, p. 573
half-life, p. 573
nuclear fission, p. 574
chain reaction, p. 574
nuclear fusion, p. 574

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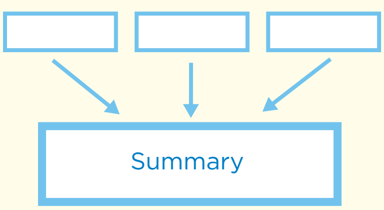
Reading Skill

Summarize



Technology

SCIENCE QUEST

Explore solar radiation with an engineer.

What is radioactivity?

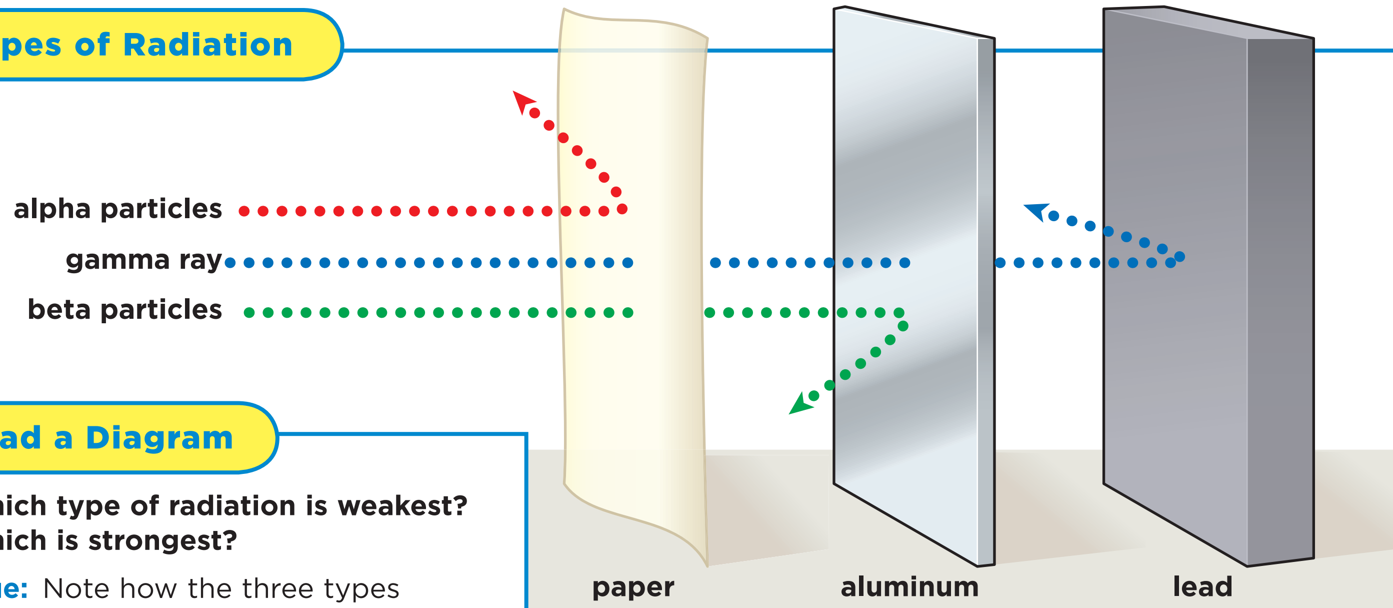
The number of protons in an atom determines what element that atom is. For example, every atom that has 6 protons is carbon. However, atoms of carbon can have different numbers of neutrons. Atoms with the same number of protons but different numbers of neutrons are called isotopes. For example, most potassium atoms have 19 protons and 20 neutrons, but some potassium atoms have 19 protons and 21 neutrons. These are examples of potassium isotopes.

Some isotopes are unstable, because the atoms have too much nuclear energy. These atoms get rid of their excess energy by giving off invisible rays or particles. This was discovered in 1896, when scientist Henri Becquerel found that photographic plates within protective holders could be exposed without light when uranium compounds were nearby. The uranium emitted rays that penetrated the plate holders and exposed the photographic plates. Materials that emit penetrating rays in this way are radioactive.

Marie Curie is the only person to win Nobel Prizes in two science disciplines—physics and chemistry. ▶

◀ Scientists measure the radioactivity of a substance with a Geiger counter.

Types of Radiation



Read a Diagram

Which type of radiation is weakest? Which is strongest?

Clue: Note how the three types penetrate the different materials.

LOG ON *Science in Motion* Watch radiation at www.macmillanmh.com

A **radioactive** element gives off energy in the form of rays or particles. Marie and Pierre Curie discovered and named two radioactive elements, polonium and radium. The energy given off by radioactive elements such as these is called **radiation**. Modern scientists use a Geiger counter to detect radioactivity.

Radioactive Decay and Half-life

As an atom gives off its radiation, the nucleus of the atom decays, or breaks down, into a different chemical element. For example, some atoms of potassium 40 decay into atoms of the element argon. Radioactive elements do not all decay at the same rate. The amount of time it takes for half of an isotope in a sample of an element to decay by emitting radiation is called its **half-life**. For example, the half-life of uranium 238 is 4.5 billion years. This means that in 4.5 billion years, half of the uranium 238 on Earth will have decayed into other elements. In another 4.5 billion years, half of the remaining uranium 238 will have decayed.

There are three common forms of radiation. *Alpha particles* are made of two protons and two neutrons. They are relatively large, heavy, and slow. They cannot penetrate many materials. *Beta particles* are electrons. They are fast, light, and able to penetrate some materials. *Gamma rays* are not particles but electromagnetic waves. They have a short wavelength, which means that they have lots of energy. They can penetrate most materials.

Quick Check

Summarize How are uranium, polonium, and radium alike?

Critical Thinking Would a lead barrier stop a moving beta particle?

What are two types of nuclear energy?

One type of nuclear reaction is called nuclear fission (NEW•klee•uhr FISH•uhn). **Nuclear fission** is the splitting of a nucleus into two or more pieces when struck with a moving neutron. Nuclear fission produces more free neutrons and releases energy.

If enough large nuclei are present, the neutrons released by one splitting atom can strike additional nuclei, causing these additional nuclei to split. These nuclei release still more neutrons, which then split even more nuclei. A single neutron can start a series of events. The first neutron starts a **chain reaction**, a reaction in which the products keep the reaction going.

Because the forces in an atomic nucleus are very strong, the energy released is much greater than the energy produced by chemical reactions. Splitting the atoms in only about 0.25 grams (0.01 ounces) of uranium yields as much energy as burning 454 kilograms (0.5 tons) of coal.

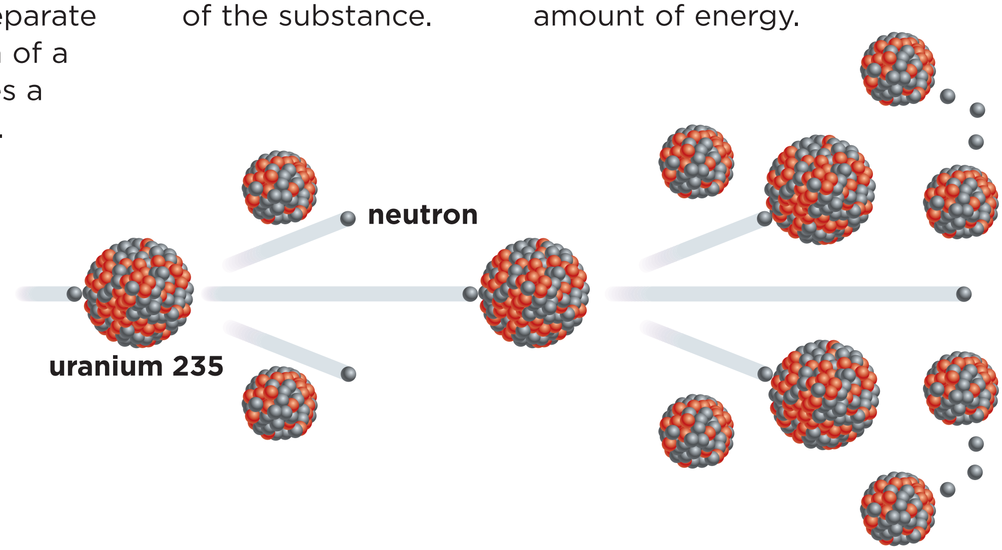
Nuclear Fusion

Splitting nuclei of heavy atoms into smaller nuclei releases energy. Another way to release energy is to merge nuclei with smaller masses to form one nucleus with a greater mass. This process is called **nuclear fusion** (NEW•klee•uhr FYEW•zhuhn). During nuclear-fusion reactions, some of the mass of the merging particles disappears. In the diagram, the helium nucleus at the end has less mass than the hydrogen isotopes from which it was made. Scientists infer that the missing mass is converted into a large amount of energy.

Types of Nuclear Energy

Nuclear Fission

1. A neutron strikes the nucleus of a large atom. The nucleus undergoes fission, splitting into smaller nuclei and several separate neutrons. The fission of a single atom produces a great deal of energy.
2. A neutron from the first fission may trigger the fission of another nucleus of the substance.
3. The chain reaction continues as long as enough atoms are available. The fission of many atoms produces a huge amount of energy.



A nuclear chain reaction is a series of nuclear-fission reactions.

Nuclear-fusion reactions occur only at very high temperatures. The nuclei that merge are positively charged and tend to repel one another. For this reason, the nuclei must be traveling at high speeds to be able to get close enough to fuse. In nature, temperatures high enough for nuclear fusion to happen are found in the cores of stars such as the Sun. Fusion reactions produce vast amounts of energy in the form of heat and light. The energy that is released from fusion reactions enables some stars to shine for billions of years.

Quick Check

Summarize How do atomic nuclei release energy by splitting?

Critical Thinking If a nuclear chain reaction does not start after an atom splits, what might have happened?

Quick Lab

Domino Chain Reactions

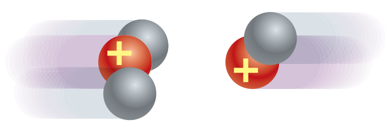
1. **Make a Model** Arrange 15 dominoes standing up on their ends so that no reaction occurs after the first domino is toppled over.
2. Arrange the dominoes standing up on their ends so that toppling the first domino causes a single chain reaction that topples them all.
3. Now arrange the dominoes so that toppling the first one causes more than one chain reaction to occur simultaneously.

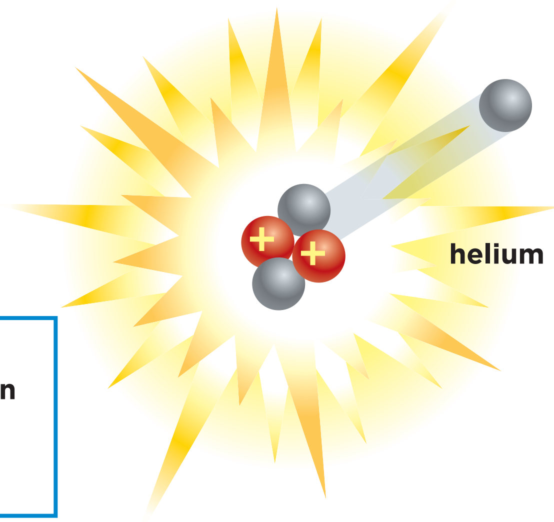
4. **Interpret Data** Compare the three arrangements. How do the three reaction models differ?
5. **Infer** Which of these reactions best represents a nuclear reaction? Explain your choice.

Nuclear Fusion

1. If two small nuclei are traveling extremely fast, they may have enough energy to collide and combine.

2. When the nuclei combine, a larger nucleus is formed, and a tiny amount of the original mass is changed into energy.





Read a Diagram

What is the main difference between nuclear fission and nuclear fusion?

Clue: Compare the fission and fusion reactions.

How is radioactivity used?

Everybody is exposed to very low levels of radiation all the time. This radiation comes from cosmic rays from space, naturally occurring radioactive materials (mostly potassium 40) inside our bodies, and radioactive elements present in the ground.

Radiation can damage or destroy the genetic information that controls how cells grow and divide. However, radiation is also very useful. Doctors use radioactive energy to "see" inside the body and detect diseases. For example, they use radioactive tracers to detect cancer tumors. Radioactive material injected into the bloodstream attaches to tumors, and machines show which parts of the body have an increased level of radioactivity.

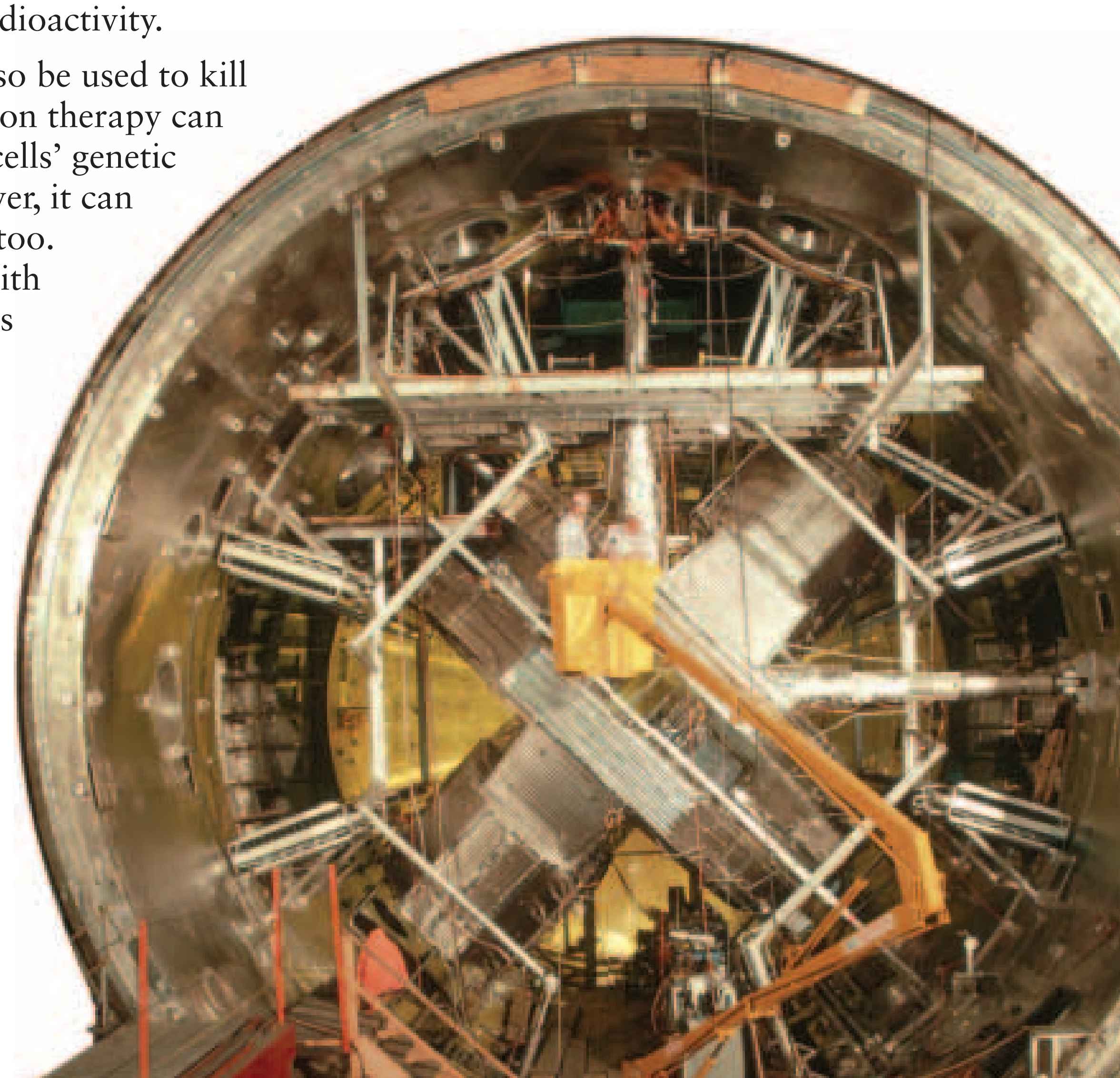
Radiation can also be used to kill cancer cells. Radiation therapy can damage the cancer cells' genetic information. However, it can affect healthy cells, too. People who work with radioactive materials use lead sheets as shields against the harmful effects of long-term exposure.

Radioactive materials are also used to produce electricity. In nuclear reactors, atoms are split apart in controlled chain reactions. Splitting an atom releases a great deal of heat energy. That energy is used in nuclear power plants to heat water to run a turbine in order to produce electricity.

Quick Check

Summarize Why are radioactive tracers used before radiation therapy takes place?

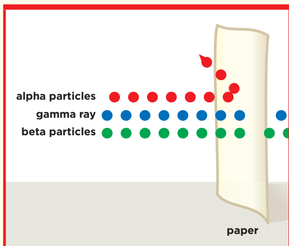
Critical Thinking Why do doctors try to protect themselves and their patients who are receiving radiation therapy?



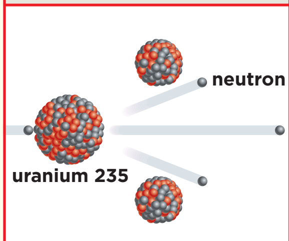
Fusion reactors have the potential to provide a clean and inexpensive source of energy. ▶

Lesson Review

Visual Summary



Radioactive rays can be formed by alpha particles, beta particles, and gamma rays.

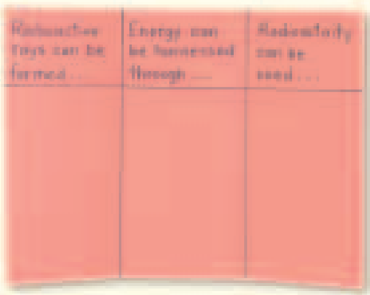


Energy can be harnessed through **nuclear fission**.

Radioactivity can be used to detect and destroy cancer cells and to produce electricity.

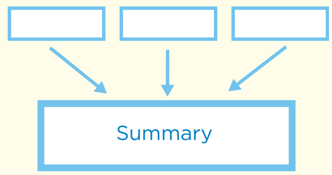
Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the phrases shown. Add other details about atoms and energy.



Think, Talk, and Write

1. **Main Idea** What is radioactivity, and how does it occur?
2. **Vocabulary** A reaction in which the products keep the reaction going is called a(n) ________.
3. **Summarize** How could you find out whether there was radioactivity inside a dark room?

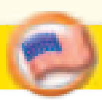


4. **Critical Thinking** An alpha particle, a beta particle, and a gamma ray travel toward a sheet of aluminum 25 centimeters away. What will happen?
5. **Test Prep** **Which is the type of radioactivity that penetrates LEAST?**
   A alpha particle
   B beta particle
   C gamma ray
   D half-life
6. **Test Prep** **Which process involves splitting a nucleus into two or more pieces?**
   A radioactive tracing
   B radiation therapy
   C nuclear fission
   D nuclear fusion

Writing Link

Explanatory Writing

Make a brochure about nuclear fission and nuclear fusion. Explain how each process releases energy.



Social Studies Link

History of Science

Research the career of a scientist who worked on the discovery or uses of radiation. Make a poster about his or her work, and share it with your class.

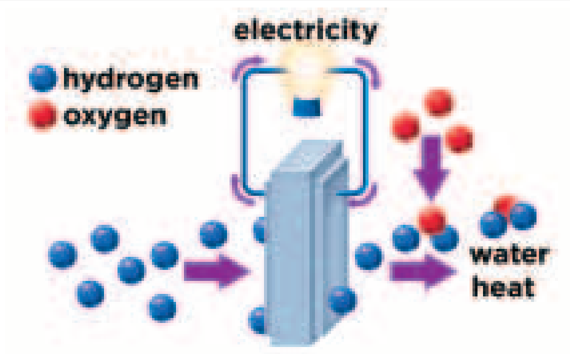
Welcome, Fuel-Cell Cars!

A few years into the future, your family might be driving a fuel-cell vehicle (FCV) instead of a gasoline-powered car. At first sight, these new cars look just like the older ones. The difference is under the hood. Instead of internal-combustion engines that burn gasoline, fuel cells power the FCVs.

The fuel cells produce electricity through a chemical process using hydrogen gas and oxygen from the air. This electricity runs the motors. There is no burning of fossil fuels.

The FCVs have special high-pressure containers with pure hydrogen gas inside. The hydrogen fuel provides electrons to make the electricity and does not produce pollutants that make the air dirty and dangerous to breathe. After fuel cells produce electricity, the hydrogen combines with oxygen, producing water in the form of steam. The FCVs give off puffs of steam as they move along.

In the future, your family might be able to buy hydrogen-gas tanks at "refilling stations." You may even have a home refueling station, with hydrogen-gas containers that you can refill. The cars of the future will certainly be a big change!



A fuel cell takes in hydrogen and oxygen and produces electricity. It also gives off steam.

Explanatory Writing

A good explanation

- tells how something looks, sounds, smells, tastes, or feels
- uses sensory words to describe something
- includes details to help the reader experience what is being described
- may use compare and contrast

Write About It

Explanatory Writing Read about hybrid cars that are powered by both electricity and gasoline. Describe how they work by comparing them to cars powered by gasoline alone.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Math in Science

How Can Scientists Use Carbon to Determine Age?

All living things contain a radioactive form of carbon called carbon 14. Plants obtain it from the carbon dioxide in the air, and animals obtain it by eating plants. When an organism dies, the radioactive carbon decays, or breaks down. The breakdown of carbon 14 proceeds at a constant rate, like the ticking of a clock. Every 5,730 years, half of the carbon 14 left in the remains of an organism breaks down. Because scientists know this rate, they can find out how long ago an organism died by measuring the amount of carbon 14 that is left in its remains.

Solve It

1. If a scientist finds a bone of an animal that died about 5,730 years ago, what percent of the original carbon 14 will the bone contain?
2. After another 5,730 years, what percent of the original carbon 14 will the bone contain?
3. If a scientist determines that an animal bone contains 12.5 percent of its original carbon 14, how long ago did the animal die?

Use Percents

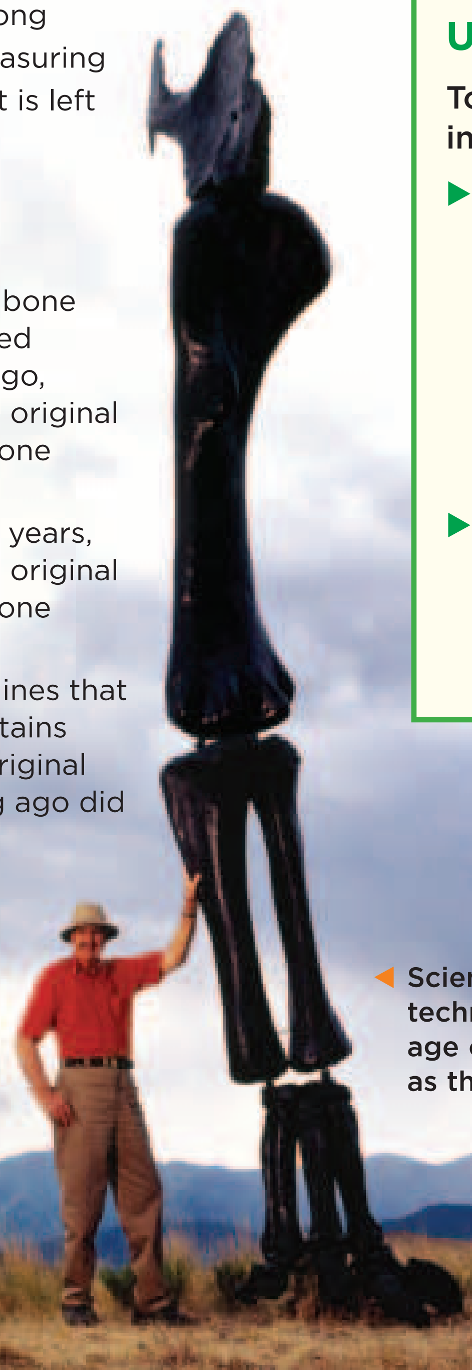
To convert a fraction into a percent,

- **divide the fraction's numerator by its denominator to express the fraction as a decimal**

$$\frac{1}{2} = 1 \div 2 = 0.5$$

- **then multiply the decimal by 100 to express it as a percent**

$$0.5 \times 100 = 50\%$$



Scientists use carbon-dating techniques to determine the age of dinosaur bones, such as the leg of this sauropod.

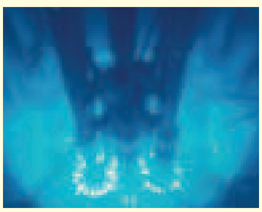
CHAPTER 10 Review

Visual Summary

Lesson 1 Chemical changes come from breaking and forming chemical bonds.

Lesson 2 Different chemical properties help us predict how matter interacts.

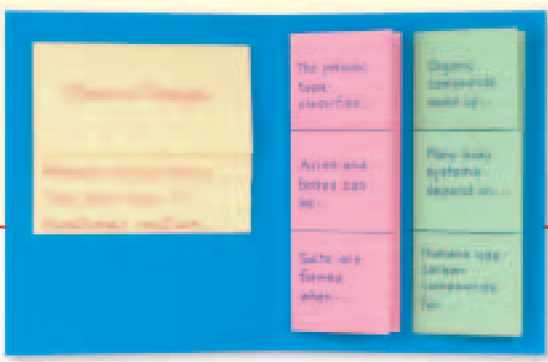
Lesson 3 Carbon and its compounds are found in the world around you.



Lesson 4 Radioactivity releases energy and can be used for detecting and treating diseases.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

base, p. 554
chemical change, p. 542
chemical property, p. 552
half-life, p. 573
organic compound, p. 562
plastic, p. 566
radiation, p. 573
reactant, p. 543

1. The amount of time it takes for half of the isotopes in a sample of an element to decay by emitting radiation is called its ________.
2. The formation of rust on an iron nail is an example of a(n) ________.
3. Unstable elements such as uranium give off ________.
4. A molded material that can keep its shape is called a(n) ________.
5. The way a substance reacts to other substances is a(n) ________.
6. A substance present before a chemical change is called a(n) ________.
7. A substance that will turn red litmus paper blue is a(n) ________.
8. A carbohydrate is a kind of ________ that is found in grain foods and sugars.

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Skills and Concepts

Answer each of the following in complete sentences.

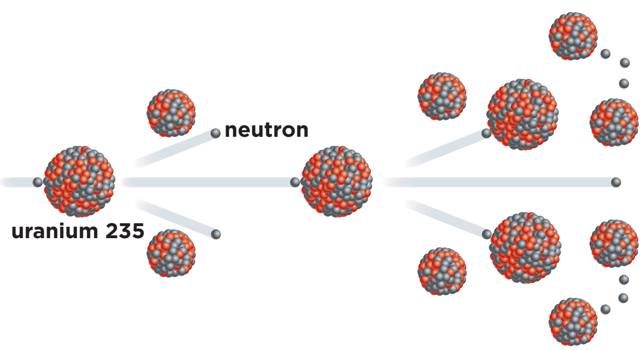
9. **Cause and Effect** Suppose that when you mixed two liquids together, a white solid formed in the liquid. What most likely caused this solid to form?

10. **Expository Writing** Explain three ways in which people use radioactivity.

11. **Form a Hypothesis** When you combine baking soda and vinegar in a container, a chemical reaction quickly occurs, producing many bubbles and making the substance overflow. If you try the experiment again using orange juice, a weaker acid, instead of vinegar, what do you think will happen?

12. **Critical Thinking** As a substance decays, it gives off carbon-dioxide gas. What kind of matter is most likely found in the substance? Explain your answer.

13. **Interpret Data** Does the diagram below show nuclear fission or nuclear fusion? Explain your answer.



The Big Idea

14. How are chemical reactions a part of your daily life?

Performance Assessment

Find the Carbon!

Read the nutrition facts on food packages, and identify carbon compounds.

What to Do

1. Select packaged foods with many ingredients. Identify the carbon compounds that each food contains.
2. Determine which ingredients might be a source of carbon compounds. Use a chart like the one shown to record your findings.

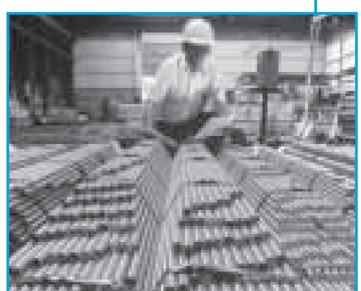
Food	Carbon Compound	Ingredients

Analyze Your Results

- Write a paragraph explaining why carbon compounds are an important part of the food people eat.

Test Prep

1. Titanium is an element in the middle of the periodic table. It is hard and shiny, and it reacts slowly with other substances.



How is titanium classified?

A as a transition metal

B as an alkali metal

C as an alkaline earth metal

D as a metalloid

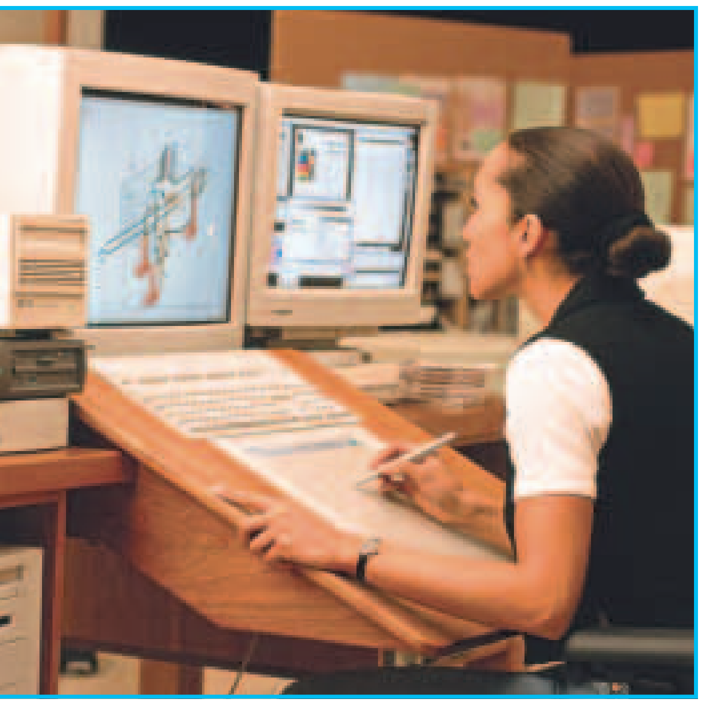
Careers in Science

Chef

Do you enjoy mixtures that make a tasty salad or chemical reactions that produce fluffy pancakes? Do you delight in butter's phase change to a creamy liquid oozing over golden kernels of corn? If so, you may be a candidate for a career as a chef. Chefs plan and prepare meals in schools, in restaurants, on cruise ships, and even in the White House. Many cooks prepare for their careers by completing high-school vocational courses or learning on the job. Chefs tend to have more training, such as cooking-school programs or apprenticeships.

▲ Adding flavor to food is one of a chef's tasks.

▼ Talented illustrators like this woman made the art for this book.



Science Illustrator

If you are interested in science and enjoy working with art and design, you might consider a career as a science illustrator. People in this field design illustrations of items such as molecules, animals, plants, landforms, and planetary systems. Their illustrations are used in science books, magazines, and other publications. Science illustrators need drawing skills and a knowledge of computer-design programs, which are often used to prepare illustrations. In addition, illustrators need a strong background in science. Many science illustrators obtain a bachelor's degree in art or design as well as specialized training in science. Others begin with a degree in science and then pursue further study in art to develop their skills.

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UNIT F

Forces and Energy

This monorail runs so quietly that stations were even built inside of buildings.

Sydney, Australia

Literature

National Wildlife Federation

Ranger Rick

Magazine Article

Out Of Sight!

We open our eyes each day trusting that what we see is really there. As strange as it may seem, however, other animals see the same world in very different ways. What the world looks like—and therefore what is "real" to you—depends on your sense of sight.

The Spectrum: How Animals See It

We see the part of the electromagnetic spectrum called visible light. This light—in red, orange, yellow, green, blue, and violet—illuminates our world. All the radiation beyond these frequencies is invisible to us. Certain other animals, though, have a visible spectrum that extends beyond ours. We can only begin to imagine how they see the world.

Bees: Flower Finders

A bee's visible range is shifted slightly toward the higher-frequency end of the spectrum. Bees do not see the color red. They do see beyond violet into the ultraviolet range. Our eyes cannot detect ultraviolet light, but we can use an ultraviolet filter to get an idea of what a bee sees. Amazingly, some flowers that look white to us are a bright shade of

flower seen in normal light

flower seen in ultraviolet light

blue-green to bees. Other flowers are decorated with patterns and lines. Like lights on an airport runway, they guide a bee in for a landing and direct it to the center of the flower. There, the bee gathers nectar and may pollinate the flower.

Pit Vipers: Heat Hunters

Beyond our visible spectrum on the opposite side is the infrared range. Although we cannot see infrared radiation, we feel it on our skin as heat. Other animals sense heat with much greater accuracy. Snakes called pit vipers see as we do through their eyes, but they have other sensory organs between their eyes and nostrils. These "pits" detect very slight variations in heat. This means that the snakes can sense warm-blooded prey even in darkness. A hungry snake "sees" a mouse because the animal's warm body stands out from the cooler environment around it. The snake adds this information to what it sees with its eyes to produce a picture of the mouse's exact location.

pit viper

Write About It

Response to Literature This article compares the ways in which different animals see. What role does light play in sight? Think about how things look during the day and at night. Write a brief essay about an indoor or outdoor scene, comparing how it looks to you during the day and at night.

LOG ON e-Journal Write about it online at www.macmillanmh.com

CHAPTER 11

Exploring Forces

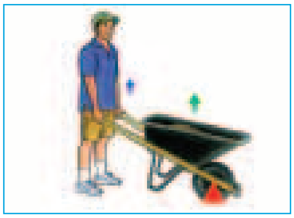
The Big Idea

How is energy used and stored?

A magnetic cube floats above a cold superconducting ceramic disk.

Key Vocabulary

weightlessness
The state of being without detectable weight. (p. 610)



lever
A simple machine consisting of a rigid bar and a pivot point. (p. 630)

wheel and axle
A simple machine that consists of a wheel that applies an effort force and a smaller axle that produces output force. (p. 632)

pulley
A grooved wheel that turns by the action of a rope in the groove. (p. 632)

inclined plane
A straight, slanted surface that can multiply an effort force. (p. 634)

screw
A simple machine made of an inclined plane wrapped around a central bar that can multiply an effort force. (p. 634)

More Vocabulary

distance, p. 590

position, p. 590

motion, p. 590

speed, p. 592

velocity, p. 592

acceleration, p. 593

force, p. 594

friction, p. 596

momentum, p. 607

work, p. 616

energy, p. 618

potential energy, p. 618

kinetic energy, p. 618

thermal energy, p. 618

power, p. 622

simple machine, p. 628

mechanical advantage, p. 629

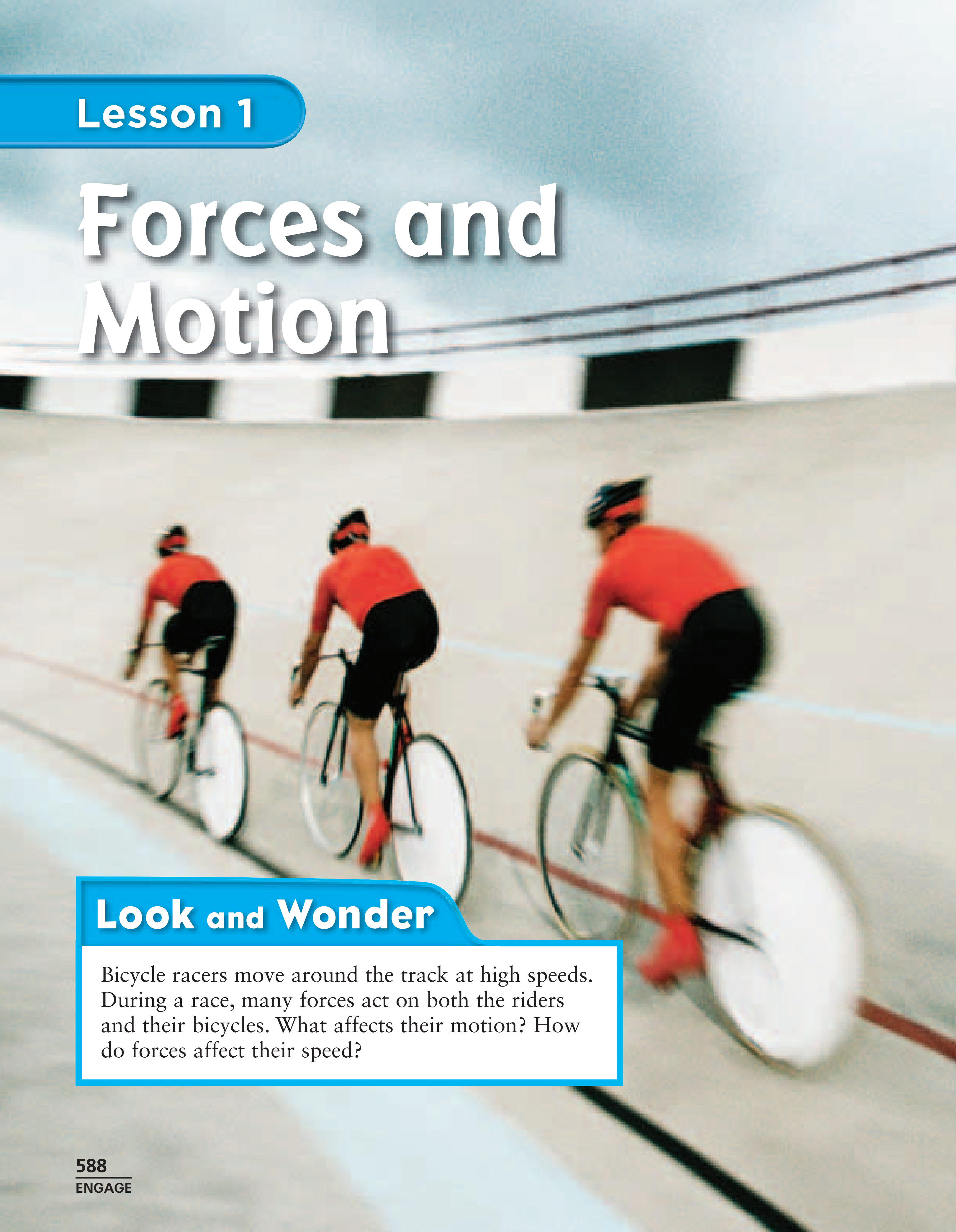
wedge, p. 635

compound machine, p. 636

efficiency, p. 636

Lesson 1

Forces and Motion



Look and Wonder

Bicycle racers move around the track at high speeds. During a race, many forces act on both the riders and their bicycles. What affects their motion? How do forces affect their speed?

Explore

Inquiry Activity

How can you tell how fast things move?

Purpose

How can you determine how fast an object is traveling? See whether you can determine which of two different toy cars is faster.

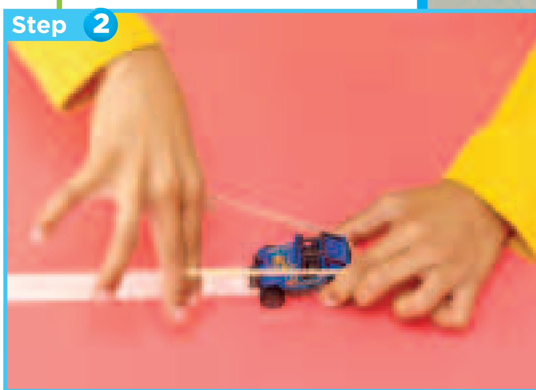
Materials

- 2 different toy cars
- masking tape
- large rubber band
- stopwatch (or watch with a second hand)
- meterstick
- calculator

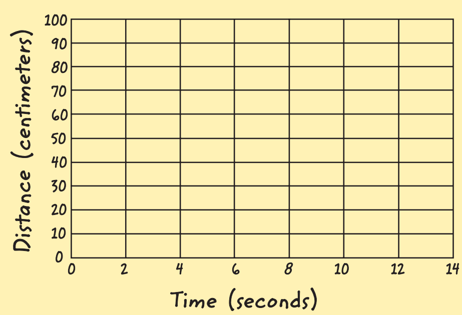
Procedure

1. Label the cars *Car 1* and *Car 2*. Place a long piece of masking tape on a smooth surface.
2. **Experiment** Hold car 1 over one end of the tape. Stretch a rubber band with two fingers. Place the toy car against the rubber band, and pull the car and rubber band back about 6 cm with the other hand. Release the car, and have a partner measure the time that it is in motion.
3. **Measure** Mark the masking tape where the car came to a stop. Record the distance from the start to the finish in centimeters.
4. Repeat steps 2 and 3 with car 1. Repeat steps 2 and 3 twice with car 2.
5. **Interpret Data** Average the results of each car's trials. Organize your data in a line graph like the one started here. Graph distance in centimeters on the *y*-axis and time in seconds on the *x*-axis. Label the lines *Car 1* and *Car 2*.

Step 2



Step 5



Draw Conclusions

6. **Interpret Data** Which car moved the greater distance? Which car was in motion longer?
7. **Draw Conclusions** Which car do you think moved faster? Explain your reasoning.

Explore More

If you tape coins to the top of the faster car, will your results for this car differ? Design an experiment to test your prediction.

Read and Learn

Main Idea

Change of position, velocity, and acceleration are three characteristics of motion.

Vocabulary

distance, p. 590
position, p. 590
motion, p. 590
speed, p. 592
velocity, p. 593
acceleration, p. 593
force, p. 594
friction, p. 596
Newton's first law of motion, p. 600

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Reading Skill

Summarize

Summary

What is motion?

Have you ever given someone directions to a location or used a map to find your way? When you are traveling, you might use a map to find a location. When you explain to someone how to get somewhere, you most likely indicate direction, which describes which way you have to go to find where a place is located. You are also likely to indicate **distance**, which is the length between two places. Using distance and direction can help you identify the position of something. An object's **position** is its location compared to other things.

Runners can use position to tell where they are in a race. The start line is a reference mark. This mark shows the runners' positions in relation to a fixed location. The runners can detect changes in their positions by observing the objects, such as the start line, that remain still while the runners are in motion. **Motion** is a change in an object's position compared to a fixed object. If you ride in a car, your position changes compared to a tree or a telephone pole.

Your position in relation to the seats, dashboard, and other parts of the car does not change, so you are motionless within the car. When you ride in a car, the trees and buildings appear to you to move backward. This movement is *apparent motion*, when things appear to an observer to be moving but are not actually changing position. You use apparent motion to determine what direction you are moving in and to find out how fast you are really moving.

Quick Check

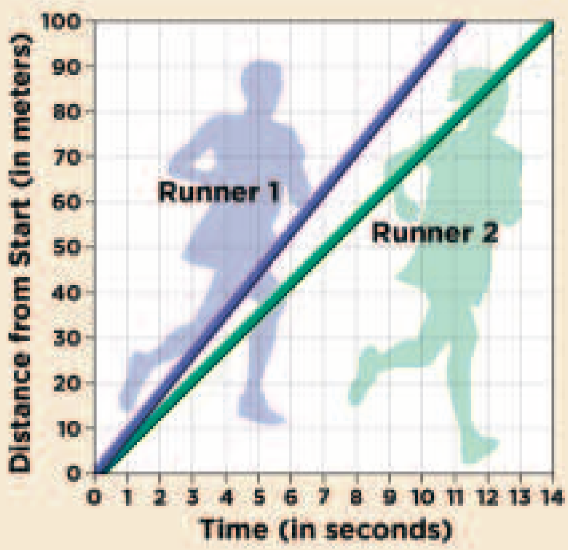
Summarize What are two things you must know to describe the relative position of an object?

Critical Thinking How can you tell which train is in motion if the train next to the one in which you sit appears to be rolling backward?

Distance and Time

Distance Traveled

Time (in seconds)	Distance from Start (in meters)	
	Runner 1	Runner 2
0.0	0.0	0.0
1.0	9.1	7.1
2.0	18.2	14.3
3.0	27.3	21.4
4.0	36.4	28.6
5.0	45.5	35.7
6.0	54.5	42.9
7.0	63.6	50.0
8.0	72.7	57.1
9.0	81.8	64.3
10.0	90.9	71.4
11.0	100.0	78.6
12.0		85.7
13.0		92.9
14.0		100.0



Read a Graph

How far did each runner travel in 8 seconds? Which runner was faster?

Clue: Trace a line up from 8 seconds on the *x*-axis.

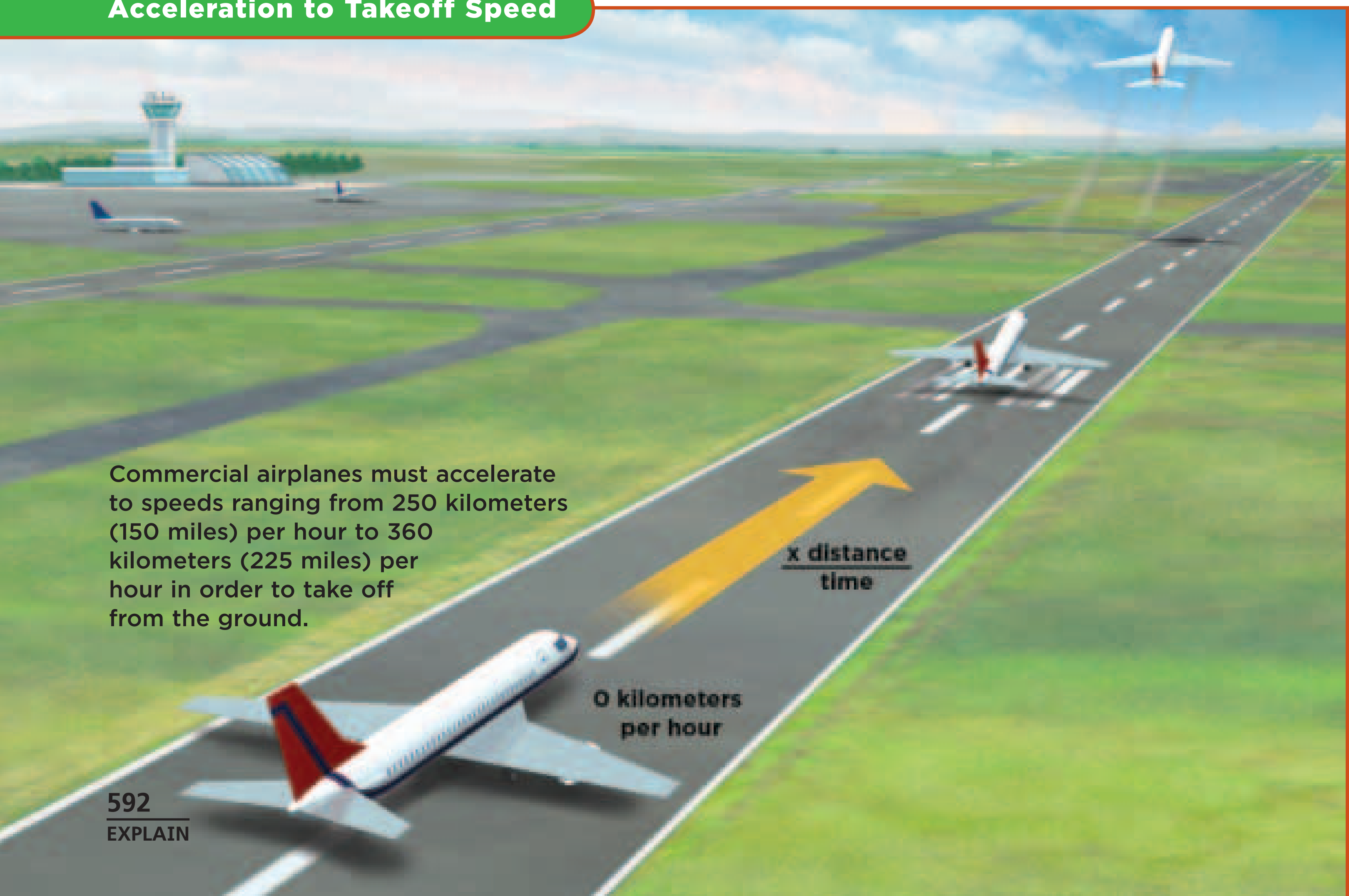
What are speed, velocity, and acceleration?

When you describe how fast something is moving, you are describing its speed. **Speed** is how fast an object's position changes with time at any given moment. Speed is calculated by dividing the distance traveled by the time taken to travel. A car with a speed of 80 kilometers (48 miles) per hour is going faster than a car traveling at 70 kilometers (42 miles) per hour. The first car moves at a faster speed because it travels a greater distance than the second car travels in the same amount of time.

Most moving objects do not travel at the same speed at all times. If you are standing still, you have a speed of zero. If you walk or run, your speed increases. The actual speed at which an object travels is likely to vary, depending on when it is calculated. For this reason, it is useful to calculate an average speed. The *average speed* of a moving object is the total distance traveled divided by the total amount of time.

For example, to figure out the average speed of a car that traveled 60 kilometers (37 miles) in 2 hours, you would divide by 2. The result would be an average speed of 30 kilometers (18.5 miles) per hour. That car may have stopped at some stop signs or traveled faster than 30 kilometers (18.5 miles) per hour for part of the time, but its average speed is calculated using only the total time and the total distance.

Acceleration to Takeoff Speed



Commercial airplanes must accelerate to speeds ranging from 250 kilometers (150 miles) per hour to 360 kilometers (225 miles) per hour in order to take off from the ground.

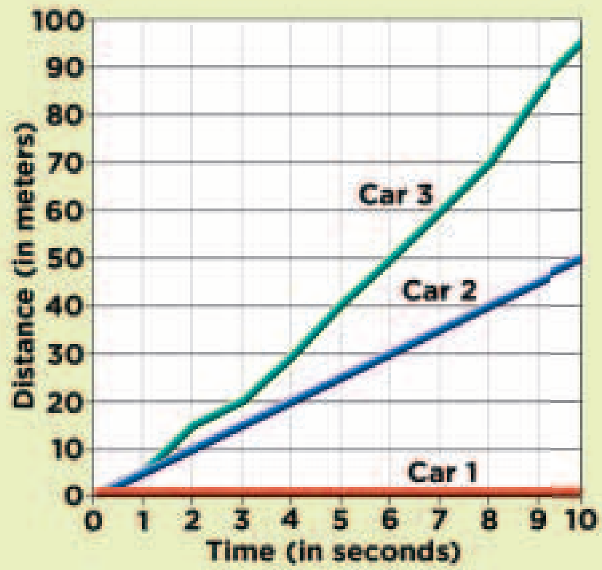
If you know both the speed of an object and the direction in which it is moving, then you know the object's velocity. **Velocity** is a description of a moving object's speed and direction. When you know the velocity and present position of an object, then you should be able to predict where it will be located after a certain amount of time.

If an object travels in a straight line at a steady speed, its velocity is constant. Any change in the speed or direction of an object causes its velocity to change. **Acceleration** is a change in the velocity of an object over time. Like velocity, acceleration also has both size and direction. If the velocity of the moving object increases with time, then the acceleration is in the direction of the velocity. If the velocity of the moving object decreases with time, then the acceleration is in the direction opposite the velocity.

Many people think of acceleration as an object's either speeding up or slowing down. However, an object can accelerate while maintaining the same speed. For example, if a car moved at a constant speed and turned a corner without changing its speed, the change in direction would be a change in the velocity of the car. This means that the car is actually accelerating.

People who ride on a merry-go-round also experience acceleration. When the ride begins, the speed of the merry-go-round increases from zero.

Speed and Acceleration



One graph can show both speed and acceleration.

Which car has an average speed of 5 meters per second?

Which two of the cars had a constant acceleration?

Which car was the fastest?

The riders undergo a steady change in both speed and direction, which is acceleration, as the ride moves. Once the ride maintains a constant speed, the riders continue to accelerate. This is because they continuously change direction, even though their speed is constant. As the ride slows down, the riders still experience acceleration as the speed decreases and eventually reaches zero once again.

Quick Check

Summarize How can you find the average speed of a runner?

Critical Thinking What are two ways in which a bus could accelerate?

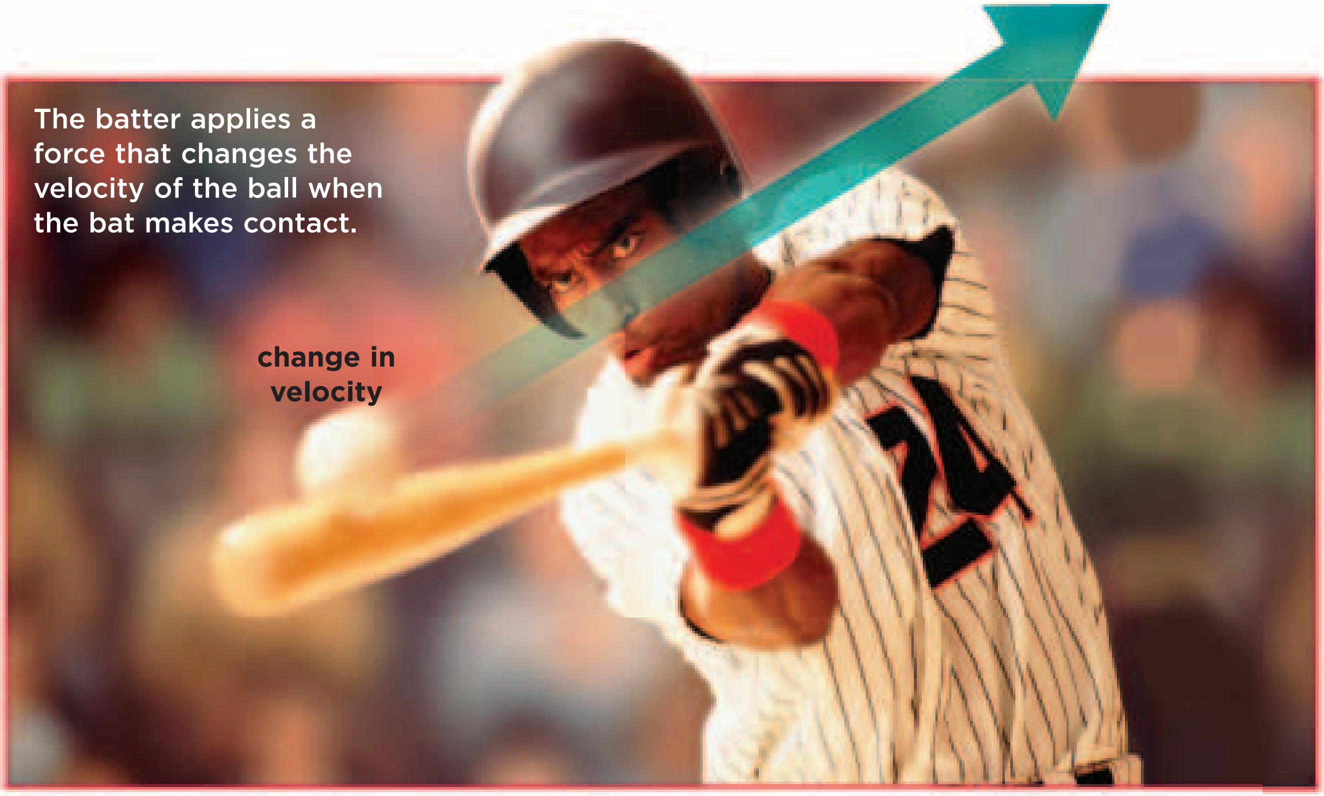
The rocket's engine applies a downward force, which then pushes the rocket and the shuttle upward.

What is a force?

There are many factors that can affect the motion of an object. A ball can change direction because it bounces off a wall, or a magnet can move an iron nail. Any push or pull on an object is a **force**. Forces can cause a moving object to accelerate. This happens when a person pulls a wagon, when a tugboat pushes a barge on a river, when you press on the brakes on a bicycle, or when gravity keeps Earth in orbit around the Sun. Anyone who has ever been on a roller coaster has felt the effects of forces. The cars are pulled to the top of a hill, and then they accelerate positively as they rapidly move downward. When the cars reach the bottom of the hill, they accelerate negatively as they slow down and eventually stop.

A force constantly applied to an object is a *continuous force*. There are many examples of continuous forces. The downward force of Earth's gravity on all objects is a continuous force called weight. Continuous forces change the motion of rockets as they blast off from Earth. A rocket engine provides *thrust*, which is a strong push in the direction opposite an object's weight. Thrust causes the rocket to accelerate upward, away from the launch pad. This thrust will continue to be applied as long as the rocket engine burns fuel.

Airplanes also rely on continuous forces. Thrust from the airplane's engine accelerates it down the runway. As the airplane moves faster, the shape and tilt of its wings causes air to move even faster over the top of each wing than it does below the wing. *Lift* then provides an upward force that helps make it possible to fly. You can even test this idea yourself. Hold a strip of paper in front of you by one end. Make the air above it move faster by blowing air quickly along the top edge of the paper. You will notice that the paper rises up and straightens itself out.



Kinds of Forces

Lift, like thrust, is a continuous force. As long as an airplane keeps moving, the wings provide lift to balance the weight of the airplane and keep it up in the air.

Not all forces are continuous. A moving object sometimes collides with another object, causing a change in velocity. This is called a *momentary force*. One example of a momentary force is when a baseball player hits a baseball with a bat. First, the pitcher throws the ball toward the batter. Then, the batter swings the bat. When the bat makes contact with the ball, the momentary force applied by the bat causes the ball to accelerate in another direction. The force applied by the bat is limited and does not keep continuously acting on the ball. However, it is important to remember that other forces, such as gravitational force, do act on the ball continuously.

Forces can also change the shapes of objects. When you mold clay, your hands apply forces that squeeze the clay into a different, permanent shape. The new shape is considered permanent because the clay will stay that shape unless another force is applied and changes the shape once again. When you pull on a rubber band with moderate force, you stretch out the rubber band and change its shape, but only temporarily. If you pull too hard on the rubber band, you can break it, changing its shape permanently.

Quick Check

Summarize How can a force affect an object?

Critical Thinking How is a continuous force able to make a rocket speed up and move away from its launch pad?

What are some forces?

There are different kinds of forces that push and pull on objects. Buoyancy is a force that pushes up on floating objects in a fluid. Magnetic force attracts or repels certain objects. Gravitational force is an attraction that exists between any two objects, such as the gravity that pulls objects toward Earth.

The metric unit that measures force is the *newton*. The force of gravity on a 1-kilogram object is about 10 newtons (2.2 pounds). A newton produces an acceleration of 1 meter per second squared when applied to a mass of 1 kilogram. A spring scale is used to measure newtons. The spring stretches when force is applied to it. You can measure the force needed to slide a book across a table by connecting a spring scale to the book and pulling on the spring scale. As you pull, the spring stretches, and the pointer on the scale shows how many newtons of force are needed to slide the book across the table.

Friction

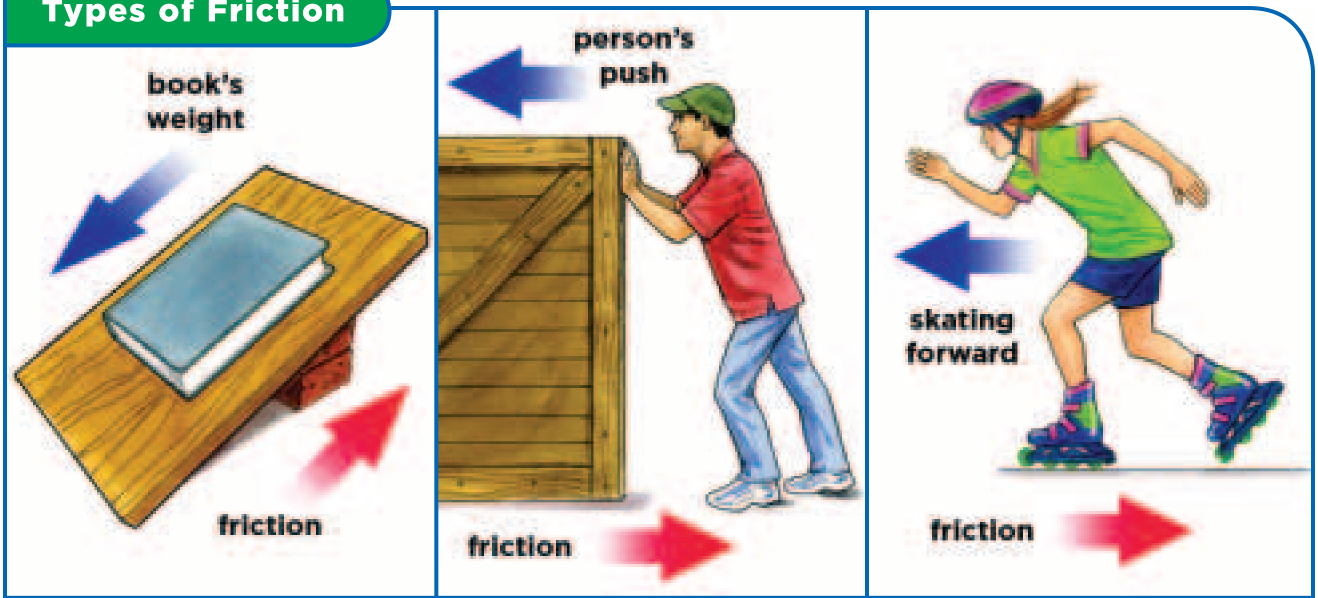
As the book is pulled across a table, a force works against this movement. **Friction** is a force that opposes the motion of an object. Friction occurs when two or more objects come into contact. In order to move the book across a table, you must pull on it with a force larger than the force of friction.

There are many types of friction. For example, the force between the surfaces of two solid objects which keeps the objects from moving is called *static friction*. Static friction keeps a book from starting to move across a table as a breeze blows through an open window. *Sliding friction* is the force that opposes the sliding of an object over a surface. You feel sliding friction as you move a book across a table. The force of sliding friction is less than that of static friction. Rolling friction is what opposes the motion of a wheel turning along a surface. The force of rolling friction is less than that of sliding friction.

Measuring Force

A spring scale can be used to measure the force needed to slide a book across a table.

Types of Friction



Static friction opposes the downward force and keeps the book in place.

In **sliding friction**, the forces act in opposite directions as the box is moved along.

Rolling friction between the skate wheels and the ground slows the skater down.

Changing and Using Friction

Wheels and rollers are used to reduce friction by replacing sliding friction with rolling friction. Wheels reduce the amount of friction that opposes the motion of an object. If you want to accelerate your bicycle, either to speed up, to stop, or to turn a corner, friction is necessary. As long as the wheels do not skid or slip, there will be static friction between the wheels and the road. This friction is what allows you to change your acceleration or velocity.

Drag Force

When an object moves through any liquid or any gas, such as air, a force called *drag force* opposes the motion. Drag force occurs when molecules in the fluid bump into a moving object and slow it down.

Friction and drag force are similar because both forces oppose motion. However, different types of friction do not depend directly on the size, shape, or speed of a particular moving object. In contrast, all three of these factors do affect drag force.

For example, a crumpled piece of paper falls faster than another piece of the same paper that is not crumpled. This occurs because of the way that air affects differently shaped objects. If there were no air molecules present, then the two pieces of paper would fall at exactly the same speed.

Quick Check

Summarize How are newtons related to force?

Critical Thinking In what situation might you want to increase friction?

How do forces affect each other?

If you have ever walked a dog on a leash, you have observed many interactions of forces. When you and the dog stand still or when you move together at a constant and equal speed, you both exert the same amount of force on the leash. As a result, it seems as if there is no force acting on the leash at all. When this happens, the net force is zero. *Net force* is the sum of all the forces that are acting on an object.

It is also possible for three or more forces to offset one another and balance. For example, a sign may be held up by two chains. The weight of the sign pulls it downward. This pull causes the sign to tug on the chains. The chains, in turn, pull up on the sign. The sign does not move up or down, because all three of the forces acting on it offset one another and are balanced.

Balanced Forces

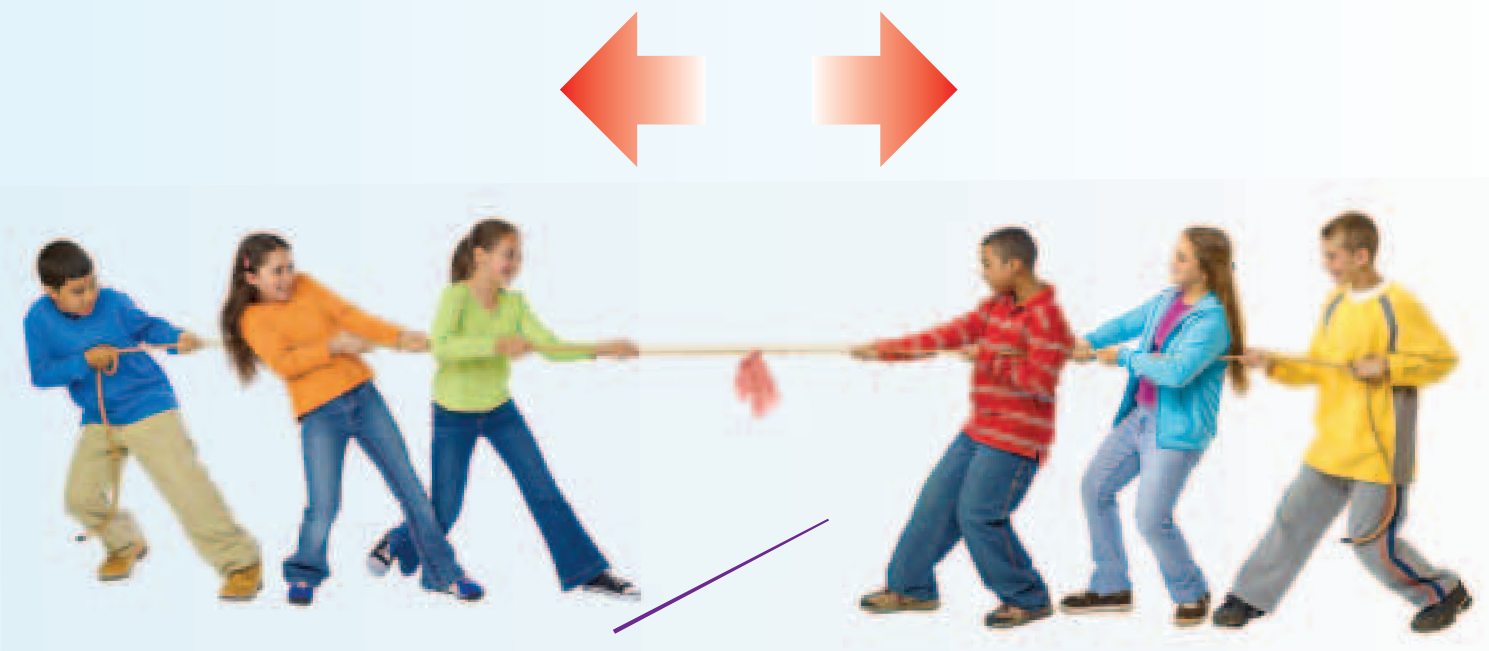
When the net forces are equal in strength and opposite in direction, they are *balanced forces*. The motion of an object remains unchanged when forces are balanced. It does not matter whether the object is motionless or moving at a constant velocity.

Unbalanced Forces

Forces of unequal strength or forces that are not opposite in direction are called *unbalanced forces*. Picture yourself walking a dog on a leash. If you stop at a corner and the dog decides to move down the road, then the dog will pull in that direction.

Balanced and Unbalanced Forces

Balanced Forces
Each team pulls with the same amount of force.



If the force of the dog pulling on the leash is greater than the force that you exert while pulling on the leash, then the leash, the dog, and you will all move down the road. Unbalanced forces cause changes in motion, always in the direction of the greater force.

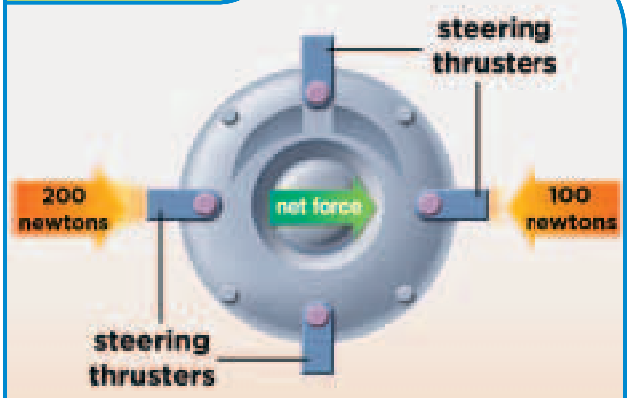
In the rocket diagram on the right, unbalanced forces cause a change in the rocket's velocity. The difference in the forces of the different steering thrusters causes velocity to increase in the direction of the greater push.

Quick Check

Summarize How do balanced forces and unbalanced forces differ?

Critical Thinking If a mover pushes on a large box but it does not move, what is the net force on the box?

Net Force

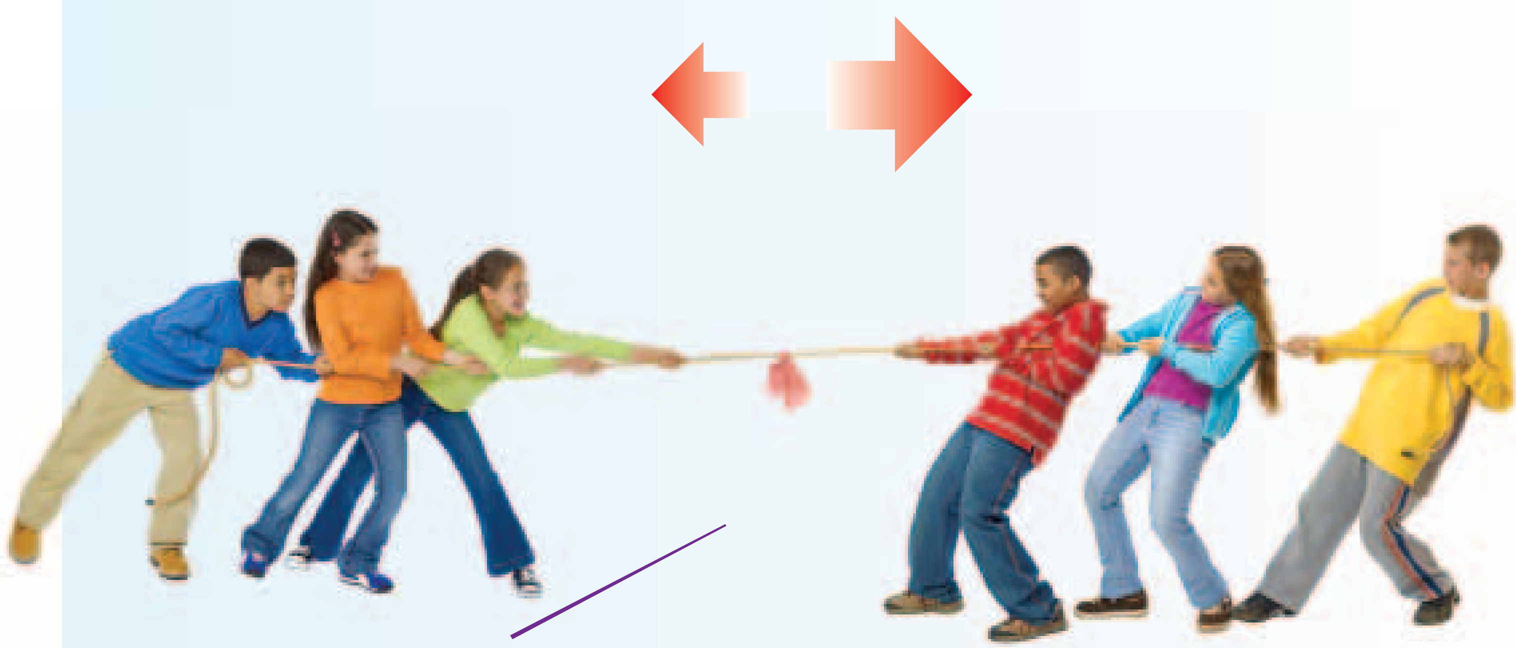


A rocket's motion changes because the forces from the steering thrusters are unbalanced.

Read a Diagram

What is the strength of the net force?

Clue: Compare the forces produced by the steering thrusters on either side.



Unbalanced Forces
One team pulls with more force than the other.

Quick Lab

Investigating Inertia

1. **Experiment** Attach a thread to a playing card, and place a coin on the card.
2. **Observe** Pull slowly on the thread. How does the coin move?
3. **Observe** Now pull on the thread very rapidly. What does the coin do?
4. **Infer** At the start the coin and the card were at rest. Why would they naturally tend to stay at rest?
5. What did the thread do when you pulled on it?
6. **Communicate** Explain why the coin moved differently in step 2 and step 3.

Inertia causes a crash-test dummy to move forward when a vehicle stops suddenly. ▼

What is inertia?

Newton's first law of motion states that an object at rest tends to stay at rest and that an object in motion will remain in motion. In other words, an object moving in a straight line at a constant speed tends to keep moving that way. According to this law, the way to change an object's velocity is to apply an unbalanced net force to it.

Think about a ball resting in the aisle of a bus that is moving at a constant velocity. When the driver steps on the brakes, the bus slows down, and the ball rolls toward the driver. Why? The bus and the ball moved at the same velocity. The brakes provided a force that changed the velocity of the bus. However, the ball was not attached to the bus, so it kept moving forward. The ball would have continued moving until it met a force that changed its velocity.

The ball exhibited *inertia*, which is the tendency of an object to keep moving at the same speed and in the same direction. Inertia is the reason the ball kept moving even though the bus slowed down. Passengers in a moving car also feel the effects of inertia. If a vehicle stops quickly, the passengers can feel their bodies move forward. Cars are equipped with seat belts and air bags to minimize the injuries that can result from inertia.

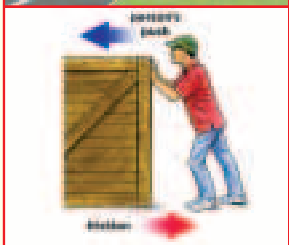
Quick Check

Summarize What is Newton's first law of motion?

Critical Thinking How does wearing a seat belt in a moving car help protect you?

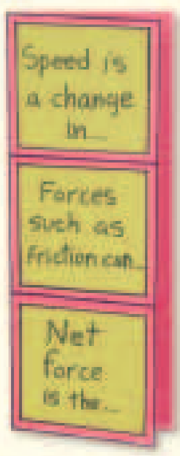
Lesson Review

Visual Summary

	**Speed** is a change in an object's position divided by the time needed to make that change.
	**Forces** such as **friction** can affect an object by changing its speed, direction, or shape.
	**Net force** is the sum of all the forces that act on an object. Forces may be **balanced** or **unbalanced**.

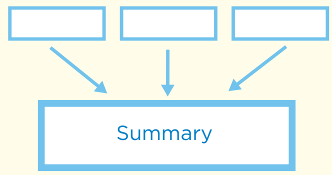
Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide supporting details.



Think, Talk, and Write

1. **Main Idea** What are four ways to describe motion?
2. **Vocabulary** A force that opposes the motion of an object is called ________.
3. **Summarize** Describe two types of friction.



4. **Critical Thinking** Why do movers strap large pieces of furniture to the inside walls of moving vans before beginning to drive?
5. **Test Prep** **If two students pull a wagon in opposite directions but the wagon does not move, the forces acting on the wagon are**
   - **A** accelerating negatively.
   - **B** unbalanced.
   - **C** accelerating positively.
   - **D** balanced.
6. **Test Prep** **The total distance traveled by an object divided by the total amount of time needed to travel equals the**
   - **A** average speed.
   - **B** friction.
   - **C** average acceleration.
   - **D** net force.

Math Link

Calculate Average Speed

It takes Mrs. Watson 1 hour and 30 minutes to drive 90 kilometers. Explain how she could find her average speed. (Hint: Express the time in hours.)

Social Studies Link

Investigate Seat-Belt Laws

Research the seat-belt laws in your state. Discover what the laws say, how they are enforced, and what penalties an unbuckled rider may receive. Share your findings in an oral report.

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Focus on Skills

Inquiry Skill: Predict

When scientists **predict**, they make a reasonable statement about what might happen under certain conditions. They base their predictions on background knowledge and experience. Then they test their predictions.

Learn It

To test a prediction, scientists make observations. They may find that their observations confirm the prediction. In other words, they may find out that they were correct. Usually, however, this is not the case—at least not the first time. Most of the time, scientists need to revise the first prediction and make new observations. The accuracy of a prediction improves as more data are collected and analyzed.

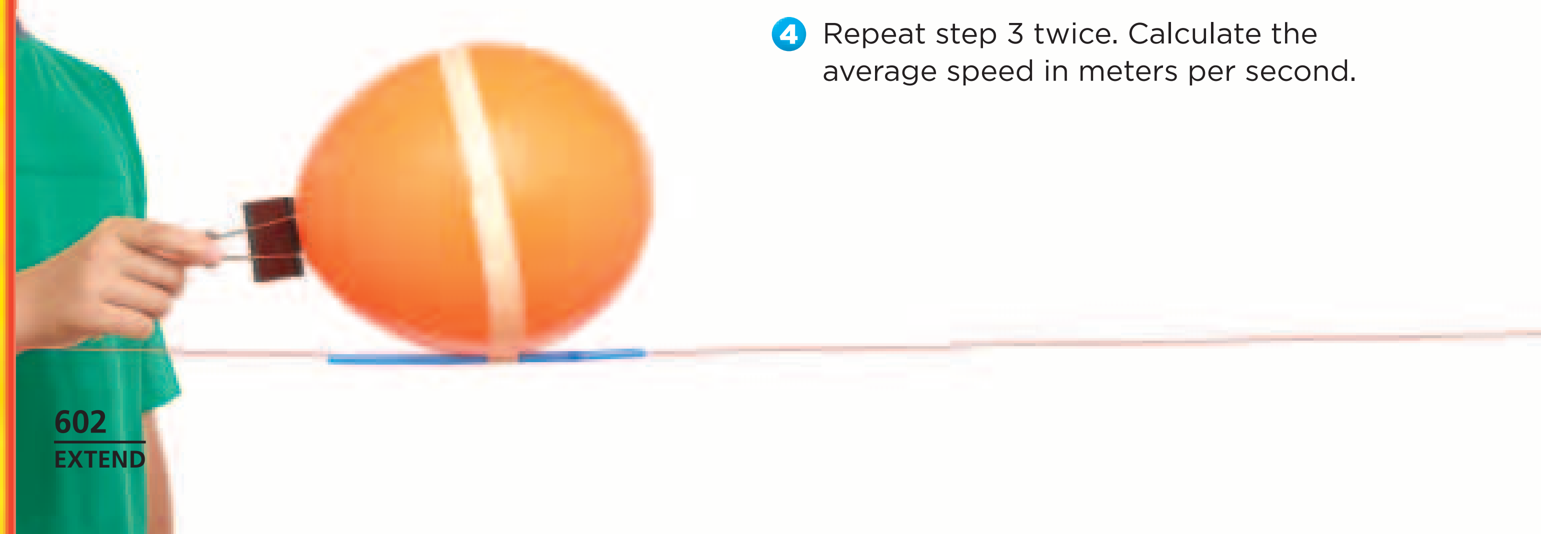
Suppose you were to inflate a balloon and let it go. Could you **predict** how fast the balloon would fly through the air? First, you would need to have some background information about how fast things travel. This would give you a basis for comparison.

Have you ever seen a moth fly toward a light? It darts from place to place much like a balloon in flight. Some moths can fly at speeds of more than 13 m/s. Can you guess how fast a balloon flies compared to a moth? Will the balloon move faster or slower? How much faster or slower will it move?

Try It

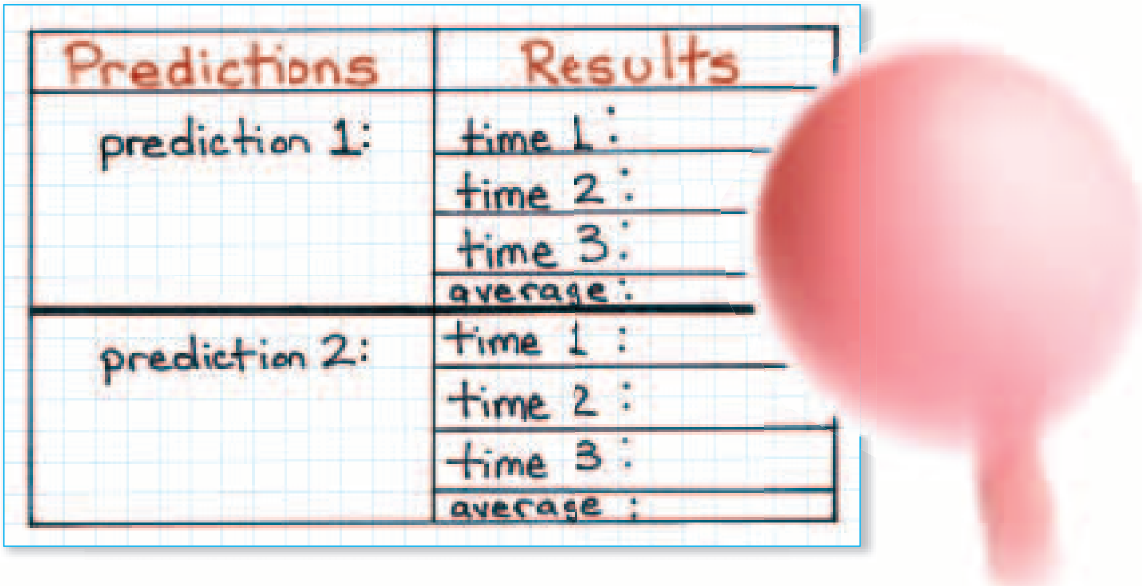
Materials **string, plastic drinking straw, tape, 2 chairs, 22.5 cm balloon, binder clip, measuring tape, stopwatch**

1. Run a 10 m length of string through a drinking straw. Tape each end of the string to one of the chairs. Inflate a balloon, and pinch it shut with a binder clip to keep the air in. Use a measuring tape to find the circumference of the balloon. Tape the balloon to the straw.
2. **Predict** how fast the balloon will fly when the binder clip is removed. Record your prediction in a data table like the one shown.
3. Move the balloon to one end of the string. Have a partner ready with a stopwatch. Your partner should begin timing as soon as you release the balloon and should stop the timer as soon as the balloon reaches the other end of the string. Record the time.
4. Repeat step 3 twice. Calculate the average speed in meters per second.



▶ Apply It

1. **Interpret Data** Did your observations confirm your prediction? Explain.
2. The way you design an experiment affects the results. For this reason scientists often improve upon their experiments to obtain more-accurate results. How could you improve upon this experiment? (Hint: How could you reduce friction between the string and the straw, in order to simulate how the balloon would fly through the air?) Check your idea with your teacher. Then **predict** the result, and test your prediction.



3. Did your results change after you changed the setup of the experiment? Explain.
4. Which prediction was more accurate? Why?
5. Is there an even better way to test your prediction? Suppose you could have any tools or technology at your disposal. Explain how you could make the most-accurate observations and get the most-accurate results.

Lesson 2

Changes in Motion

Look and Wonder

A roller coaster climbs up a slope on the track. It reaches the top, then speeds down the other side. What forces are acting on the roller coaster? What causes the change in its motion?

Explore

Inquiry Activity

What affects acceleration?

Form a Hypothesis

Will increasing the force on an object affect its acceleration? Will increasing the object's mass affect its acceleration? Write your answer in the form "If the force on an object is increased, then its acceleration will . . . and if the object's mass is increased, then its acceleration will . . ."

Test Your Hypothesis

1. **Measure** Make two balloon-inflation gauges with inside diameters of 12 cm and 6 cm by cutting the cardboard into U shapes which can measure your balloons. Mark a start line with tape, and mark a finish line 50 cm from the start.
2. **Experiment** How will force affect the acceleration of cars of equal mass? Inflate one balloon to 12 cm. Inflate another balloon to 6 cm. Attach the balloons to the toy cars, and position the cars at the starting line. Let go of the balloons at the same time. Which car crosses the finish line first?
3. **Experiment** How will mass affect the acceleration of cars with the same force applied to them? Attach one balloon inflated to 12 cm to each toy car, and tape two coins to one of the cars. Position both cars at the starting line, and let go of the balloons at the same time. Which car crosses the finish line first?

Draw Conclusions

4. **Interpret Data** What happened to the acceleration of the car with the greater force applied to it? What happened to the acceleration of the car that had more mass? Explain.

Explore More

Design a new experiment answering a question about the relationship between force, acceleration, and mass. What variable will you change in your experiment?

Materials

- meterstick
- scissors
  Be Careful.
- lightweight cardboard
- masking tape
- balloons
- 2 balloon-powered toy cars
- 2 coins

Read and Learn

Main Idea

Forces cause changes in the speed and direction of moving objects.

Vocabulary

Newton's second law of motion, p. 606

momentum, p. 607

Newton's third law of motion, p. 608

Newton's law of universal gravitation, p. 609

weightlessness, p. 610

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Reading Skill

Infer

Clues	What I Know	What I Infer

How do forces change motion?

Both the force and the acceleration of an object are related. Acceleration is a result of force. The diagram on the next page shows how mass, force, and acceleration are related. Rubber bands stretched to the same length provide force to pull a cart, the books have mass, and the cart is the object that accelerates. In trials 1 and 2, two books are placed on the cart, so the mass is the same in each of these trials. However, the force is different, because of changes in the number of rubber bands that are used. This difference causes the acceleration of the cart to vary between the two trials.

In trials 3 and 4, the force applied to the cart remains the same. However, the number of books on the cart differs in each trial, so the mass changes. As a result, in trials 3 and 4, the cart accelerates to different speeds and therefore travels different distances within the same amount of time.

These trials demonstrate **Newton's second law of motion**: acceleration depends on the object's mass and the amount of net force applied to it. Newton's second law can be written as a formula: $a = F \div m$.

The outcome of a bowling game depends upon force, mass, and acceleration.

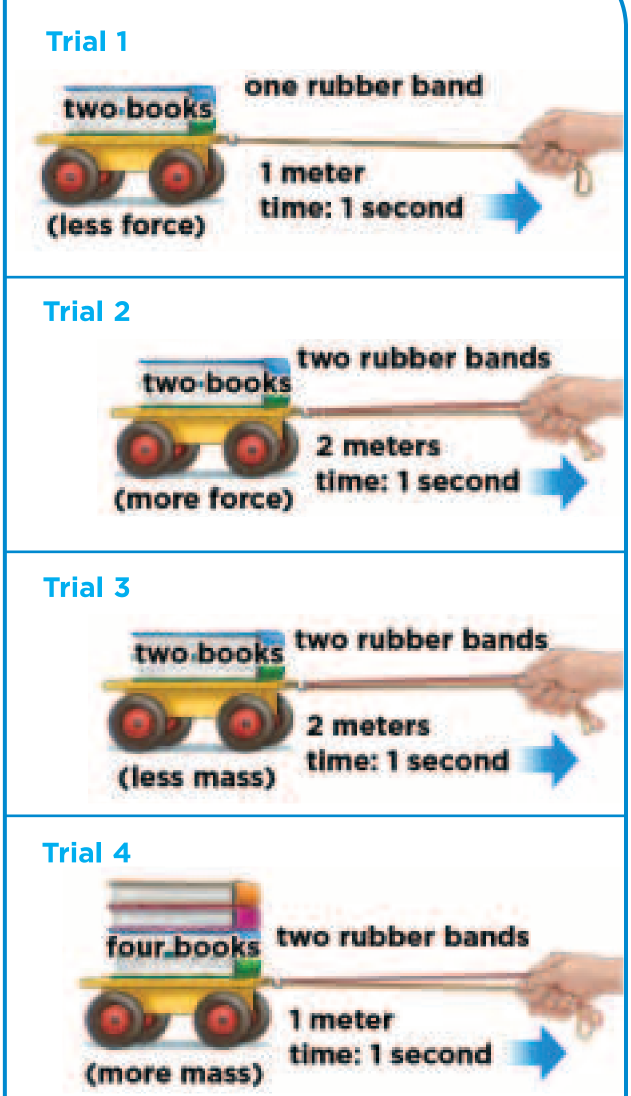
An object's acceleration (a) equals the net force on the object (F) divided by its mass (m). If the force increases, then the acceleration also increases. However, if the mass increases, then the acceleration decreases. Newton's first law shows that a net force is needed in order for an object to accelerate. Newton's second law shows how much acceleration this net force will cause.

Momentum

Suppose a baseball pitcher threw a fastball to you. From your own experience, you could probably estimate the force you would need to stop the ball when you caught it. Now suppose the pitcher threw a tennis ball at exactly the same speed. Would it be easier to catch than the baseball? Would you need more or less force to stop it? The tennis ball has less mass than the baseball, so it would be easier to catch. You would need less force to stop it.

The combination of the mass and the speed of an object is **momentum**. A baseball has more momentum than a tennis ball traveling at the same speed because the baseball has more mass. A tennis ball can have more momentum than a baseball, if the tennis ball's speed is great enough. Momentum is useful for studying the motion of colliding objects. Total momentum does not change when objects collide. Scientists call this principle *conservation of momentum*.

Force, Mass, and Acceleration



Read a Diagram

How does the amount of mass used in trial 4 affect acceleration?

Clue: Note the distance the cart travels.

Quick Check

Infer Why are race cars and bicycles made of lightweight materials?

Critical Thinking How does momentum explain why a golf ball is harder to stop than a table-tennis ball if both move at the same speed?

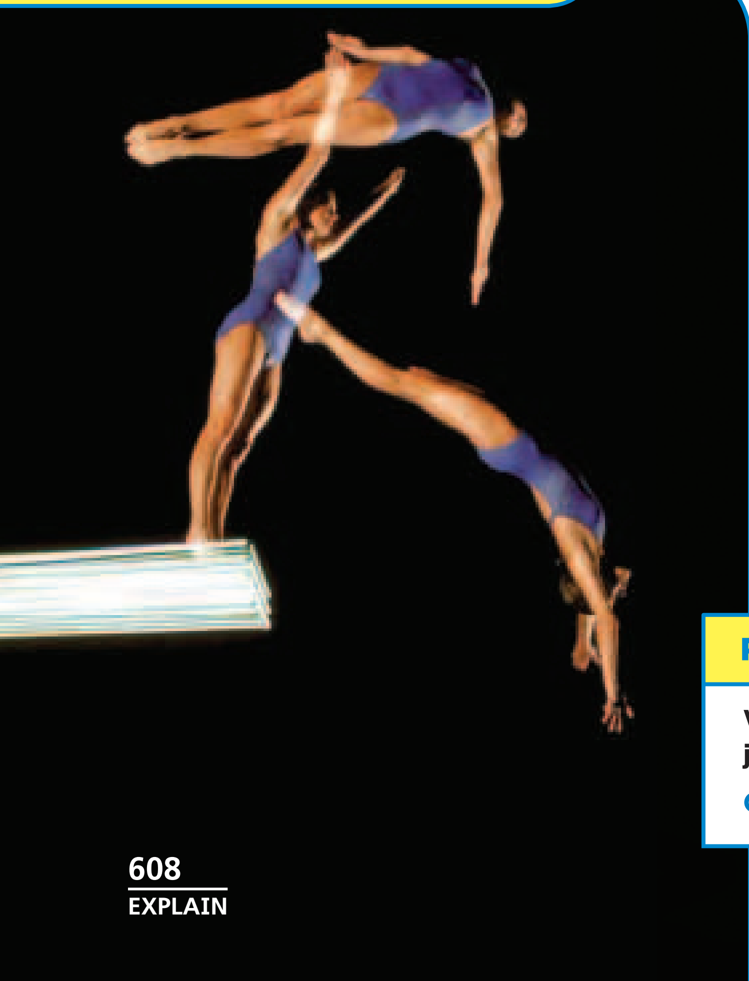
What is Newton's third law of motion?

A diver first jumps down on a diving board and then accelerates upward. A baseball player swings a bat and strikes a ball, and then the ball accelerates in a different direction. A skater pushes against the wall of a rink and then accelerates away from the wall. Each of these situations involves action-reaction forces. The downward force a diver puts on a board is an *action force*. The upward push that propels the diver into the air is a *reaction force*. Action-reaction forces are described in **Newton's third law of motion**: for every action force, there is an equal and opposite reaction force.

When a baseball player swings and hits a baseball with a baseball bat, the baseball exerts a force on the bat. The bat exerts an equal and opposite force on the ball. When a skater pushes against the wall of the skating rink, the wall pushes back with an equal force.

Newton's third law of motion explains how rockets lift off. Burning fuel produces hot gases, which are pushed downward from the rear of the rocket. The force of the rocket on the gases is the action force. The reaction force is the upward force exerted by the hot gases on the rocket. The force of the rocket on the gases is opposite the force of the gases on the rocket.

Action-Reaction Forces



Read a Photo

What is the reaction force when the diver jumps down on the board?

Clue: What action force occurred here?

Mass, Weight, and Gravity

Mass and weight are different properties. Mass is the amount of matter in an object, and weight is the force of gravity pulling down on an object. Objects with more mass have more weight. Although Earth and the Moon both have gravity, Earth exerts a far greater gravitational force than the Moon, because Earth has much more mass. The distance between objects also affects the force of gravity. As the distance between objects increases, the force of gravity decreases.

Earth is about 80 times more massive than the Moon. It is because of this difference that your weight on Earth is about 6 times what your weight would be if you were standing on the Moon.

On the Moon, this African elephant would weigh about one-sixth of what it weighs on Earth.

Would your weight be greater on Earth or on Mars? Because Mars is less massive, you would also weigh less on Mars than you do on Earth.

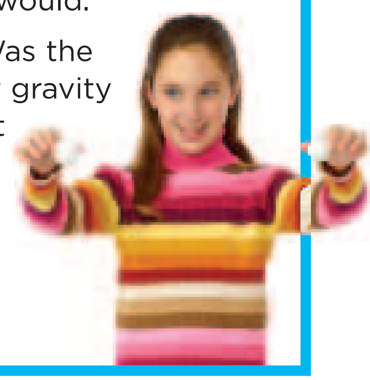
Though your weight does change with the force of gravity, your mass does not change. If you traveled away from Earth, your mass would still be the same, no matter where you were located. However, your weight would continue to decrease as you moved away from Earth's gravitational pull.

Newton accurately concluded that gravity can occur everywhere, not just on Earth. He summarized this idea in **Newton's law of universal gravitation**. According to this law, the planets, the stars, and all particles of matter exert gravitational force. Newton's explanation changed the ways in which scientists viewed the solar system. His findings explained the Moon's orbit around Earth and Earth's orbit around the Sun.

Quick Lab

Free Fall

1. **Record Data** Does gravity affect all objects in the same way? One partner should drop two table-tennis balls from the same height at the same time. The other partner should record when they hit. Repeat this three times. Did both items hit the ground at the same time? If not, which hit first?
2. **Use Variables** Use string or tape to attach 20 g of mass to one of the table-tennis balls. Repeat step 1.
3. **Observe** Crumple a piece of paper into a ball, and leave another flat. Repeat step 1.
4. **Experiment** Using paper, string, and tape, make one of the table-tennis balls hit the ground later than it normally would.
5. **Communicate** Was the time required for gravity to pull the object to Earth affected by any of your modifications? Share your ideas with others.



Quick Check

Infer Why do runners sometimes prop their feet against starting blocks at the beginning of a race?

Critical Thinking If a baseball player throws a ball and no one hits or catches it, why does the ball eventually fall to the ground?

FACT Rocket engines are more effective in space than on Earth, because there is no air drag on the rockets.

What is weightlessness?

Skydivers experience a feeling of **weightlessness**, the state of being without detectable weight. However, gravity still pulls them toward the center of Earth's mass. Why, then, do they feel as if they are weightless?

Suppose a skydiver stood on a scale inside a flying plane. The scale would measure the skydiver's weight. If a door opened underneath the skydiver, both the person and the scale would fall toward Earth at the same rate. At that time, the scale would measure the weight of the skydiver as zero. The skydiver would still have weight, but without the upward force of the ground, his or her weight would not be detected by the scale.

Astronauts in an orbiting spacecraft feel much the same way as the falling skydiver feels. They do not seem to be falling to Earth in the way that the skydiver is. However, the astronauts' movement is more similar to the skydiver's than you might initially think. The force of gravity causes the astronauts to fall toward Earth, just as the skydiver does. The astronauts are moving forward, and there is no force slowing down their acceleration. The fact that the astronauts fall downward and move forward at the same time is what keeps them on a circular path orbiting Earth, and it is why it seems as if they do not feel the force of gravity.

To perform different tasks under these unusual conditions, astronauts must practice. One method is to work underwater, because the buoyant force of water makes the submerged astronauts feel as if they are weightless.

Apparent weightlessness means that astronauts can play with their food.

True Weightlessness

Gravitational force exists among all objects in the universe. The pull from massive objects such as the Sun or other stars is much weaker when an object is located far away from them. Any object that has moved beyond these distant regions is in a position where there is no detectable gravitational pull. This condition is often referred to as "true" weightlessness. The object still has mass, but, because there is so little gravitational pull, the object lacks detectable weight. However, there is no place in the universe where gravitational pull does not exist and an object is truly without weight.

Quick Check

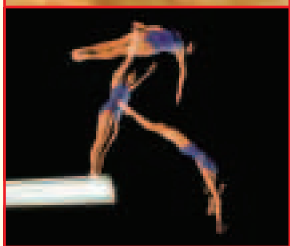
Infer Why do riders on a roller coaster feel weightless when they go over the top of a hill?

Critical Thinking Would weightlessness ever affect your mass? Explain.

Lesson Review

Visual Summary

Newton's second law of motion states that force and mass affect an object's acceleration.



Newton's third law of motion states that for every action force there is an equal and opposite reaction force.

An object's **weight** changes depending on gravitational pull, but the object's **mass** stays the same.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Complete the statements shown. Add details for each law or concept.

Think, Talk, and Write

1. **Main Idea** Forces can cause changes in the speed and direction of ________.

2. **Vocabulary** The measurement of the combination of the mass of an object and its speed is ________.

3. **Infer** On which planet would you weigh less: one more massive than Earth or one less massive than Earth? Explain.

Clues	What I Know	What I Infer

4. **Critical Thinking** Why must large trucks have more powerful engines than compact cars?

5. **Test Prep** **When one object exerts a force on another object, the pair of forces that act are called**
   - **A** action-reaction forces.
   - **B** balanced-unbalanced forces.
   - **C** friction-drag forces.
   - **D** positive-negative forces.

6. **Test Prep** **If equal forces were applied to four identical wagons, which one would have the MOST acceleration?**
   - **A** the one holding 500 kg of wood logs
   - **B** the one holding 400 kg of dirt
   - **C** the one holding 100 kg of books
   - **D** the one holding a 50 kg pile of leaves

Writing Link

Explanatory Writing

Think of a sports activity or household task that involves gravity or momentum. Write a paragraph describing the activity and the role that gravity or momentum plays in it.

Math Link

Calculate Weight

An astronaut weighs 90 kg (198 lbs) on Earth. How much would that same astronaut weigh on another planet of the same diameter with gravity that is only 33 percent as strong?

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Be a Scientist

Materials

building-block car

marbles of different sizes

books

pencil

Structured Inquiry

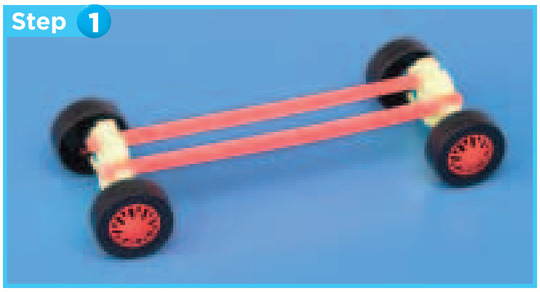
How does inertia apply to passengers in a moving vehicle?

Form a Hypothesis

Newton's laws of motion explain how objects respond to forces. How do these laws affect you when you travel in a moving vehicle? When a car accelerates positively, what happens to the passengers? What happens when the car accelerates negatively? Write your answer in the form of a hypothesis: "When a car accelerates positively, then the passengers will. . . and when a car accelerates negatively, then the passengers will . . ."

Test Your Hypothesis

1. Assemble a building-block car with two connector rods, two axles, four wheels, and two pieces to block the ends of the rods. The rods should be close enough together to hold a marble.
2. Place a medium-sized marble in the front of the car. Place the car about 30 cm from books that will stop the forward progress of the car.
3. **Observe** Push the car in the direction of the books. How does the marble move in response to your push? Use a pencil to mark the position of the marble.
4. **Observe** Repeat step 3. This time, observe the marble upon impact—when the car hits the books. How does the marble move? Explain.



Step 1

Step 2

Step 3

Draw Conclusions

5. Did your results confirm your hypothesis, or do you need to make changes to it? Explain.

6. **Form a Hypothesis** What will happen if the distance between the car and the books is increased?

7. **Experiment** Try changing the distance between the car and the books. Was your hypothesis correct? Explain.

Guided Inquiry

How is inertia affected by the mass of an object?

Form a Hypothesis

You have modeled a passenger in a vehicle, using a building-block car and a marble. Will it make a difference if the marble has a greater or lesser mass? Write your answer in the form of a hypothesis: "If the marble has a greater mass, then . . . If the marble has a lesser mass, then . . ."

Test Your Hypothesis

Design an experiment to determine whether the mass of a marble on a building-block car affects its response to the force of a push and the car's impact with the books. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

Did your results support your hypothesis? Why or why not? Present your results to your classmates.

Open Inquiry

What else can you learn about Newton's laws of motion? For example, what happens when passengers are provided with restraints such as seat belts? Which materials make the best seat belts? How might you test how well a seat belt design works? Come up with your own question to investigate. Design and carry out an experiment to answer your question. Write your experiment so another group could repeat the experiment by following your instructions.

Remember to follow the steps of the scientific process.

Ask a Question → Form a Hypothesis → Test Your Hypothesis → Draw Conclusions

Lesson 3

Work and Energy

Look and Wonder

A tugboat pulls a massive ship into a harbor. A tow truck pulls a car into a repair shop. Which of these jobs takes more work? How do scientists define *work*?

Explore

Inquiry Activity

What is work?

Make a Prediction

Scientists define *work* in terms of both a force and a distance through which the force moves an object. Which requires more force: moving an object across a smooth surface or moving it across a rough surface? Write your answer in the form "If the same object is moved the same distance along different surfaces, then . . ."

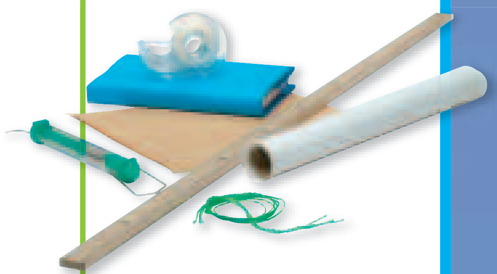
Test Your Prediction

1. **Measure** Use string to connect a weight to the spring scale. Tape a 1 m sheet of waxed paper to a flat surface. Place the meterstick over the waxed paper.
2. **Record Data** Place the weight at the start of the meterstick. Pull on the spring scale's handle at a constant rate, moving the weight to the end of the meterstick. What was the average measurement on the spring scale as the weight moved along? Record the amount of force needed to pull the weight the length of the meterstick.
3. Repeat steps 1 and 2 using 1 m of sandpaper in place of the waxed paper.

Draw Conclusions

4. **Interpret Data** On which surface was more force required to pull the weight the same distance? Why do you think this surface required more force?
5. **Infer** Compare the two trials. Which trial seemed to require more work? If you increased the distance used in the experiment, would that change the amount of work that you would have to do? What if you used a heavier weight? Explain your answers.

Materials



- string
- book or other weight
- spring scale
- tape
- waxed paper (1 m)
- meterstick
- medium-grain sandpaper (1 m)

Step 3

Explore More

Do you think the same amount of force is needed to slide the same weight 1 m across surfaces such as carpeted or wooden floors? Test your prediction, and then share your results.

Read and Learn

Main Idea

Energy is the ability to do work. Energy can take many forms.

Vocabulary

work, p. 616

energy, p. 618

potential energy, p. 618

kinetic energy, p. 618

thermal energy, p. 618

law of conservation of energy, p. 619

power, p. 622

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Reading Skill

Fact and Opinion

Fact	Opinion

What is work?

Picture yourself holding a heavy box for a minute or two while your friend makes a place for it on a shelf. Your arms might get tired. You might even start sweating a little. It would be tempting to say that you were working very hard while holding the box up. However, you were actually doing no work in the scientific sense. How could this be?

Scientists define **work** as what is necessary for a force to move an object through a distance. This definition of work explains why simply holding up a heavy box results in no work being done. You are applying a force to the box to counteract gravity, but the force does not move the box through a distance. However, if you had lifted the box up to the height where you now hold it, you would have done work. In that case, you would have applied a force that changed the box's position.

Have you ever worked hard to accomplish something? In science, the term *work* relates to a force and a distance through which the force moves an object.

Calculating Work

Work is equal to the force of a push or pull multiplied by the distance the object is moved. The force must act in the same direction as the motion. If the force is expressed in newtons and the distance is expressed in meters, the units for the work done are newton-meters (Nm), also called *joules* (J).

Suppose a student uses a rope to lift a bucket filled with books up to a tree house that is 5 meters high. The weight of the bucket is 30 newtons. How can you calculate the work done on the bucket by the student?

When an object is lifted at a constant speed, the force is equal to the weight of the object. Since the bucket has a weight of 30 newtons, the student must have applied an upward force of 30 newtons to the bucket.

Now that you know the force applied, you need to know the distance the object was moved. In this case the bucket has been lifted 5 meters. You can find the work done by using this formula:

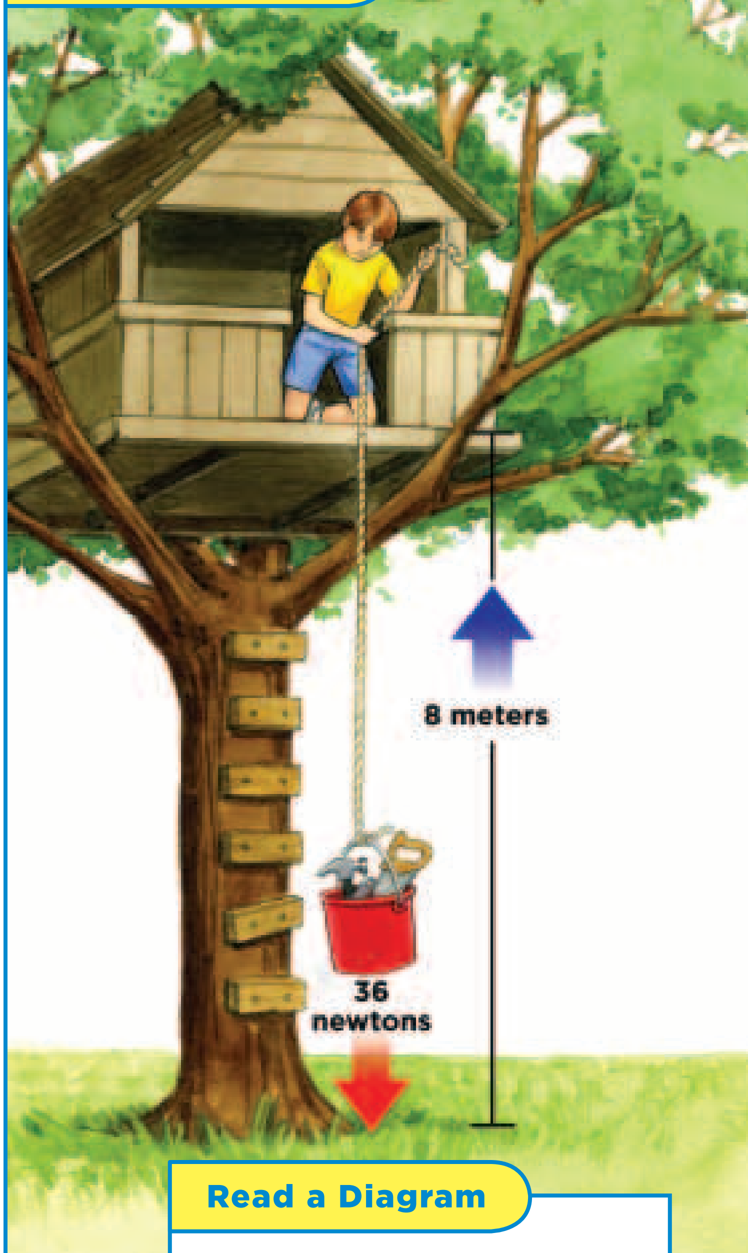
work = force × distance

work = 30 N × 5 m

work = 150 Nm = 150 J

This means that the work done on the bucket totaled 150 joules.

Force × Distance



Read a Diagram

How much work does it take to raise the bucket from the ground to the tree house?

Clue: Find both the force and the distance for the bucket.

Quick Check

Fact and Opinion "Applying a force to an object to move it is difficult work." Is this statement a fact or an opinion? Explain.

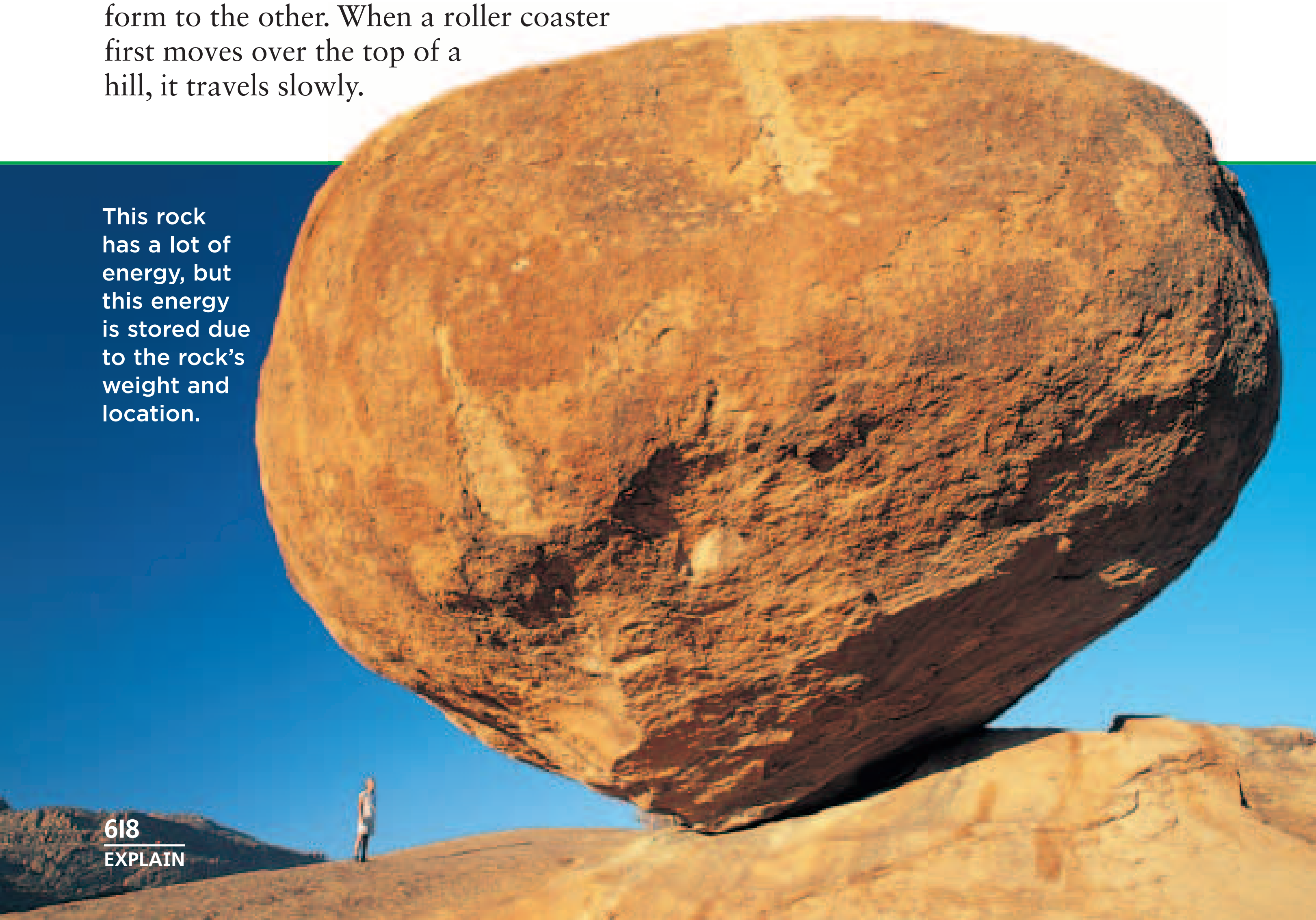
Critical Thinking Why is weightlifting considered work but holding a weight steady is not?

How does energy change form?

If work is to be accomplished, energy is needed. **Energy** is the ability to do work. Like work, energy is measured in joules. Stretched rubber bands or wound-up springs store energy because of their elasticity. A rock on the edge of a cliff stores energy because of its position and the force of gravity. **Potential energy** is energy that is stored. However, not all energy remains stored. A moving object also has energy, because it has mass and speed. The energy of motion is called **kinetic energy**. Objects with greater masses or higher speeds have greater kinetic energy. All energy is either potential or kinetic.

Energy often changes from one form to the other. When a roller coaster first moves over the top of a hill, it travels slowly. Most of its energy is potential energy. A roller coaster speeds up as it starts down the hill. At the bottom, the roller coaster is at its highest speed. Most of the potential energy is changed to kinetic energy. However, this change in energy is not the end of the ride.

Thermal energy is the heat energy in an object. Friction between the track and the roller-coaster cars changes some of the total energy to heat. This thermal energy can warm the track, but it cannot run the roller coaster. Because some energy is wasted, the roller coaster would not be able to reach the top of the next hill if it were as high as the first one. This explains why the first hill is always the tallest.



This rock has a lot of energy, but this energy is stored due to the rock's weight and location.

Conservation of Energy

All forms of energy have a source, a means of transfer, and a receiver. For example, in a flashlight the energy source is the potential energy in the battery. An electrical circuit enables the energy to be transferred to the bulb. The bulb is the receiver of this energy. It can then give off energy in the form of light and heat.

Energy does change from one form to another, but energy cannot be created or destroyed. Scientists call this the **law of conservation of energy**. Think about how energy changes form as you ride a bicycle. Your body contains potential energy stored from food. As you pedal, this stored energy changes to kinetic energy. If you and the bicycle move up a hill, some of your kinetic energy becomes potential energy again. If you then coast down the hill, this potential energy becomes kinetic energy again. If you apply your brakes, friction slows the wheels, and some kinetic energy becomes wasted thermal energy in the wheels and the brakes as you stop. Although some of the energy is wasted, none of it is ever created or destroyed. The energy simply changes form.

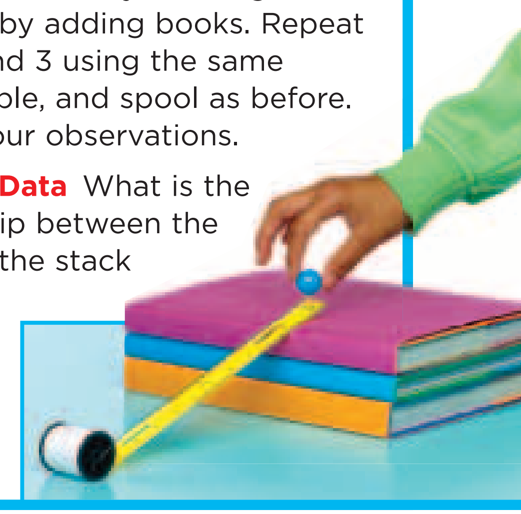
Forms of Energy

Form	Example of Source
nuclear	the Sun, radioactive material
chemical	food
electrical	a generator, a battery
light	the Sun, an electric lamp
mechanical	moving parts in a machine
sound	vibrations of a stereo speaker
thermal	hot water in a radiator

Quick Lab

Potential Energy and Distance Traveled

1. **Predict** How far will a spool of thread travel when hit by a rolling marble? What will happen if the marble rolls from a greater height?
2. **Observe** Place a marble at the top of a ramp made from three stacked books and a ruler with a groove in it. Place a spool at the bottom of the ramp. Allow the marble to roll down the ruler so that it hits the spool, causing the spool to roll forward.
3. **Measure** Find the distance that the spool moved after being hit by the rolling marble.
4. **Use Variables** Vary the height of the ramp by adding books. Repeat steps 2 and 3 using the same ruler, marble, and spool as before. Record your observations.
5. **Interpret Data** What is the relationship between the height of the stack of books and the distance the spool moves?



Quick Check

Fact and Opinion "Energy is the ability to do work." Is this statement a fact or an opinion? Explain.

Critical Thinking Explain how a roller coaster can demonstrate the law of conservation of energy.

Examples of Energy Transformation

How does energy change?

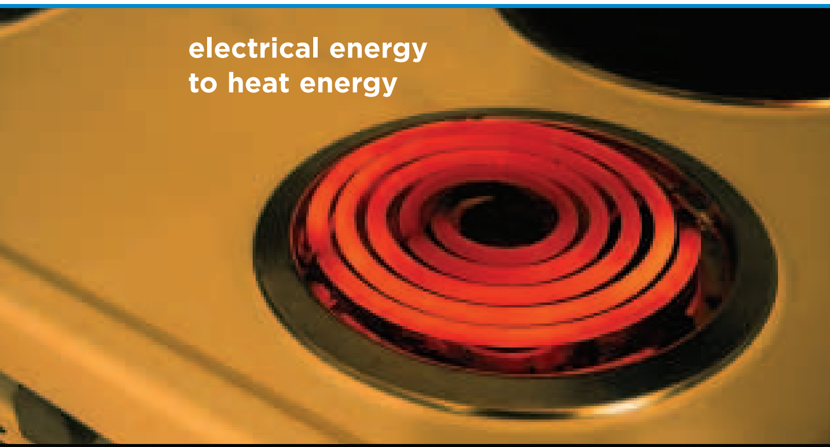
Energy can change from a potential to a kinetic form. Objects such as light bulbs, electric motors, refrigerators, and stoves all change energy from one potential or kinetic form to another. How does this happen?

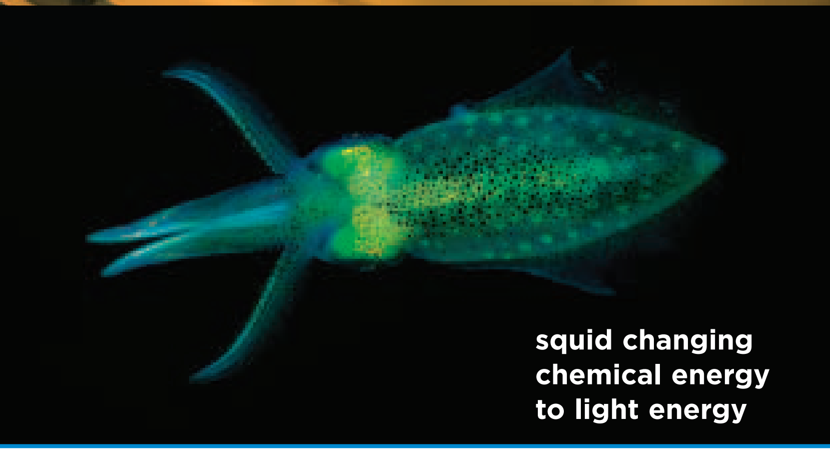
You experience the change of energy from one form to another every day. If you turn on a television, electrical energy changes to light and sound energy. If you turn on a hair dryer, electrical energy changes to heat energy. If you turn on a blender, electrical energy changes to mechanical energy. If you use a portable radio, chemical energy in the battery changes to sound energy. If you play a musical instrument, mechanical or electrical energy changes to sound energy.

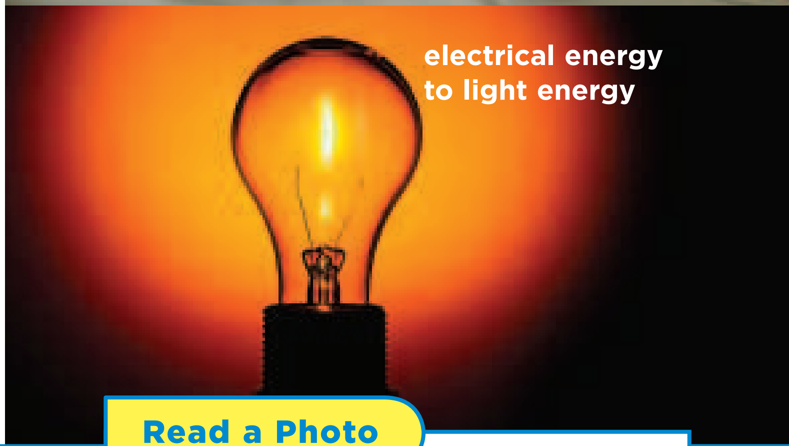
Batteries contain stored chemical energy. Reactions inside a battery change potential chemical energy to electrical energy. This electrical energy can then be changed to various other forms of energy, such as light or heat. A stereo changes electrical energy to mechanical energy. This mechanical energy vibrates the stereo speakers, and this causes the air molecules to move, producing sound.

Energy for Living Things

Energy also changes from one form to another inside living organisms. The molecules of the food we eat contain stored chemical energy. The energy that is stored in food originated from the Sun.







Read a Photo

Which energy transformation takes place during photosynthesis?

Clue: Photosynthesis takes place in green plants.

The energy of the Sun changes to forms of electromagnetic energy such as visible light. This form helps provide energy for Earth. When light strikes a green leaf on a plant, the plant uses this light energy to build molecules of sugar from carbon dioxide and water. The sugar molecules store this potential energy in the form of chemical bonds, and the sugar molecules are stored in the plant. Another living thing can then eat the plant, and respiration releases the energy the organism needs to live.

Energy for Transportation

Changing energy from one form to another enables things to move. Both machines and living things need energy to get from one place to another.

When you walk or ride a bicycle, your muscles change the chemical energy in your food to mechanical energy. As a car moves, its engine changes the chemical energy of fuel to mechanical energy.

Quick Check

Fact and Opinion "Electrical energy is the most useful form of energy." Is this statement a fact or an opinion? Explain.

Critical Thinking Describe an energy change from your own experience.

What is power?

You climb the stairs one day and take the elevator the next day. You arrive faster when you ride the elevator than when you walk up the stairs. The amount of work accomplished is equal, but the time it takes to get that work done is different. The amount of work done per unit of time, or work divided by time, is called **power**. The elevator moves you to the top floor much faster, so the elevator has more power than you do.

If work is expressed in joules and time is expressed in seconds, then power is expressed in joules per second (J/s). One joule per second is also known as a *watt* (W). The watt is the standard unit of power.

Suppose you moved a wagon 5 meters. The task required 400 joules of work and took 20 seconds. What is the power for this task? You can calculate power by using the following formula:

power = work ÷ time

power = 400 J ÷ 20 s

power = 20 J/s = 20 W

Light-bulb labels indicate the power the device uses per second. The more power a light bulb has, the brighter the light bulb is. Household bulbs has about 100 watts or less of power. *Kilowatts* (kW) measure large amounts of power. The prefix *kilo-* means "one thousand." A kilowatt is 1,000 watts of power.

Horsepower (hp) is a measurement of power as well. More than 200 years ago, James Watt invented this unit to compare the power of a machine to the work done by a horse. A horsepower equals 746 watts. The watt as a unit of power is named in honor of James Watt.

Quick Check

Fact and Opinion "A 500 N person in an elevator is lifted 5 m in 10 s, so the power for this task is 250 W." Is this statement a fact or an opinion? Explain.

Critical Thinking In 1 L of milk there are about 600 food calories (Cal), and 1 Cal equals about 4,200 J. How much energy is in the milk?

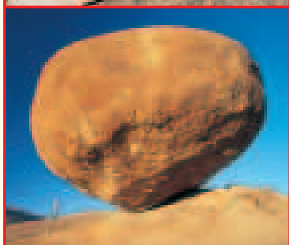
A shovel could do the same amount of work as this earthmover but would take much longer. ▶

FACT One horsepower is less than 1 kilowatt.

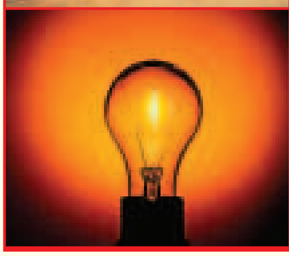
Lesson Review

Visual Summary

Work is directly related to the force that moves an object and the distance through which the object is moved.



Energy is the ability to do work. All energy is either potential or kinetic.



Power is the amount of work done per unit of time. Power is measured in watts.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide supporting details.

Think, Talk, and Write

1. **Main Idea** How are energy and work related?

2. **Vocabulary** The quantity that describes the amount of work divided by the time required is _________.

3. **Fact and Opinion** "Work is equal to force times distance." Is this statement a fact or an opinion? Explain.

Fact	Opinion

4. **Critical Thinking** Two machines use the same force to move identical boxes the same distance. How could one machine increase its power?

5. **Test Prep** **A force of 20 N is used to move a wagon 10 m. How much work is done?**
   A 2 J
   B 10 J
   C 20 J
   D 200 J

6. **Test Prep** **Where would a book have the MOST potential energy?**
   A on the floor
   B on the top shelf of a bookcase
   C on the middle shelf of a bookcase
   D on the lowest shelf of a bookcase

Writing Link

Personal Narrative
Write a journal entry that describes all the ways you use energy. In each case identify the form of energy, such as chemical energy, mechanical energy, light energy, electrical energy, and so on.

Math Link

Calculate Power
Seth applied a force of 30 N for 6 s to move a box 12 m. Marco applied a force of 24 N for 3 s to move the same box 10 m. Who generated more power to move the box?

Museum Mail Call

Scientists at the American Museum of Natural History study the natural world and the people who live in it. They also look at how to help people conserve energy and natural resources. Here is how some students are helping.

Weather stripping keeps your home warmer in winter.

Energy-efficient light bulbs can save both money and energy.

Dear Museum Scientists,

Hi! My name is Amanda, and I live in Baton Rouge, Louisiana. It is "Energy Conservation Week" at my school. We're learning about fuels that produce energy, such as oil, coal, and nuclear power. Fuels like these produce pollution, and some of them are running out. We are finding ways to cut back on our energy use.

Here's how my family and I conserve energy every week:

1. I help with the laundry. We wash only full loads and use cold water whenever possible. The clothes dryer uses a lot of electricity, so we try not to overload it, and we clean out the lint filter to help it run efficiently. We also dry some of our laundry on a clothesline. This saves my family 3 kilowatt hours per week. Each kilowatt hour costs 17 cents. That's 51 cents per week, or $26.52 per year. That may not seem like a lot, but every little bit helps.

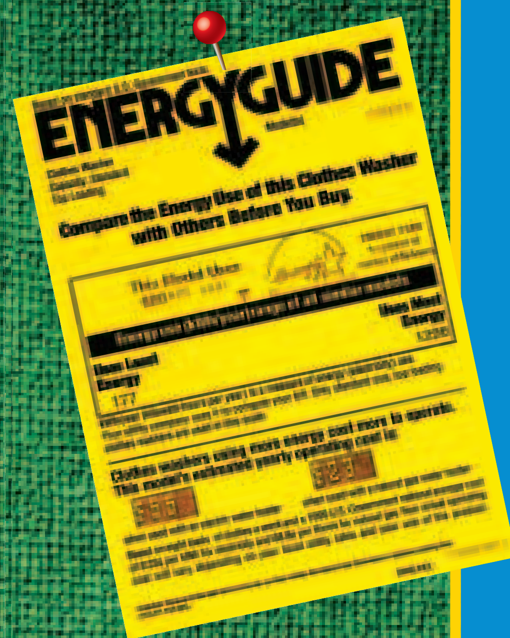
2. We replaced ten regular light bulbs with energy-efficient ones. Each energy-efficient bulb lasts longer and uses 66 percent less energy. Each bulb can save us more than $12 per year in energy costs. That's $120 for the year.

3. Dad carpools to work rather than driving his own car every day. We figure that this saves 5 gallons of gas every week. A gallon of gas costs about $2.50, so we save $12.50 per week, or $650 per year.

4. Mom and I seal the air leaks around the air conditioner and windows. We only turn the air conditioner on when we are home, and then only in rooms we use. We stay cool, and we also save $5 in electricity per day, or $35 per week. We use the air conditioner about 40 weeks each year, so that's a savings of $1,400.

These four things save us $2,196.52 each year. More importantly, think of all the energy we save!

Amanda



Infer

- Review the facts and details.
- Think about how the facts relate to one another and to other topics.

Write About It

Infer

1. Which washing machine do you think uses more energy: one washing clothes in cold water or one using hot water? Why?
2. How does sealing air leaks around windows save energy?

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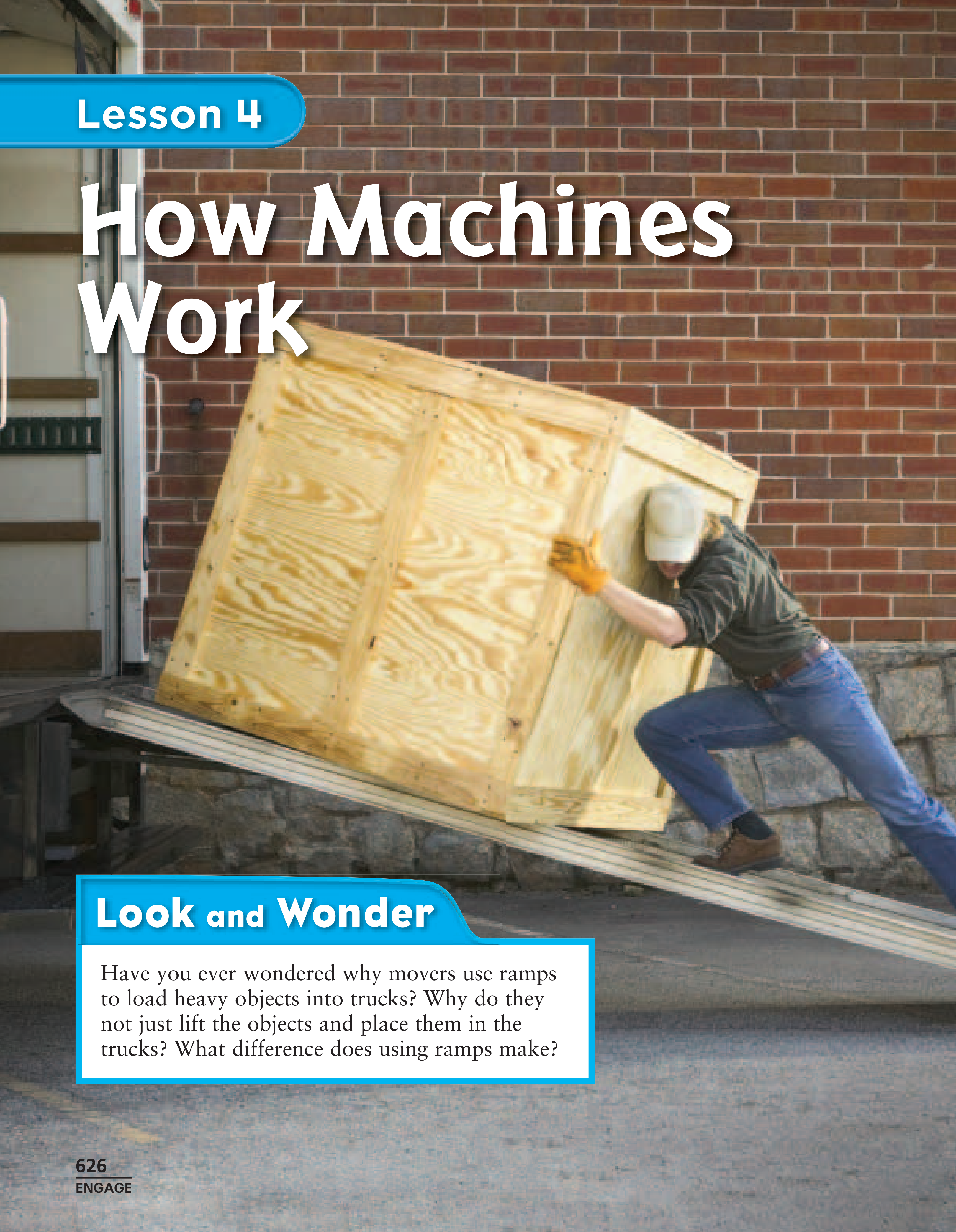
American Museum of Natural History

Lesson 4

How Machines Work



Look and Wonder

Have you ever wondered why movers use ramps to load heavy objects into trucks? Why do they not just lift the objects and place them in the trucks? What difference does using ramps make?

Explore

Inquiry Activity

How is a ramp a simple machine?

Form a Hypothesis

You can use a ramp to help lift objects. Will the steepness of the ramp affect how much force is needed to lift an object? Write your answer in the form of a hypothesis: "If I make a ramp steeper to lift an object, then the amount of force needed will . . ."

Test Your Hypothesis

1. **Measure** Use the spring scale to measure the amount of force needed to lift the book tied with string straight up to a height of 20 cm. Record your results.
2. **Experiment** Stack books to a height of 20 cm. Position the end of the board on the stack so that the board forms a ramp up to the top book.
3. **Predict** How much force do you think will be needed to pull the book up the ramp? Use the spring scale to slowly pull the book to the end of the ramp at a steady pace. Hold the spring scale so that you are pulling in a direction parallel to the ramp. Record your results.
4. **Record Data** Make the ramp steeper by positioning the board so that its midpoint rests against the top of the stack. Predict the force needed to pull the book up the steeper ramp. Then use the spring scale to pull the book up this ramp. Record your results.

Draw Conclusions

5. **Interpret Data** Which required more force: lifting the book straight up or pulling it up the ramp? Explain your answer.
6. **Interpret Data** Did the amount of force needed to pull the book up the ramp change when you made the ramp steeper? Explain your answer.
7. **Infer** What caused these differences?

Materials

- spring scale
- book with string tied around it
- meterstick
- several other books
- flat cardboard or board

Explore More

Perform this experiment again, using objects of different masses. Calculate the amount of force needed. Do you always save the same amount of force?

Read and Learn

Main Idea

Simple machines make it easier for people to do work.

Vocabulary

simple machine, p. 628
mechanical advantage, p. 629
lever, p. 630
fulcrum, p. 630
wheel and axle, p. 632
pulley, p. 632
inclined plane, p. 634
screw, p. 634
wedge, p. 635
compound machine, p. 636
efficiency, p. 636

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Reading Skill

Classify

What is a simple machine?

You have learned that work is applying a force to an object to move it through a distance. A **simple machine** is a device with few, if any, moving parts that makes it easier to do work. For example, a hammer, which has no moving parts, is a simple machine.

Simple machines can change either the force that is needed or the direction or distance through which a force is applied. The hammer can make work easier by changing the direction of the force applied to an object. This occurs when you use a hammer to pull a nail out of a board. You push down on the handle of the hammer, but the hammer applies an upward force to the nail. The hammer also makes work easier by increasing the strength of the applied force. It would be difficult, if not impossible, to pull a nail out of a wooden board with your bare hands. A hammer makes that job much easier. This is because the upward force the hammer applies to the nail is much greater than the downward force you apply to the hammer's handle.

▼ Simple machines such as this hammer make work easier.

Mechanical Advantage

The force that you apply to a simple machine is called the *effort force*. The force against which the machine acts is called the *resistance force*. The force that the machine applies to an object in response to the effort force is called the *output force*.

In the example of a hammer pulling a nail out of a board, the effort force is the force that a person applies to the handle of the hammer. The resistance force is the force that the nail being pulled out exerts on the hammer. The output force is the force that the hammer applies to the nail.

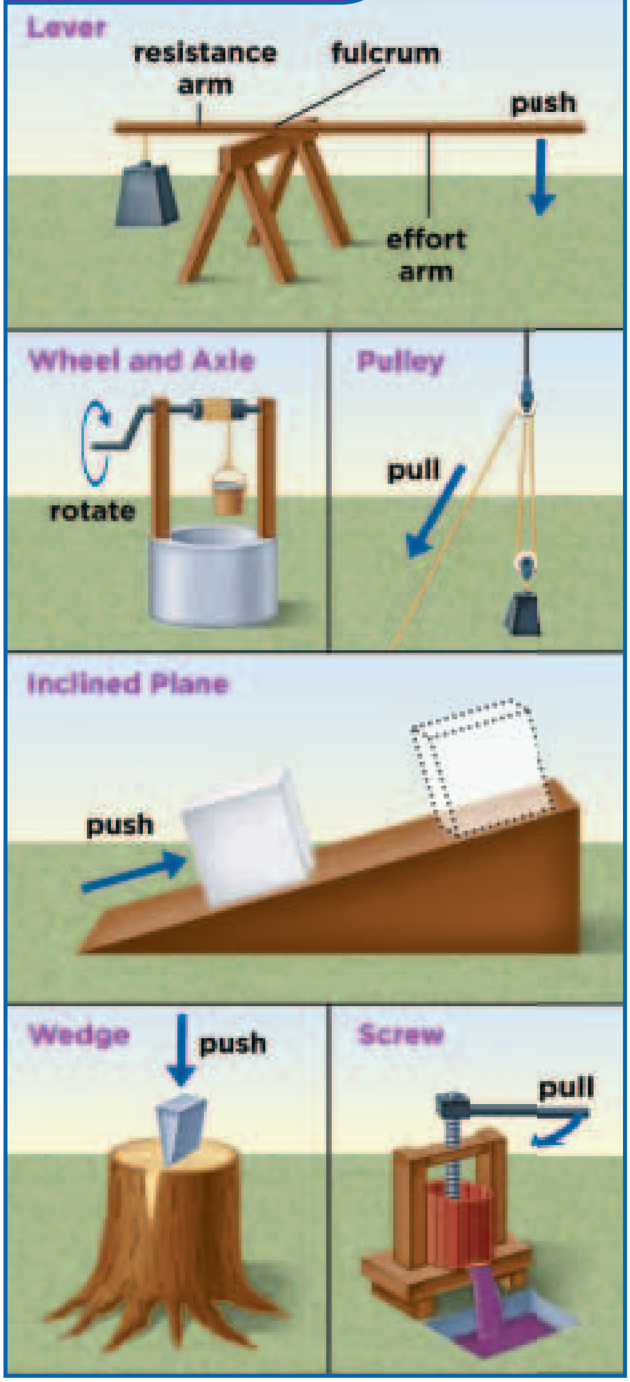
The number of times a simple machine multiplies an effort force is called its **mechanical advantage** (MA). You can find the mechanical advantage of a simple machine by dividing the output force by the effort force.

Suppose you applied a force of 100 newtons to a simple machine to lift a box that weighed 500 newtons. The mechanical advantage would be 500 divided by 100, which equals 5. This means that the machine would multiply your effort force by 5.

Types of Simple Machines

There are two main classes of simple machines: the lever and the inclined plane. The lever class also includes the wheel and axle and the pulley. The inclined-plane class also includes the wedge and the screw.

Simple Machines

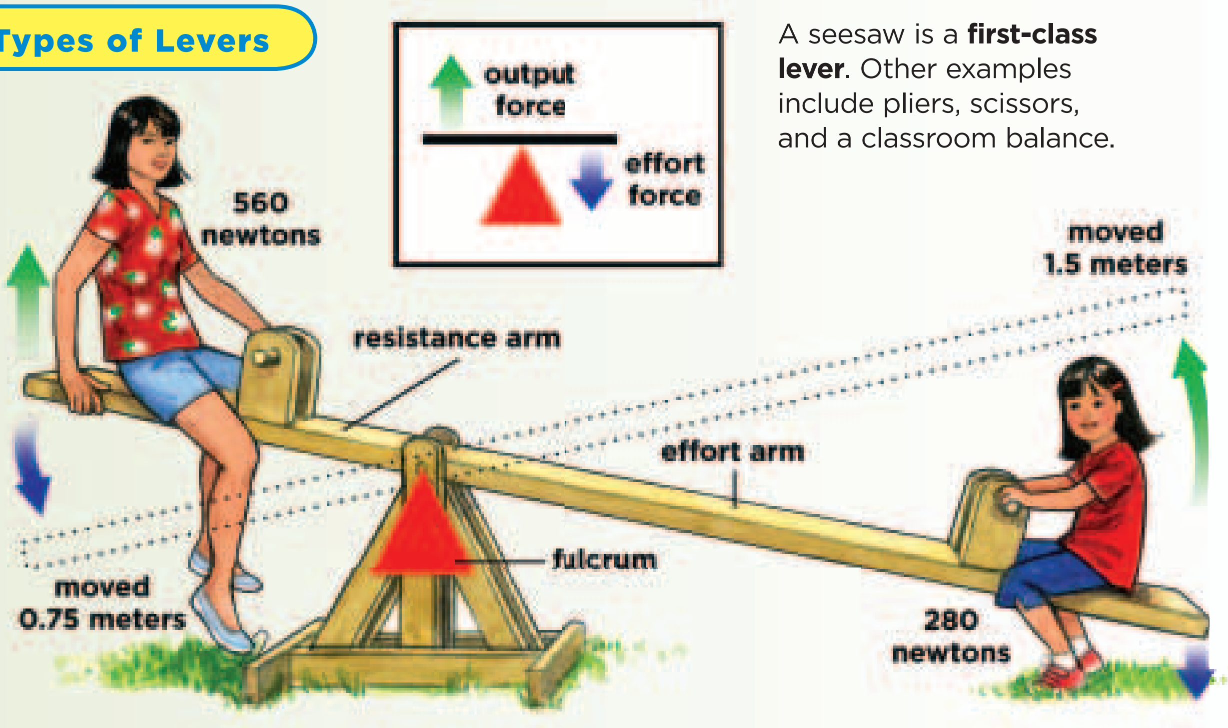


Quick Check

Classify Explain how a hammer is a simple machine.

Critical Thinking How would an increase in effort force affect the mechanical advantage of a simple machine?

Types of Levers



A seesaw is a **first-class lever**. Other examples include pliers, scissors, and a classroom balance.

What are the kinds of levers?

A **lever** is a simple machine consisting of a rigid bar and a pivot point. The pivot point is called the **fulcrum**. The part of the bar on which a person applies an effort force is called the *effort arm*. The portion of the bar on which the lever produces an output force is called the *resistance arm*. The positions of the fulcrum, effort force, and output force vary among levers. Based on these differences, there are three classes of levers.

First-Class Levers

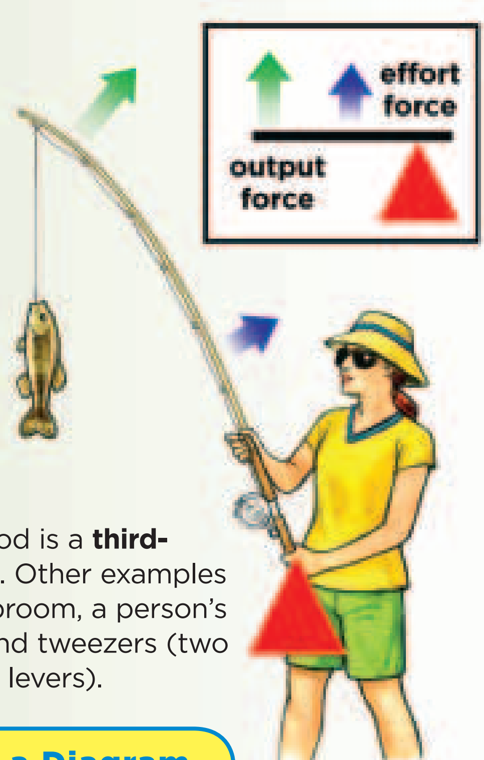
In a first-class lever, the fulcrum is between the effort force and the output force. For this reason, a first class lever changes the direction of the effort force.

As the diagram on this page shows, a first-class lever sometimes produces an output force greater than the effort force. The output force is greater than the effort force when the fulcrum is closer to the output force than to the effort force—that is, when the effort arm is longer than the resistance arm.

This gives the lever its mechanical advantage, which can be found by dividing the distance the effort arm moves by the distance the resistance arm moves. This ratio is the same as that found by dividing effort-arm length by resistance-arm length. For the lever shown in the diagram above, the mechanical advantage is 1.5 divided by 0.75, which equals 2. This means that the lever multiplies the effort force by 2.

Because work equals force times distance, the product of the lesser effort force and the greater effort distance equals the product of the greater output force and the lesser output distance.

A wheelbarrow is a **second-class lever**. Other examples include a bottle opener, a paper cutter, and a nutcracker (two connected levers).



A fishing rod is a **third-class lever**. Other examples include a broom, a person's forearm, and tweezers (two connected levers).

Read a Diagram

In which lever is the fulcrum between the effort force and the output force?

Clue: Find the fulcrum in each lever.

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Second-Class Levers

In a second-class lever, the output force is between the effort force and the fulcrum. Second-class levers do not change the direction of the effort force. However, they produce a mechanical advantage because the effort arm is longer than the resistance arm. In the wheelbarrow example on this page, the person moves his hands farther but is able to lift a larger load because of the machine's construction.

Third-Class Levers

In a third-class lever, the effort force is between the output force and the fulcrum. Like second-class levers, third-class levers do not change the direction of the effort force. Unlike second-class levers, however, third-class levers always produce an output force that is less than the effort force.

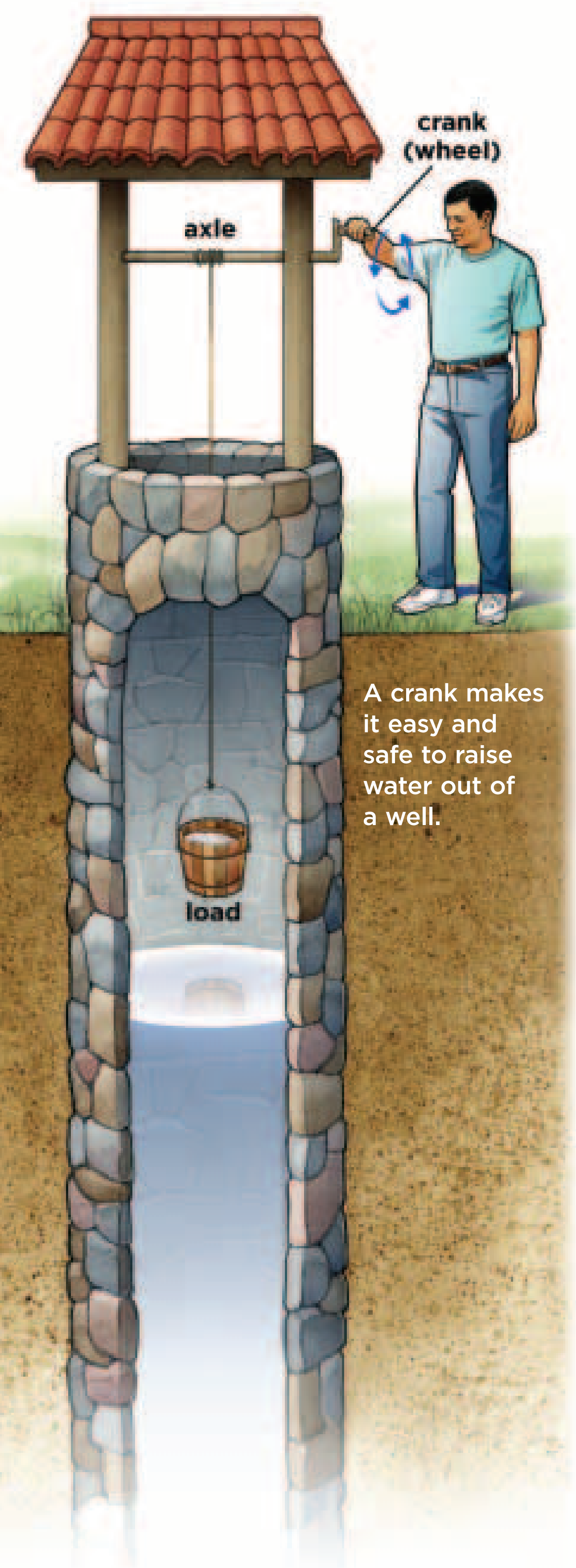
As the diagram of the fishing rod on this page shows, a third-class lever multiplies the distance of the effort. The person would only need to move her hands a short distance to move the tip of the rod through a greater distance. This allows her to cast a lure through a long distance.

Quick Check

Classify How are all three classes of levers alike?

Critical Thinking Suppose the effort arm of a lever moves 5.1 meters while its resistance arm moves 1.7 meters. What is this lever's mechanical advantage?

Wheel and Axle



A crank makes it easy and safe to raise water out of a well.

What other machines are like levers?

The **wheel and axle** is a simple machine that is actually a type of first-class lever. This machine usually consists of a wheel that applies an effort force and a smaller axle that produces the output force. The mechanical advantage of a wheel and axle is generally calculated by dividing the length of the effort arm by the length of the resistance arm. The effort arm is the radius (half the distance across the circle) of the wheel. The resistance arm is the radius of the axle. Since the effort arm can be quite large compared to the resistance arm, this machine can have a large mechanical advantage.

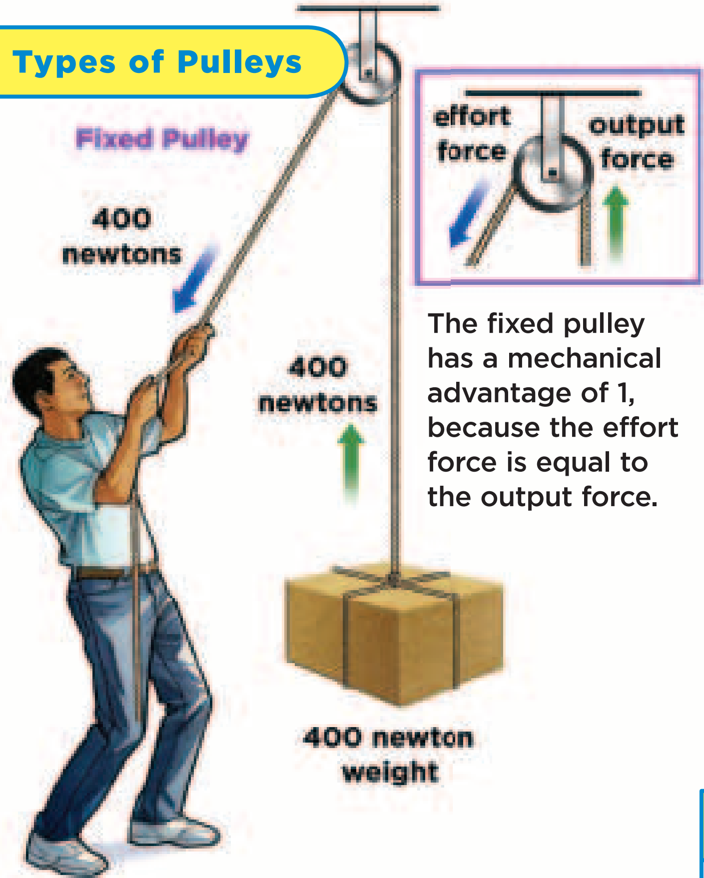
A wheel and axle can also make work easier in another way. If the radius of the wheel is smaller than the radius of the axle, then the length of the effort arm is smaller than the length of the resistance arm. This machine increases the output distance and reduces the output force. Helicopters and ceiling fans use this type of wheel and axle. Because work is a product of force and distance, a machine that reduces either force or distance will reduce the total amount of work done.

Pulley

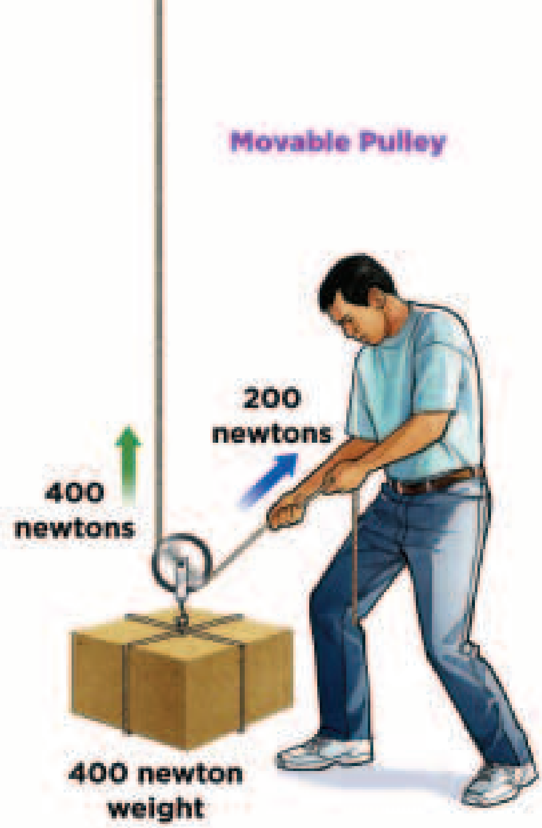
A **pulley** is a grooved wheel that turns by the action of a rope in the groove. When the rope moves, the wheel turns. A pulley is also a type of lever, one in which the rope forms the arms and the wheel serves as the fulcrum.

A pulley may be either fixed or movable. The wheel of a fixed pulley is attached to a fixed support. It acts like a large number of levers that are continuously rolling into place. A fixed pulley makes work easier by changing the direction of the effort force. It does not change the strength of the effort force itself.

Types of Pulleys



The fixed pulley has a mechanical advantage of 1, because the effort force is equal to the output force.



Read a Diagram

How are fixed and movable pulleys alike? How are they different?

Clue: Note how the two types of pulleys are used.

The wheel of a movable pulley is attached to the object being lifted and moves with it. A single movable pulley multiplies the effort force by 2, so it has a mechanical advantage of 2. However, a single movable pulley does not change the direction of the effort.

A pulley system is made up of several pulleys acting together. Some pulley systems contain both fixed and movable pulleys. The addition of a fixed pulley enables the system to change the direction of the effort. The mechanical advantage of a pulley system can be expressed in terms of the distance it moves an object compared to the distance its rope must be pulled when the effort is applied. You can calculate this mechanical advantage by dividing the distance the effort rope moves by the distance the object moves. A simple way to measure the mechanical advantage of a pulley system is to count the number of rope strands pulled downward by the object being lifted. This number is the mechanical advantage of the system.

Quick Check

Classify In a wheel and axle, the fulcrum lies between the effort arm and the resistance arm. Based on this position, what class of lever is the wheel and axle?

Critical Thinking How does a pulley system made up of a fixed pulley and a movable pulley make it easier to do work?

What are inclined planes?

Ramps make the entrances to public buildings such as schools or post offices wheelchair accessible. A ramp is an example of a simple machine called an inclined plane. An **inclined plane** is a straight, slanted surface that can multiply an effort force. An inclined plane makes it easier to move a heavy load upward.

Mechanical Advantage

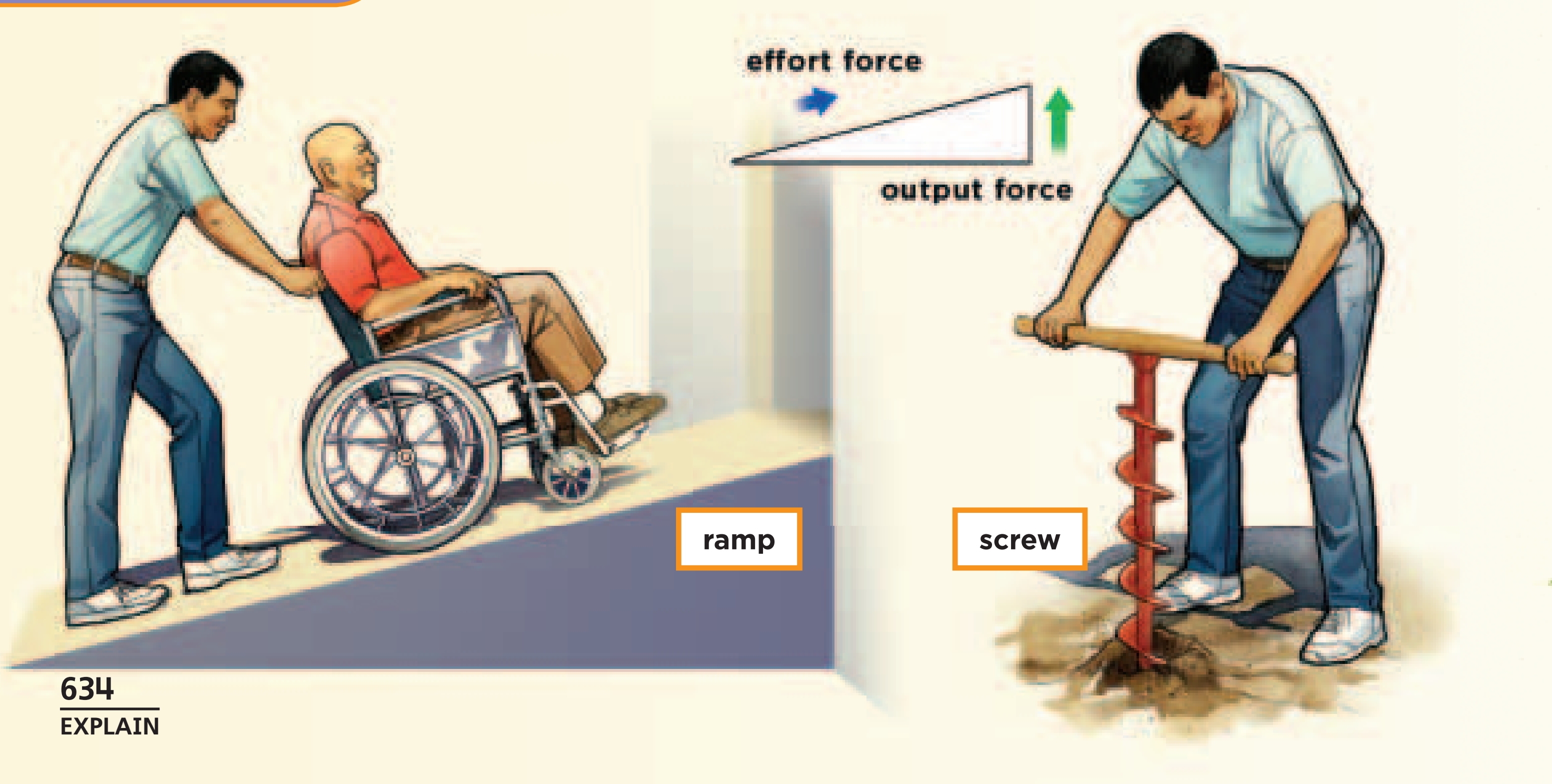
The mechanical advantage of a ramp is equal to the output force divided by the effort force. Suppose two students use ramps to slide boxes weighing 300 newtons onto a stage. One student uses a steeper, shorter ramp and applies an effort force of 225 newtons. The other uses a shallower, longer ramp and applies an effort force of 135 newtons.

For both planes in this example, the output force is the weight of the box, or 300 newtons. The effort force of the steeper ramp is 225 newtons. Its mechanical advantage is 300 divided by 225, which equals 1.33. The effort force of the longer ramp is 135 newtons. Its mechanical advantage is 300 divided by 135, which equals 2.22. The longer ramp has the greater mechanical advantage.

The ratio of output force to effort force is the same as that of effort distance to output distance. For this reason, a ramp's mechanical advantage can also be found by dividing the length of the incline by its height.

A **screw** is another simple machine that can multiply an effort force. A screw is an inclined plane wrapped around a central bar. Spiral ridges called *threads* move into an object as the head of the screw turns. The space between the threads is called the *pitch*. A screw's mechanical advantage is calculated in a similar way to a ramp's.

Inclined Planes



To find the mechanical advantage, divide the effort distance by the output distance. The effort distance of a screw is the distance around its head. The output distance is the pitch of the screw. If the distance around the head of a screw were 1.5 centimeters and its threads were 0.1 centimeters apart, its mechanical advantage would be 1.5 divided by 0.1, which equals 15.

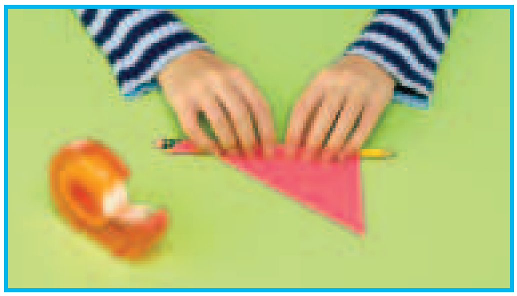
Wedges

A **wedge** is an inclined plane that changes the direction of an applied effort force. A knife is a wedge. When you push down on a knife to cut food, the knife presses sideways against the food, pushing it apart. A wedge may be a single inclined plane or two inclined planes joined back-to-back. Inclined planes that are longer than they are high have greater mechanical advantages. In a similar way, wedges that are thin have greater mechanical advantages than those that are thick.

Quick Lab

Make an Inclined Plane into a Screw

1. **Make a Model** Does a screw include an inclined plane? Draw a right triangle on a piece of construction paper. Make the base 22 cm and the height 12.5 cm. Cut it out, and label it *Triangle A*. Color the hypotenuse with a marker.
2. **Measure** Place a pencil parallel to the base of the triangle. Roll the triangle tightly around the pencil so that the colored edge makes a model of the threads on a screw. Measure the distance between the colored lines on your model screw.



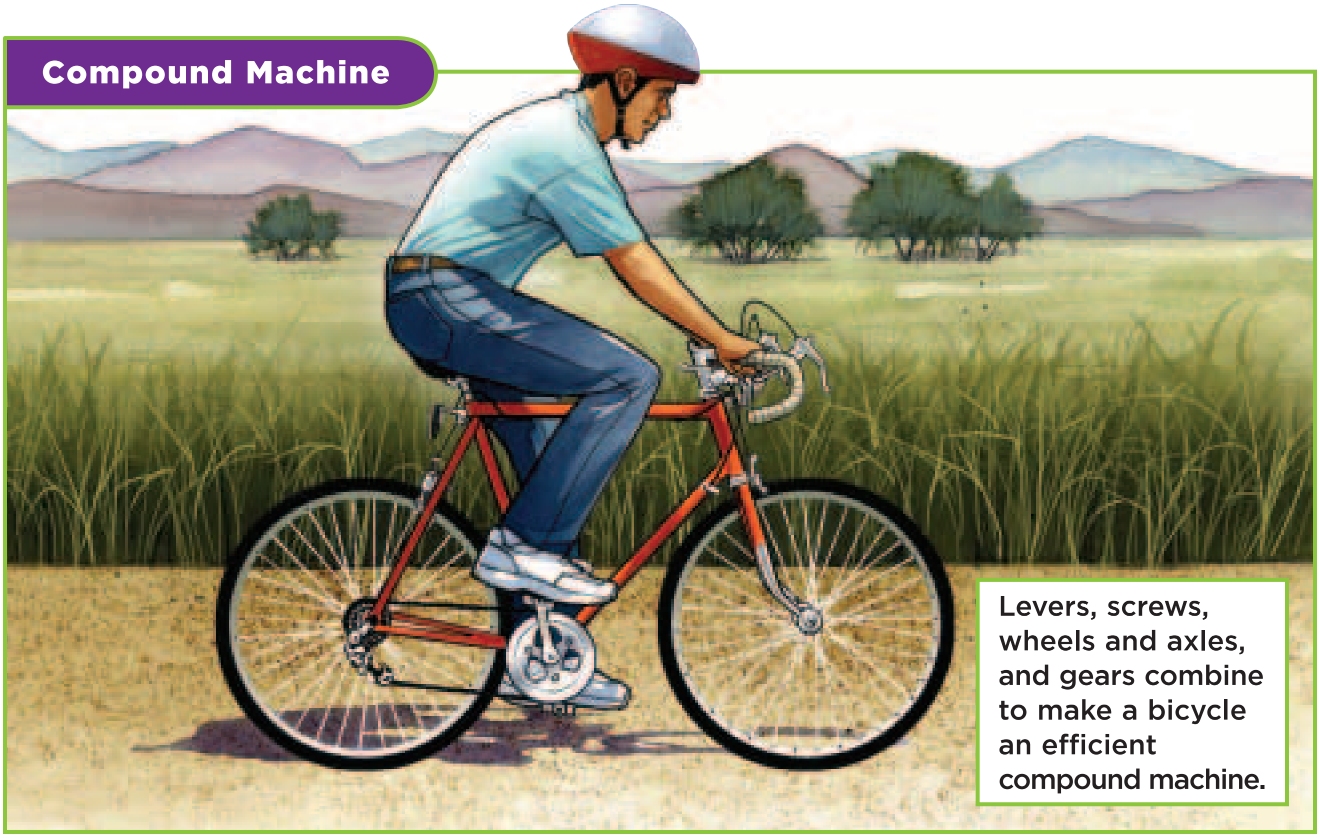
3. Repeat steps 1 and 2, using a right triangle with a 22 cm base and an 8 cm height. Label this *Triangle B*.
4. **Infer** Which model screw had more threads in a given distance? If used as a screw, which triangle would result in a higher mechanical advantage? Explain your answer.

Quick Check

Classify What do wedges, screws, and inclined planes have in common?

Critical Thinking How do inclined planes make work easier?

Compound Machine



Levers, screws, wheels and axles, and gears combine to make a bicycle an efficient compound machine.

What are compound machines?

A **compound machine** is a combination of two or more simple machines. For example, scissors include two levers and two wedges. The pivot point for the blades and handles is the fulcrum, and the blades are the wedges.

A bicycle is another compound machine. The brakes are composed of two levers. The pedals are wheel-and-axle machines. A bicycle also has a system of connected wheels and axles called gears. These allow a rider to change the mechanical advantage. In the lowest gear, a small effort force is needed to turn the pedals. In higher gears, larger effort forces are needed.

The work put into a machine is always greater than its resulting work output. This is because friction causes some of the work input to be lost as heat. Energy that is wasted as heat reduces the machine's efficiency. **Efficiency** is the ratio of the work done by a machine to the work that was put into it. To calculate efficiency, divide the output work by the effort work.

Coating certain parts of a machine with substances such as oil can reduce friction. Oil can reduce the amount of energy that is wasted as heat and increases the efficiency of a machine.

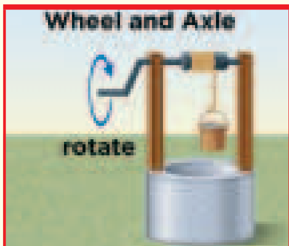
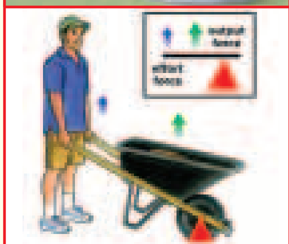
Quick Check

Classify Suppose a worker rolls a filled wheelbarrow up a ramp. What types of machines are used?

Critical Thinking Is it possible for the mechanical advantages of two compound machines with different-sized inclined planes to be the same? Explain why or why not.

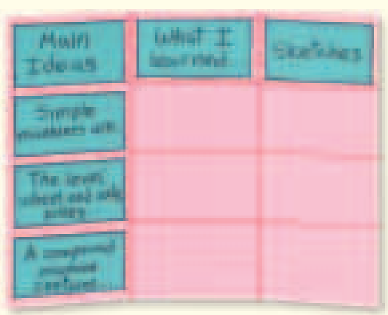
Lesson Review

Visual Summary

	**Simple machines** are devices that make work easier. They have few, if any, moving parts.
	The **lever**, **wheel and axle**, **pulley**, **inclined plane**, **screw**, and **wedge** are types of simple machines.
	A **compound machine** contains two or more simple machines that work together.

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the labels shown. Complete the statements, and include a sketch of each type of machine.



Think, Talk, and Write

1. **Main Idea** What are the six types of simple machines?
2. **Vocabulary** The number of times a simple machine multiplies an effort force is called the machine's ________.
3. **Classify** Why is a screw classified as an inclined plane?

4. **Critical Thinking** How can you minimize friction on a bicycle?
5. **Test Prep** **As a simple machine is used, some of the work put in is lost as heat, and this reduces the machine's**
   - **A** energy.
   - **B** friction.
   - **C** efficiency.
   - **D** heat.
6. **Test Prep** **Which of the following are compound machines?**
   - **A** scissors
   - **B** pulleys
   - **C** ramps
   - **D** levers

Writing Link

Expository Writing
Different parts of your body act as levers. Write a paragraph that describes how three different parts of your body can act as levers.

Math Link

Calculate Efficiency
A machine does 1,500 J of work when 2,000 J of work are put into it. Calculate the machine's efficiency. Express the result as a percent.

HOW GEARS WORK

Explanatory Writing

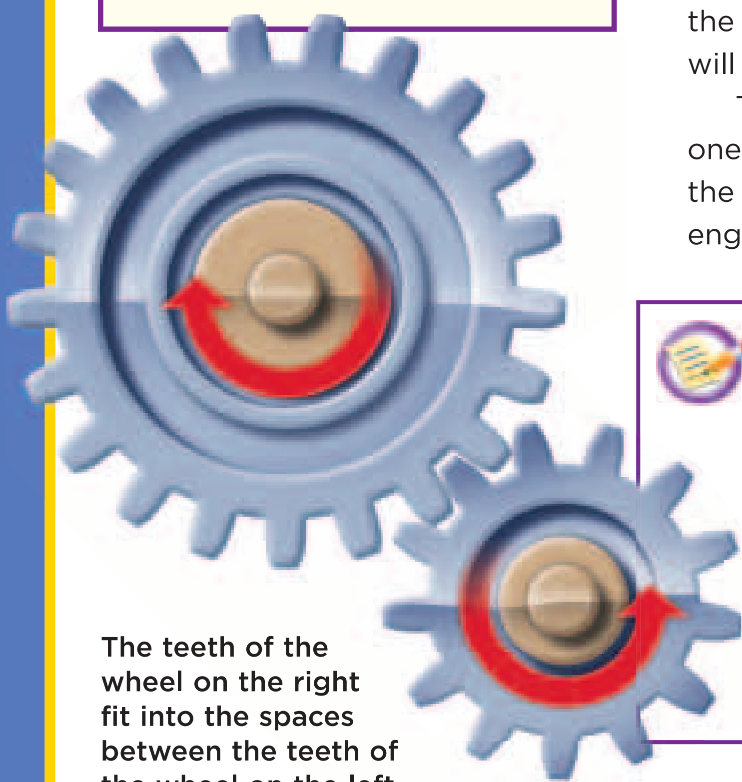
Good explanatory writing

- explains or gives information about a process, a task, or the way something works
- gives clear details that are easy to follow
- uses spatial words or time-order words to make the process or task clear

A gear is a type of connected wheel and axle that transmits motion and force. Any machine that has spinning parts probably has gears. Bicycles, cars, and wind-up clocks all have gears.

Each of the gears is a circular disc with teeth cut into its edges. The teeth of one disk fit into the spaces between the teeth of another disk as the two rotate. The two wheels rotate in opposite directions. If the two wheels are the same size, then they rotate at the same speed. However, one wheel is usually smaller than the other. In this case, the two gears remain synchronized, because the smaller gear rotates faster than the larger one. For example, if the larger gear is twice the size of the smaller gear, then the smaller one will rotate twice as fast as the larger one.

The turning of gears transfers energy from one part of a machine to another. For example, the turning of gears transfers energy from the engine of a car to the wheels.



The teeth of the wheel on the right fit into the spaces between the teeth of the wheel on the left.

Write About It

Explanatory Writing Choose an everyday gadget or device that uses gears to make work easier. For example, you might choose a ten-speed bicycle, a clock, or a mechanical can opener. Write an explanation of how it works.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Which Car Is the Most Fuel Efficient?

Hybrid cars use less energy from fossil fuels by using a combination of gasoline for the combustion engine and electricity from a battery. These cars can be very fuel efficient.

Fuel-efficiency information is usually written in miles per gallon (mi/gal) or kilometers per liter (km/L). These ratios tell car buyers how many miles or kilometers the car can travel on 1 gal or 1 L of gasoline. This helps a car buyer determine how much it might cost to drive a car, given the price of gasoline and the number of miles or kilometers the buyer drives in a year.

Convert Measurements

For accurate calculations use these measurements:

1 mi/gal = 0.425 km/L
1 km/L = 2.35 mi/gal

- **To convert mi/gal to km/L, multiply the mi/gal by 0.425.**
  22 mi/gal × 0.425 = 9.35 rounded to 9.4 km/L
- **To convert km/L to mi/gal, multiply the km/L by 2.35.**
  9.35 km/L × 2.35 = 21.97 rounded to 22 mi/gal

Solve It

1. The table lists different types of vehicles. In order to compare efficiency, all the measurements must be in a single system. Complete the table by converting mi/gal to km/L or km/L to mi/gal to fill in the missing information.

2. Which car is the most fuel efficient? Which is the least fuel efficient?

3. Hybrid car B travels 46 mi on 1 gal of gasoline. How many gallons are needed for the car to travel 500 mi?

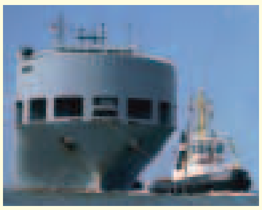
Vehicle	Fuel Use (in mi/gal)	Fuel Use (in km/L)
Sports Car A		9.8
Sports Car B	18	
Hybrid Car A		15.3
Hybrid Car B	46	
Sedan A		16.2
Sedan B	20	
Luxury Car		5.2
Compact Car A		15.3
Compact Car B	29	
Station Wagon		11.0
Sport Utility Vehicle	14	

CHAPTER 11 Review

Visual Summary

Lesson 1 Change of position, velocity, and acceleration are three characteristics of motion.

Lesson 2 Forces cause changes in the speed and direction of moving objects.

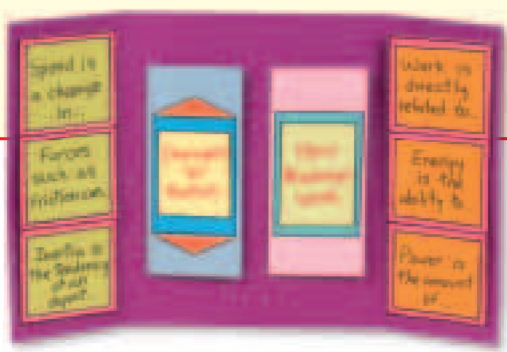


Lesson 3 Energy is the ability to do work. Energy can take many forms.

Lesson 4 Simple machines make it easier for people to do work.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you have learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

force, p. 594	**velocity**, p. 593
kinetic energy, p. 618	**wedge**, p. 635
lever, p. 630	**weightlessness**, p. 610
motion, p. 590	
potential energy, p. 618	

1. A simple machine with a rigid bar and a fulcrum is called a(n) ________.
2. Because it can snap back, a stretched rubber band has ________.
3. The condition that exists in places without a detectable gravitational pull is ________.
4. A moving object's speed and direction determines its ________.
5. An object that is moving has ________.
6. An inclined plane that changes the direction of an applied force is a(n) ________.
7. A push or pull on an object is called a(n) ________.
8. Speed, velocity, and acceleration are ways to describe ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. **Fact and Opinion** Kate put 12 books on the middle shelf of a bookcase. Natasha put 10 books on the top shelf of the bookcase. Natasha told Kate, "I did more work than you did." Was her statement a fact or an opinion? Explain.

10. **Explanatory Writing** Explain the three characteristics of motion and how each is calculated.

11. **Predict** Suppose you dropped a dime and a quarter off the top of a skyscraper. Which would hit the ground first? Why?

12. **Critical Thinking** Machines make work easier. Are there any disadvantages to using machines?

13. **Infer** Is the energy of this skater potential or kinetic, and how does friction affect this skater moving forward? Explain.

The Big Idea

14. How is energy used and stored?

Performance Assessment

How Powerful Is He?

Your goal is to calculate the power for climbing a flight of stairs.

What to Do

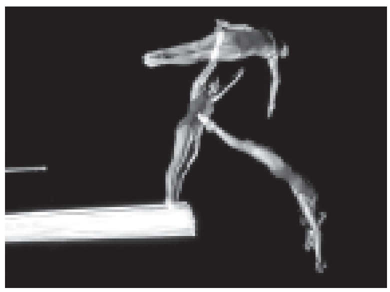
1. Your friend weighs 110 pounds. Convert his weight to newtons by dividing his weight by 0.22. Find the height of a staircase in meters by measuring the height of one stair and multiplying it by the total number of stairs.
2. Calculate the total amount of work he would do. Multiply his weight in newtons by the staircase's height in meters. Express your answer in joules.

Analyze Your Results

▶ Calculate power: divide the amount of work done by the time it took. What was the power if it took two minutes? Three minutes? Express your answers in watts.

Test Prep

1. Look at the picture below.



Which of Newton's laws does this picture illustrate?

A universal gravitation

B action-reaction

C inertia

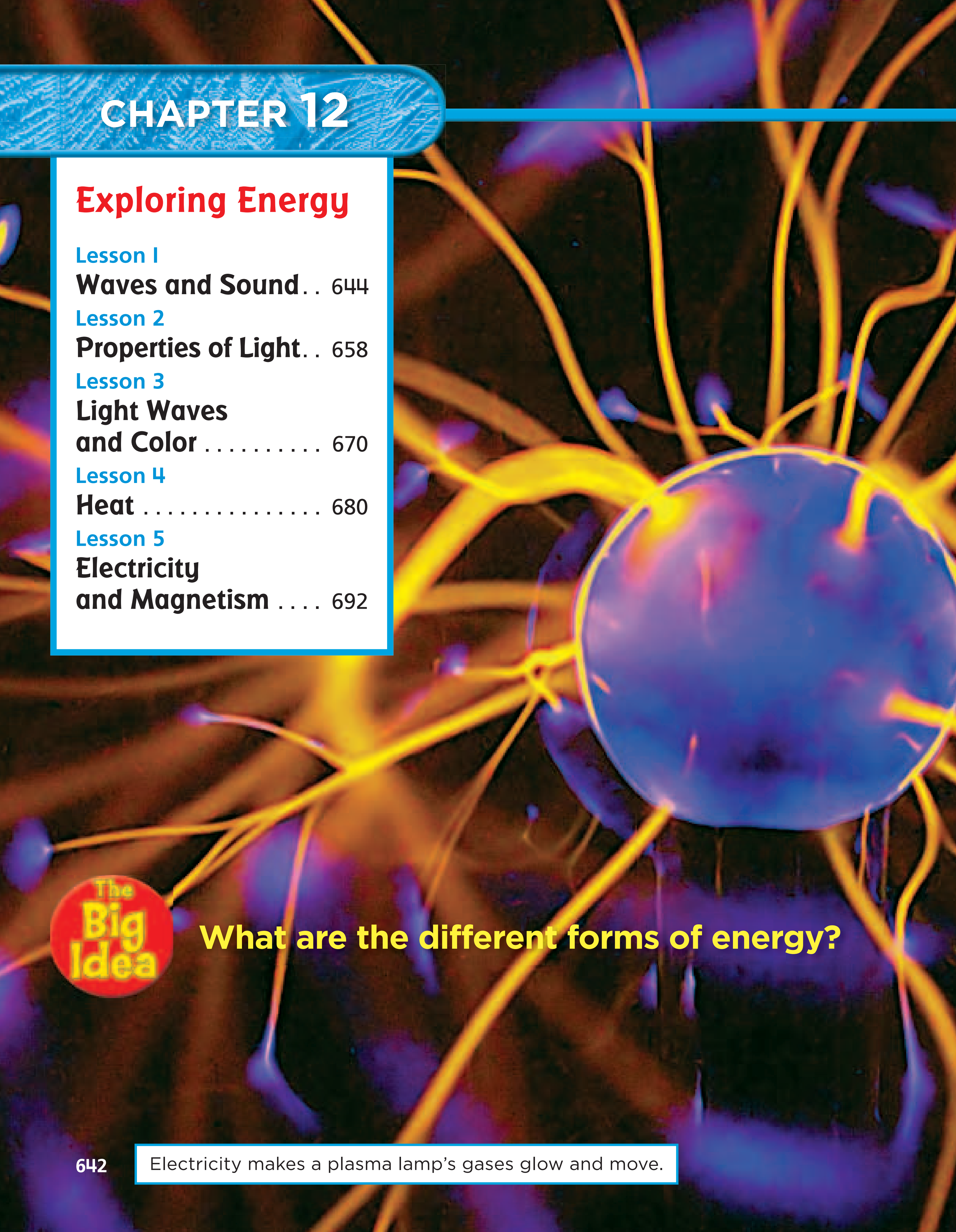
D conservation of momentum

CHAPTER 12

Exploring Energy

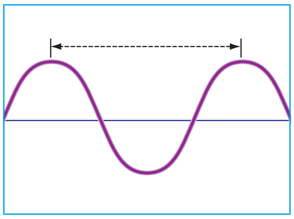
The Big Idea

What are the different forms of energy?

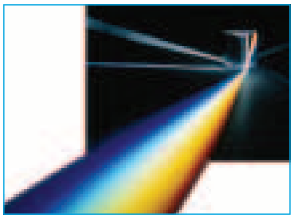


Electricity makes a plasma lamp's gases glow and move.

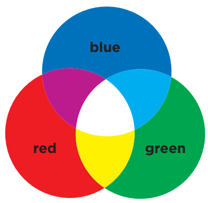
Key Vocabulary



wavelength
The distance between wave crests or troughs. (p. 648)

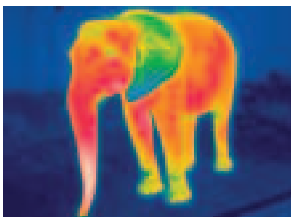


visible light
The light that you can detect with your eyes. (p. 672)

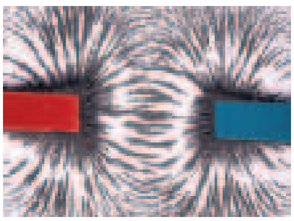


primary color
One of three colors of light—red, green, or blue—from which all other colors of light can be produced. (p. 676)

mirror
An object with a polished surface that forms reflected images. (p. 662)



heat
The flow of energy from one object to another. (p. 682)



magnetic field
An invisible area where the forces of magnetic attraction or repulsion can be detected. (p. 702)

More Vocabulary

compression, p. 647

rarefaction, p. 647

frequency, p. 648

amplitude, p. 648

sound wave, p. 650

reflection, p. 650

Doppler effect, p. 652

transparent, p. 661

lens, p. 661

translucent, p. 661

opaque, p. 661

mirror, p. 662

electromagnetic spectrum, p. 674

secondary color, p. 676

pigment, p. 676

heat, p. 682

conduction, p. 684

convection, p. 684

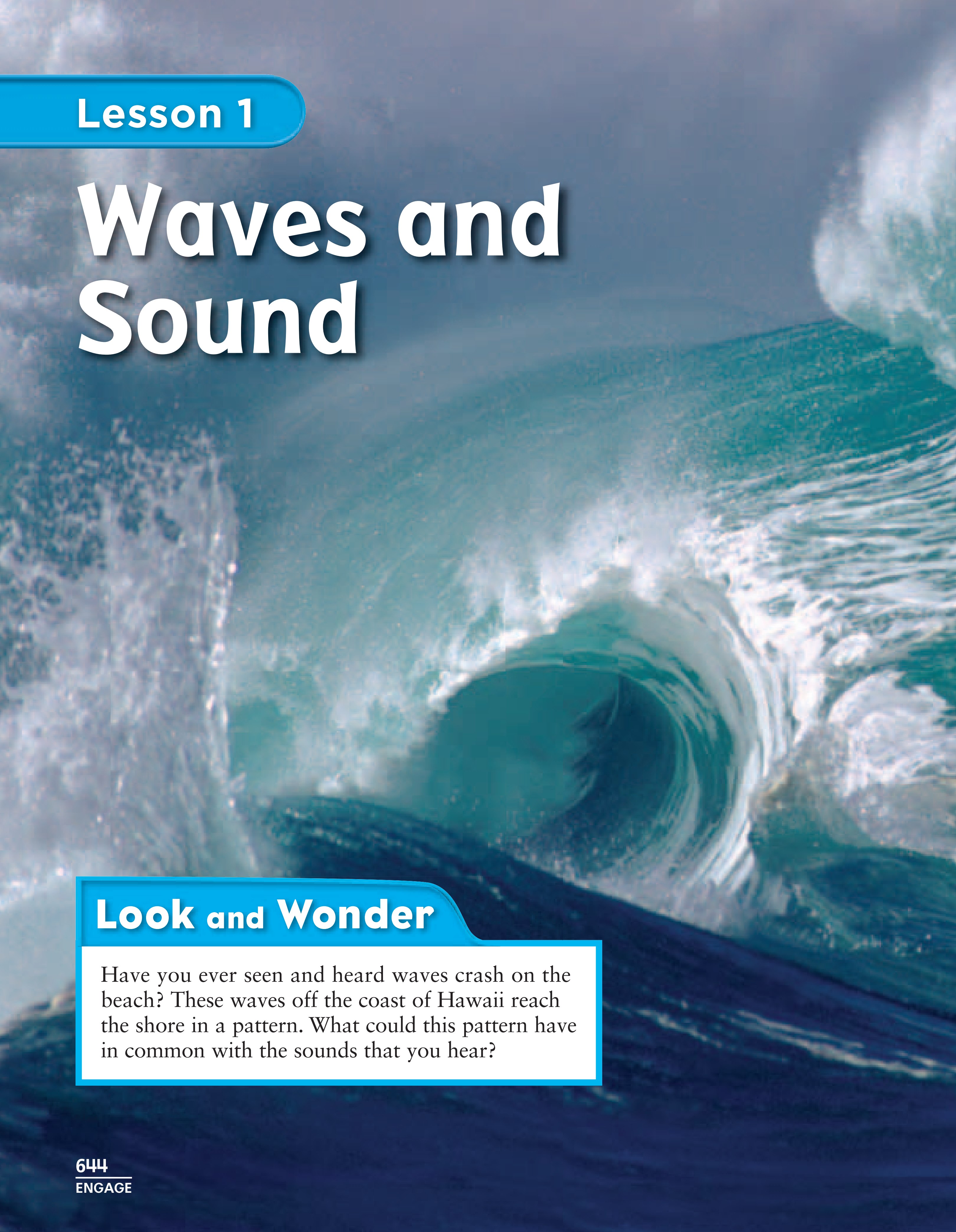
electricity, p. 694

series circuit, p. 700

parallel circuit, p. 701

magnetic field, p. 702

electromagnet, p. 703



Lesson 1

Waves and Sound

Look and Wonder

Have you ever seen and heard waves crash on the beach? These waves off the coast of Hawaii reach the shore in a pattern. What could this pattern have in common with the sounds that you hear?

Explore

Inquiry Activity

How do waves affect the motion of objects?

Make a Prediction

On calm days, ocean waves are usually small, and they roll gently toward the shore. On windy days, the height of ocean waves increases. What happens when waves reach floating objects? Do the objects move with the wave or stay in the same position? Write your answer in the form of a prediction: "If a wave hits a floating object, then the object will . . ."

Test Your Prediction

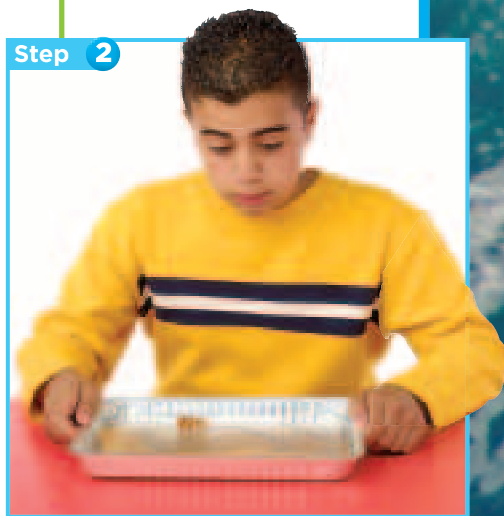
1. **Experiment** Fill the pan with water to a depth of about 2.5 cm. Place the cork in the middle of the pan, and wait until the cork stops moving.
2. **Observe** Gently move the pan back and forth once or twice, so that a series of waves moves across the pan. Observe and record the motion of the cork.
3. When the waves stop and the cork stops moving, what is the cork's final position compared to where it started in the middle of the pan?
4. **Experiment** Try moving the pan from side to side. How does this change the waves? How does this affect the cork's motion? Move the pan a little harder. What happens to the cork?

Draw Conclusions

5. **Interpret Data** Would this type of wave move an object through a distance? Explain.

Materials

- rectangular baking pan
- water
- ruler
- cork



Explore More

Try using more or less water or using a container with a different shape. How will these changes influence how a wave moves an object? Test your prediction, and share the results with your class.

Read and Learn

Main Idea

Waves transfer sound energy from a source through a medium.

Vocabulary

- transverse wave, p. 646
- compressional wave, p. 646
- compression, p. 647
- rarefaction, p. 647
- wavelength, p. 648
- frequency, p. 648
- amplitude, p. 648
- reflection, p. 650
- refraction, p. 651
- Doppler effect, p. 652

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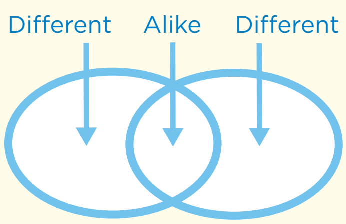
Reading Skill

Compare and Contrast



Technology SCIENCE QUEST

Explore solar radiation with an engineer.

What are waves?

When a duck lands in a pond, it disturbs the water. This disturbance produces a series of circles that grow larger as they move away from the duck. These circles are waves. A *wave* is a disturbance that transfers energy from one point to another. Some waves, such as light waves, can travel through empty space. Other kinds, such as sound waves, must travel through a *medium*, or substance, in order to transfer energy. A medium can be a solid, a liquid, or a gas. The movement of particles by a wave is called *vibration*. Waves are classified by the type of vibration they cause in a medium.

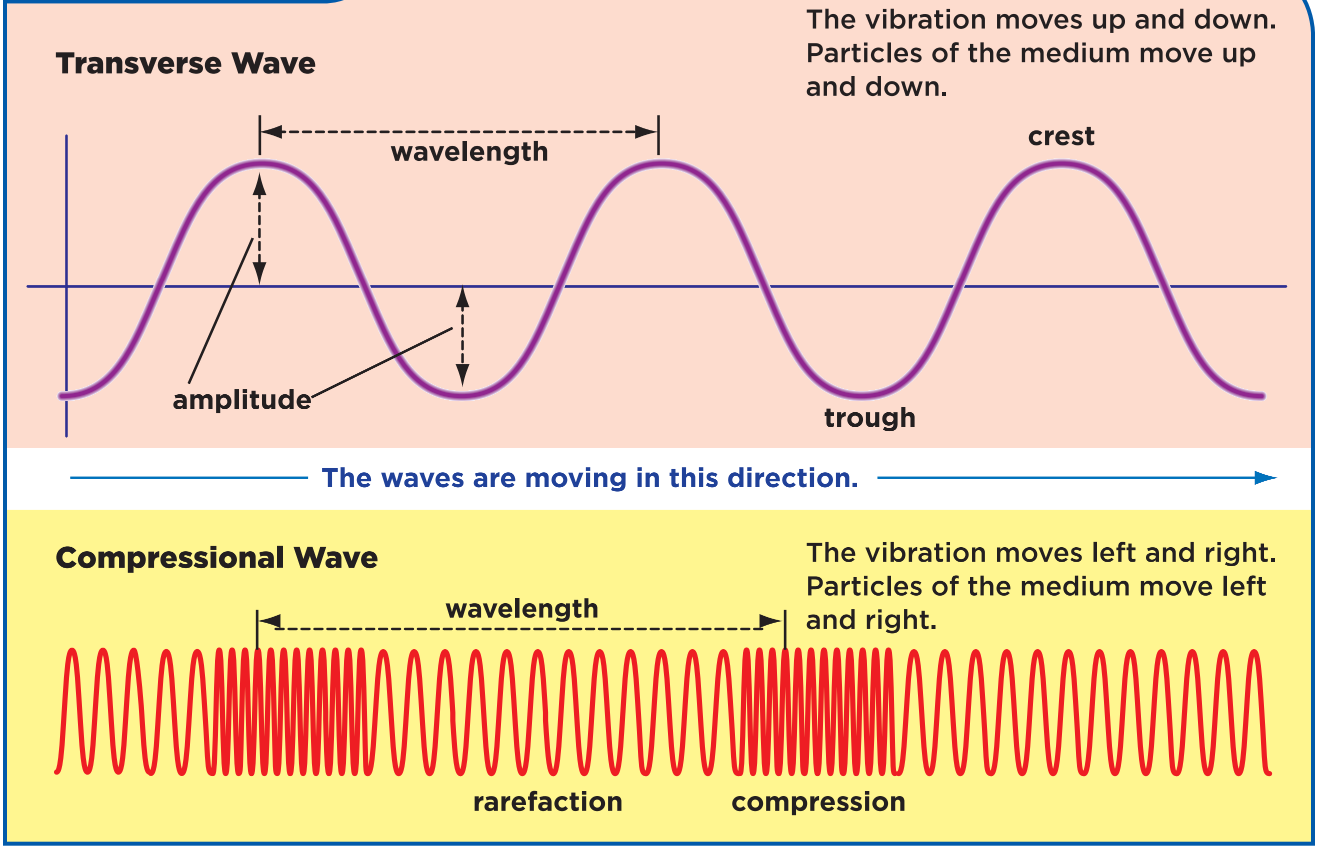
Types of Waves

When a **transverse wave** travels through a medium, matter moves up and down as the wave travels through it. A wave that you might make by moving in the water is a transverse wave.

When a **compressional wave** travels, matter moves back and forth as the wave travels through it. Think of a long coiled spring. If you move one part back and forth, it hits the next coil on the spring. The coil then returns in the other direction. A wave travels down the coils, moving each coil back and forth.

A feeding dunlin causes ripples in still water. ▼

Types of Waves



The vibration of the coils produces a **compression**, an area where particles are pushed together. Behind the compression is a **rarefaction** (rayr•uh•FAK•shuhn), an area where particles are spread apart. The wave moves through its medium as a series of compressions and rarefactions.

Features of Waves

The crest of a transverse wave is its highest point. In a compressional wave, the crest is the point of greatest compression—the area where particles are closest together. Waves also have *troughs* (trawfs). The trough of a transverse wave is its lowest point. In a compressional wave, the trough is the point of greatest rarefaction—the area where particles are farthest apart.

All waves travel and transfer energy from one point to another, with little or no displacement of the particles of the medium. Once the wave has passed, the particles end up in about the same position they started in. This is similar to "the wave" at a sporting event. After the wave moves across a group of spectators, the fans are once again sitting in the same places they were in before the wave.

Quick Check

Compare and Contrast How are light energy and sound energy similar? How are they different?

Critical Thinking Explain which type of wave – transverse or compressional – is most similar to "the wave" at a sporting event.

How can you measure waves?

Wavelength is the distance between wave crests or troughs. **Frequency** is a measure of how many wave crests or troughs pass a given point in one unit of time, such as a second. High-frequency waves have shorter wavelengths and transfer greater energy. If you vibrated a clothesline rapidly, the waves would move at a high frequency. If you vibrated it more slowly, the waves would have a lower frequency. The *period* of a wave is the amount of time it takes for a wave to complete one full cycle. Period is the inverse of frequency. **Amplitude**, the height of the wave from its trough or crest to its midpoint, is a measure of the wave's intensity. In the ocean, a wave's amplitude increases as it nears the shore.

Frequency and Speed of Waves

Frequency is measured in hertz (Hz), the number of waves per second. *Hertz* means "cycles per second" with respect to frequency. Picture a motorboat passing a floating buoy. Waves from the boat cause the buoy to vibrate up and down 4 times in 16 seconds. The frequency of the vibrations is 0.25 hertz.

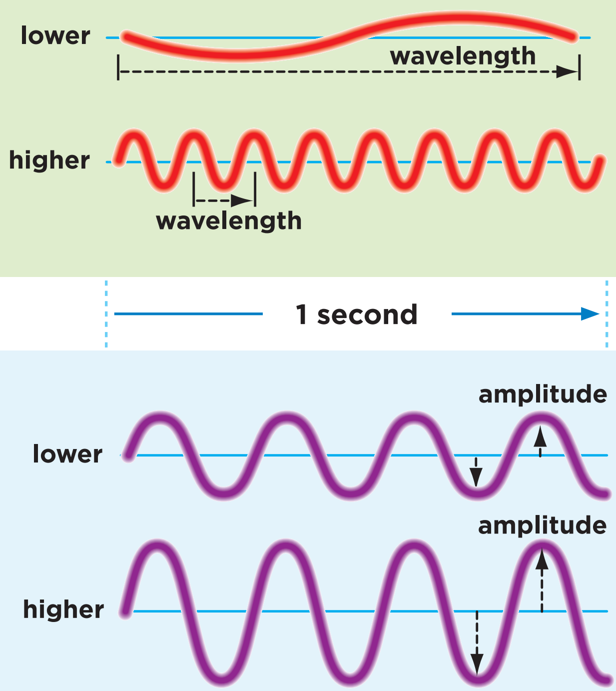
Frequency and Amplitude

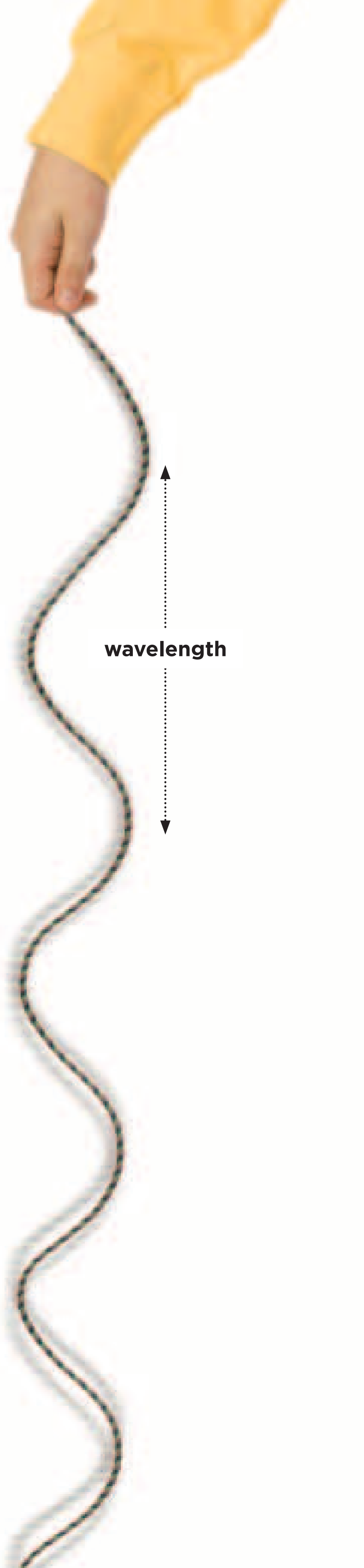
Frequency

Lower-frequency waves disturb a medium with fewer wave cycles per second than higher-frequency waves would.

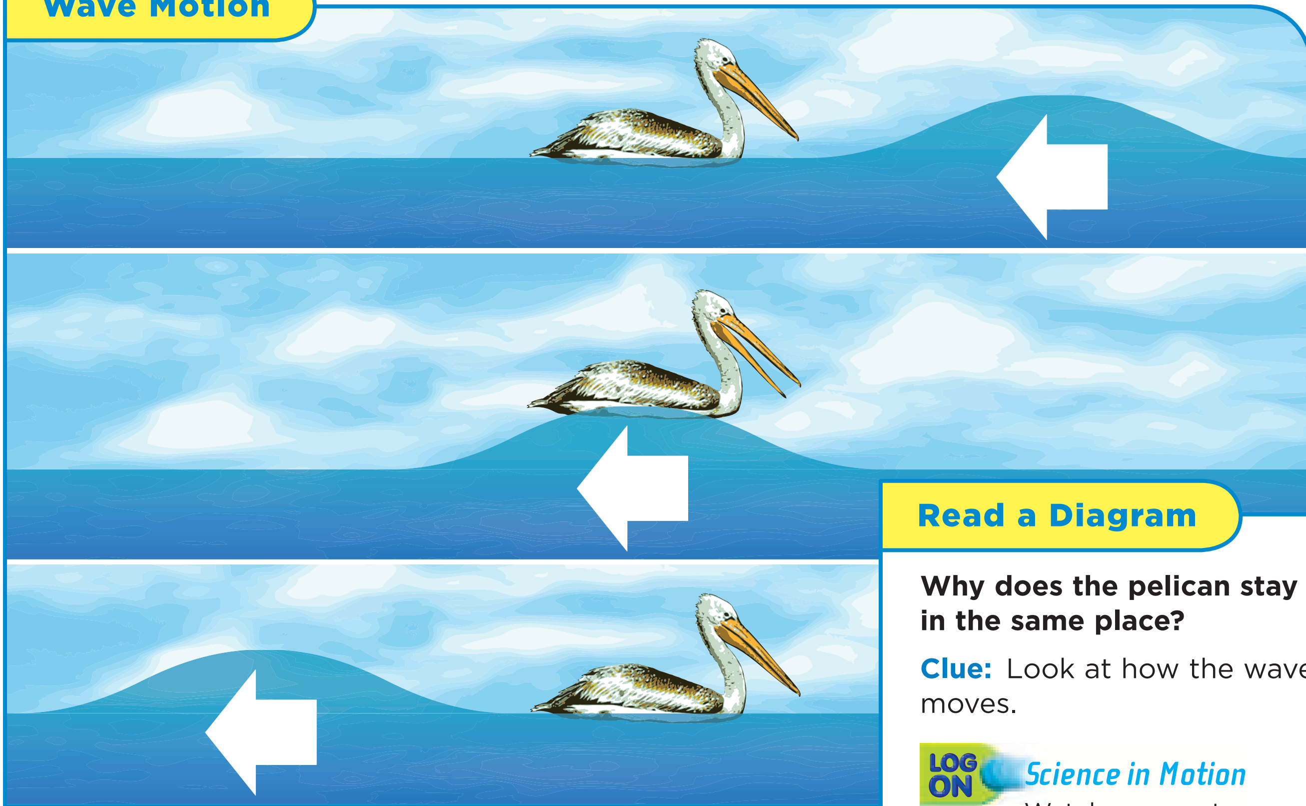
Amplitude

Higher-amplitude waves are more intense, or stronger, than lower-amplitude waves.





Wave Motion



Read a Diagram

Why does the pelican stay in the same place?

Clue: Look at how the wave moves.

LOG ON *Science in Motion* Watch waves at www.macmillanmh.com

Speed describes how fast something travels in a specific amount of time. The distance a wave travels per second determines its speed. For example, a boat passes within 65 meters of a buoy. The waves from the boat take 5 seconds to reach the buoy. The wave's speed is 65 meters divided by 5 seconds, or 13 meters per second. A high-frequency wave can travel slowly. Likewise, a fast-moving wave can have a low frequency.

Factors That Affect Speed

The medium through which a wave travels affects its speed. The depth of the water affects the speed of ocean waves. The deeper the water, the faster the wave travels. In sound waves, the distance between particles affects wave speed. Sound waves, as you might infer, move fastest through solids, slower through liquids, and slowest through gases. Think of two springs of equal length, one with more coils than the other. The coils represent particles of matter in the medium. The spring with more coils conducts sound waves more rapidly, because the particles are in closer contact and will spring back and transmit energy faster.

Quick Check

Compare and Contrast How is a wave's frequency different from its speed?

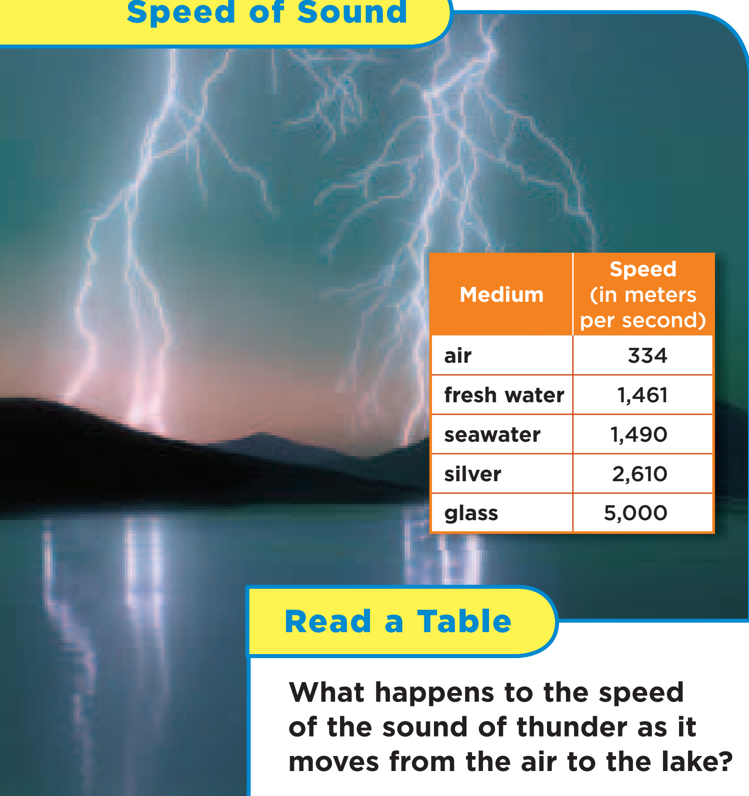
Critical Thinking Which would transmit sound better: a wire or air? Explain.

How does sound travel?

A *sound wave* is a compressional wave produced by vibrations in matter. Molecules in the medium move back and forth, pushing nearby molecules. A compression forms as the molecules are pushed closer together. A rarefaction then forms behind the compression. The compression and the rarefaction together form one cycle of a sound wave. Since sound waves depend on the compression of matter, they need a medium to travel through. For this reason, sound waves cannot travel through empty space.

Tuning forks vibrate at particular frequencies. The vibrations produce compression waves in the air. Waves can be studied by scientists with devices such as oscilloscopes (uh•SIL•uh•skohps).

Speed of Sound



Medium	Speed (in meters per second)
air	334
fresh water	1,461
seawater	1,490
silver	2,610
glass	5,000

Read a Table

What happens to the speed of the sound of thunder as it moves from the air to the lake?

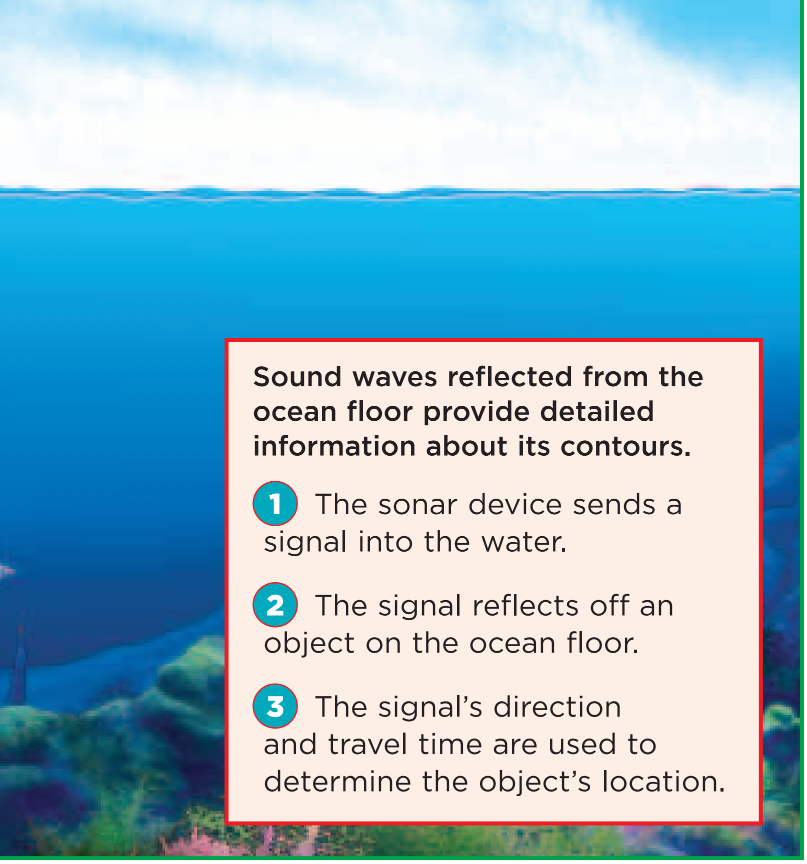
Clue: Does sound move faster in air or water?

Sonar

Reflected Sound

When you look in a mirror, light waves bounce off the mirror into your eyes and enable you to see your image. Sounds also reflect off objects. **Reflection** refers to how waves bounce off an object and change their direction of travel. An *echo* is a reflected sound wave.

The technology called sonar uses reflected sound waves, or echoes, to locate unseen objects and to make maps of the ocean floor. Fishers and marine biologists use sonar to locate schools of fish. Sonar works by bouncing sound waves off an object and measuring the time the echoes take to return. The speed of sound waves in a particular medium is known for many different substances, such as seawater and air. Therefore, the exact location of an object can be determined from the travel time of the echo in a medium.



Sound waves reflected from the ocean floor provide detailed information about its contours.

1. The sonar device sends a signal into the water.
2. The signal reflects off an object on the ocean floor.
3. The signal's direction and travel time are used to determine the object's location.

Refracted Sound

Refraction occurs when the direction of a wave changes because of a change in medium. This happens because waves move at different speeds through different media. Sound waves travel faster through deep water than through shallow water. Sound waves traveling through air are refracted as they enter water. If the type of medium through which waves travel changes, the waves generally change speed and direction.

Absorbing Sound Waves

The material a sound wave strikes affects how the sound wave moves. Hard surfaces easily reflect sound waves. Soft surfaces absorb sound waves. A material that absorbs sound well does not reflect sound waves. Ceiling tiles that absorb sound waves are used in concert halls, offices, and libraries.

Quick Lab

String Telephone

1. **Make a Model** Obtain two paper cups and about 10 m of string. Make a small hole in the bottom of each cup. Thread one end of the string through each hole. Tie a knot in each end of the string so the ends cannot slip through the holes.
2. **Experiment** Try your model with a partner. Each partner should take one of the cups. Move far enough apart that the string is taut between the two of you.
3. **Observe** Take turns speaking softly into the cup as your partner listens. How well are you able to communicate?
4. **Use Variables** Coat the string with wax. Does doing this improve your ability to communicate using this device?
5. **Predict** What other variables could you test that might make your string telephone more effective?

Quick Check

Compare and Contrast How are reflection and refraction similar? How are they different?

Critical Thinking How could you increase echoes in a room?

What are properties of sounds?

When the water in a whistling teakettle boils, you hear a high, shrill sound. When a musician plays a tuba, you hear a low, deep sound. Although both sounds are made by waves, they differ in pitch. The *pitch*, or the highness or lowness of a sound, depends on the frequency of the sound waves. High-pitched sounds have a high frequency. Low-pitched sounds have a low frequency. The teakettle makes a sound with a higher pitch. The tuba makes a sound with a lower pitch.

Most people can hear sound waves in the range of about 20 hertz to about 20,000 hertz. These are sound waves that cause matter to vibrate between 20 times and 20,000 times per second.

Some animals can hear sounds with frequencies higher or lower than our ears can detect. For example, many dogs have the ability to hear sounds with frequencies of up to 50,000 hertz. Certain whistles produce sounds with frequencies greater than 20,000 hertz. If you used this type of whistle, you would not hear anything, but most dogs would hear it clearly. Bats use higher-frequency sounds as sonar to find their insect prey. Other animals, such as elephants, can hear lower-frequency sounds. They communicate over long distances using sounds that are below the range of human hearing.

The Doppler Effect

The pitch of a sound can seem to change if its source or listener is in motion. This is called the **Doppler effect**. Think of what happens when the driver of an approaching car blows the car's horn. The motion of the car toward you causes the sound waves in front of the vehicle to arrive closer and closer to one another. This increases the frequency of the sound waves.

The designs and materials of instruments produce sounds of various pitches.

Therefore, you hear a sound wave with a higher pitch than the wave produced by the car's horn. The opposite occurs as the car passes. Sound waves behind the receding car arrive farther and farther apart. Your ears hear a sound wave with a lower pitch.

Although you heard the pitch of the horn move up and down, the person inside the passing car would not hear any change. The change in pitch you heard only had to do with the way in which you and the source of the sound were moving in relation to each other.

Hearing protection is necessary for airport ground-crew workers due to high-decibel sounds.

Volume of a Sound

The difference in the loudness of a sound is called *volume*. The amount of energy, or intensity, of the sound wave determines the volume of a sound. Volume is determined by amplitude. The larger the amplitude of a wave, the greater its energy. Loud sounds are produced by high-intensity waves with large amplitudes.

The volume of a sound is measured in units called *decibels* (dB). A whisper has a volume of about 30 decibels, and regular speech has a volume of about 60 decibels. Sounds of greater than 90 decibels can damage people's hearing.

Interference

If you play a song on a stereo, sound waves move through the air. Listeners can hear the sound produced. Suppose another set of speakers played the same song in the same room. This motion of two or more waves passing through the same medium at the same time is called interference.

Interference can be either positive or negative. If the crests or troughs of the waves meet, as they would if both stereos were side by side and playing the same song, the amplitudes of the waves combine. The combined sound waves of the stereos would produce a louder sound than that from one stereo alone. This is *constructive interference*.

However, this does not occur if the crest of one wave meets the trough of another. In this case the sound waves together have a lower amplitude than the sound made by one source alone. This is *destructive interference*.

Quick Check

Compare and Contrast How do destructive interference and constructive interference compare?

Critical Thinking How are sound volume and amplitude related?

How do we hear music?

The sounds made by musical instruments differ according to the types of vibrations they produce. Stringed instruments, such as guitars or violins, produce vibrations of wires or strings. Wind and brass instruments, such as trombones or flutes, produce vibrations in columns of air. The difference among sounds of the same pitch and amplitude in various instruments is called *sound quality*.

As sound waves travel, they transfer energy. When sound waves reach your ear, they pass through the ear canal to your eardrum. The sound waves strike the eardrum and cause it to vibrate. The vibrations stimulate nerve cells located deep inside the ear. These vibrations are then converted to nerve impulses that your brain recognizes. By interpreting pitch and sound quality, the brain identifies different sounds.

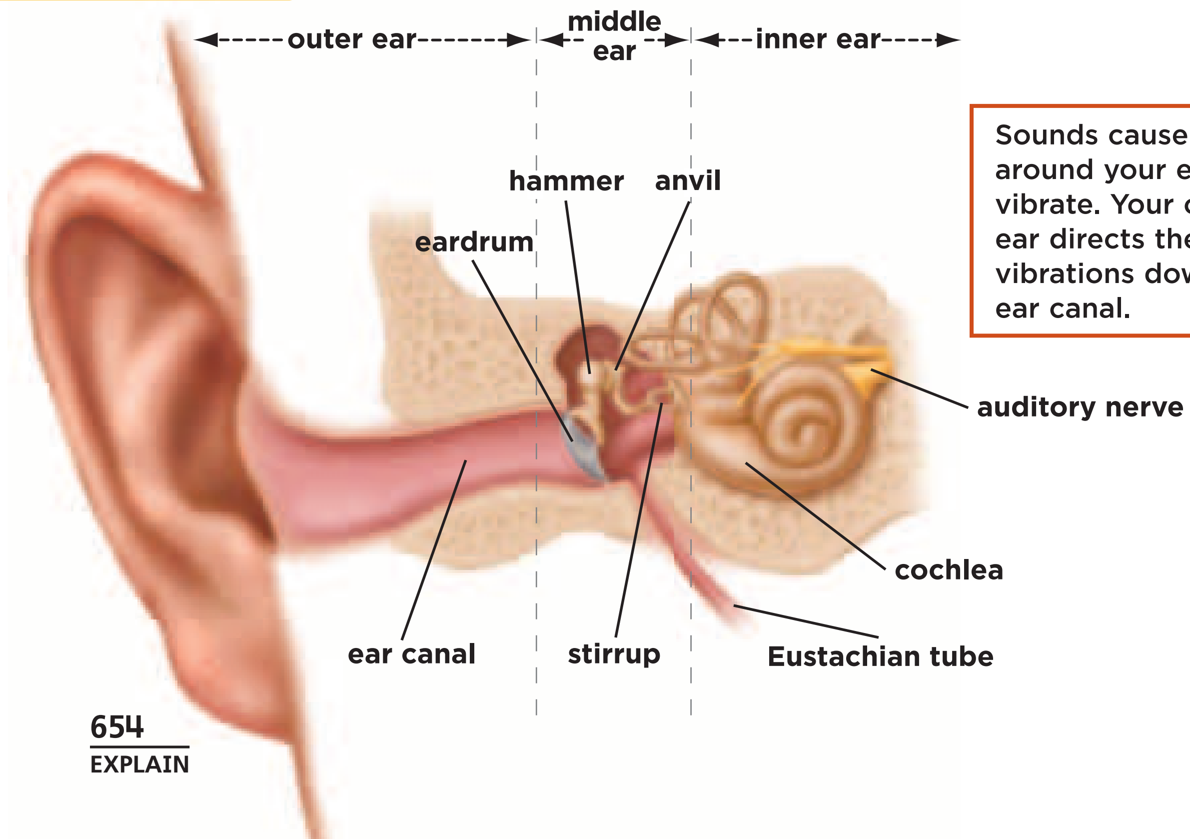
"Music" is a combination of sounds that a listener finds pleasing, and "noise" is a combination of sounds that a listener finds unpleasant. Music usually blends instrumental or vocal tones in a structured and continuous manner. However, any agreeable and harmonious sounds can be interpreted as musical. Sound that is interpreted as musical has a mathematical structure of both tones and silence. This structure is often referred to as *rhythm*. Sounds that lack harmony, rhythm, and mathematical structure are interpreted as noise.

Quick Check

Compare and Contrast How are noise and music similar? How are they different?

Critical Thinking What must occur for you to hear a sound?

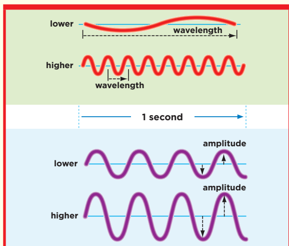
Human Ear



Sounds cause the air around your ear to vibrate. Your outer ear directs these vibrations down the ear canal.

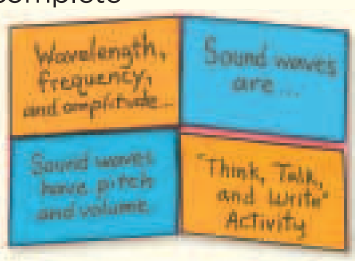
Lesson Review

Visual Summary

	**Wavelength**, **frequency**, and **amplitude** are characteristics of waves.
	**Sound waves** are vibrations that travel through a medium and cause vibrations in a receptor.
	Sound waves have **pitch** and **volume**. Their frequency is measured in hertz, and their volume is measured in decibels.

Make a FOLDABLES Study Guide

Make a Four-Door Book. Inside of each tab, complete the statement and provide details. Include your work for the Compare and Contrast question on this page.

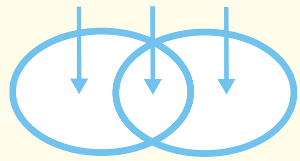


Think, Talk, and Write

1. **Main Idea** What are waves?

2. **Vocabulary** The highest point of a transverse wave is called its ________.

3. **Compare and Contrast** How are transverse waves and compressional waves alike? How are they different?



4. **Critical Thinking** If a sonar device sends out signals to two objects and one signal bounces back before the other, what conclusion can you draw?

5. **Test Prep** **An echo is heard when sound waves are**
   - **A** changed by the Doppler effect.
   - **B** absorbed by a material.
   - **C** moving through empty space.
   - **D** reflected from a surface.

6. **Test Prep** **As the amplitude of a sound wave increases, its**
   - **A** pitch decreases.
   - **B** pitch increases.
   - **C** volume decreases.
   - **D** volume increases.

Writing Link

Explanatory Writing

You want to reduce the likelihood of echoes in the new school library. Write a paragraph explaining what materials should be used and how the library should be built. Include a design sketch.

Math Link

Calculate Wave Speed

A wave takes 20 seconds to travel 460 meters. What is its speed?

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Focus on Skills

Inquiry Skill: Experiment

Scientists **experiment** by performing procedures under controlled conditions that help them test a hypothesis, discover an unknown effect, or illustrate a known effect or scientific law.

Sometimes an experiment does not produce the expected result. Does this mean the experiment was a failure? No. It just means that now you have new data to lead you to more experiments to find out why you got the results you did. Who knows—you may come up with results that change everyone's thinking about a hypothesis.

I like to warm up by the fireplace.

Kirby likes to warm up on the radiator.

▶ Learn It

When you **experiment** you perform a test to support or disprove a hypothesis. To carry out a successful experiment, you need to plan and perform a procedure, make observations, and record data. It is usually easier to record data on a chart or graph. That way you can see differences at a glance. Once you have enough information, you can draw a conclusion about whether or not the hypothesis has been proved. Of course, the more information you have, the more accurate your conclusion will be.

In the following experiment, you will gather data to prove or disprove this hypothesis: "The more times you stretch a rubber band, the warmer the rubber band will become."

▶ Try It

Materials **heavy rubber band**

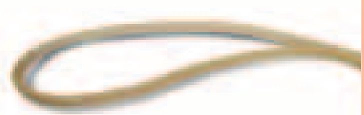
1. Link a thumb through each end of a heavy rubber band. Without stretching it, hold it to your forehead. Does the rubber band feel warm, cool, or the same as your skin? Record your results on a chart like the one that has been started here. Hold the rubber band away from your face, and quickly stretch it as far as you can. Hold it steady, and touch it to your forehead. Does it feel warmer, cooler, or the same as before? Record the results.

2. Continue to **experiment** by holding the rubber band away from your face again. Relax the rubber band, and then hold it to your forehead. Record how the rubber band feels. Repeat stretching the rubber band and touching it to your forehead, then relaxing it and touching it to your forehead, two times. Record the results. Try stretching the rubber band four times before touching it to your forehead to see whether there is a change in the amount of heat energy that builds up. Record the results.

▶ Apply It

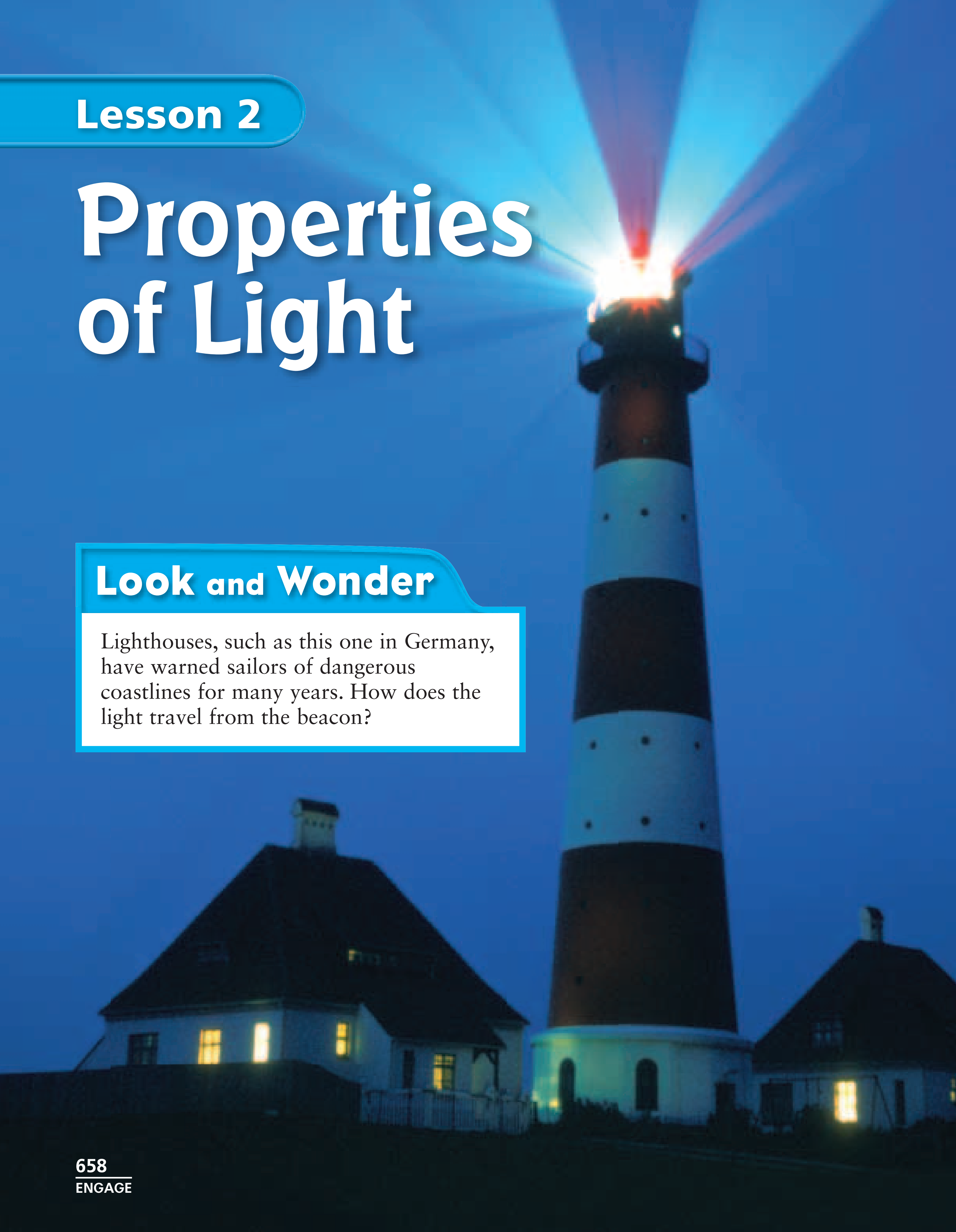
1. Now analyze the results of your experiment. Do they prove or disprove the hypothesis? From your results, can you draw a conclusion about why the stretched rubber band felt warmer than, cooler than, or the same temperature as your skin? If the rubber band felt warmer or cooler after stretching, does that mean that the rubber band itself had more or less heat energy after stretching than it did before?
2. Can you predict what would happen if you used a thinner rubber band? A thicker one? **Experiment** to test one of your predictions. Then share your results with the rest of your class.

Trial Number	Rubber Band Position	Result
1	Relaxed Stretched	
2	Relaxed Stretched	
3	Relaxed Stretched	
4	Relaxed Stretched 2 times	
5	Relaxed Stretched 4 times	



Lesson 2

Properties of Light



Look and Wonder

Lighthouses, such as this one in Germany, have warned sailors of dangerous coastlines for many years. How does the light travel from the beacon?

Explore

Inquiry Activity

How does light move away from its source?

Make a Prediction

On what kind of path does a light beam travel? How many mirrors are needed to bend a light beam around an obstacle? Write your answer in the form "To bend a light beam around an obstacle, it will take . . ."

Test Your Prediction

1. **Make a Model** Trace the outline of a flashlight's face on a piece of construction paper. Cut out the shape, and make a small hole in the center. ⚠ **Be Careful.** Tape the cutout over the face of the flashlight. Fold a second sheet of construction paper in half. Set it in a lump of clay at one end of a meterstick, as a target. Darken the room.
2. **Observe** Hold the flashlight at the other end of the meterstick. Aim the beam at the target. Blow powder into the beam to make it more visible. Compare the beam's path to the meterstick. What is the shape of the light beam's path?
3. **Experiment** Block the beam of light from reaching the target. Fold a piece of construction paper in half. Set it in a piece of modeling clay, and attach the clay to the middle of the meterstick. Can you bend the light beam to reach the target with mirrors while keeping the flashlight steady? Are one or two mirrors needed to get the beam to the target?

Draw Conclusions

4. **Interpret Data** Could you make a light beam follow a curved path? How could you change a light beam's path?

Explore More

What if you wanted the light beam to hit the back of the target? How many mirrors would you need? Design an experiment to test your prediction.

Materials

- flashlight
- 3 pieces of construction paper
- scissors
- tape
- modeling clay
- meterstick
- talcum powder
- 2 mirrors

Step 2

Step 3

Lightning is a natural source of light.

Read and Learn

Main Idea

Light travels from its source in straight lines that move out in all directions.

Vocabulary

- **transparent**, p. 661
- **lens**, p. 661
- **translucent**, p. 661
- **opaque**, p. 661
- **law of reflection**, p. 662
- **mirror**, p. 662
- **concave**, p. 663
- **convex**, p. 663

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Reading Skill

Sequence

First → Next → Last

Technology

SCIENCE QUEST

Explore solar radiation with an engineer.

How does light travel?

Light is a form of energy that travels in waves. Light waves spread out as they move away from a source. Light travels in straight lines called rays. Light waves can travel through empty space, without needing a solid, liquid, or gas medium. Light travels through space at the fastest speed matter and energy can possibly reach: about 300,000 kilometers (186,000 miles) per second. The speed of light is represented in scientific formulas by the letter *c*.

Light has both natural and human-made sources. Natural sources include the Sun and other stars, which produce light by continually fusing simpler elements into more complex ones. Another natural source is lightning, which is produced by electrical charges in clouds. Human-made light sources, such as lamps and candles, rely on chemical reactions or electricity to produce light. Light rays from any source always travel in straight lines. However, a light wave will spread out if it travels past the edge of a thin object or if it moves through a narrow opening. Regardless of its source, a ray of light will not change direction unless it travels through a different medium or is disturbed in some way.

A spotlight provides a human-made source of light.

Matter interacts with light in various ways. **Transparent** matter allows light to pass through with almost no disturbance. Behind transparent materials, objects look clear and crisp, even if the transparent materials change the color of the light. A **lens**, such as the one found in either side of a pair of eyeglasses, is a piece of transparent material with at least one curved surface.

When light rays strike matter that is **translucent** (trans•LEW•suhnt), some light passes through, and some is either blocked or bent in different directions. Objects viewed through translucent materials do not look clear or crisp; they appear blurred.

Light does not pass through matter that is opaque (oh•PAYK). **Opaque** matter reflects or absorbs all light. The light that is absorbed is converted to heat energy. If you tried to look through an opaque material, you would not be able to see an object on the other side. An opaque object casts a crisp shadow when in front of a light source. A *shadow* is a dark area produced by an opaque object blocking the passage of light. Since light always moves in straight lines, when light is blocked by the surface of an opaque object, a shadow forms that is similar in shape to the object that produces it.

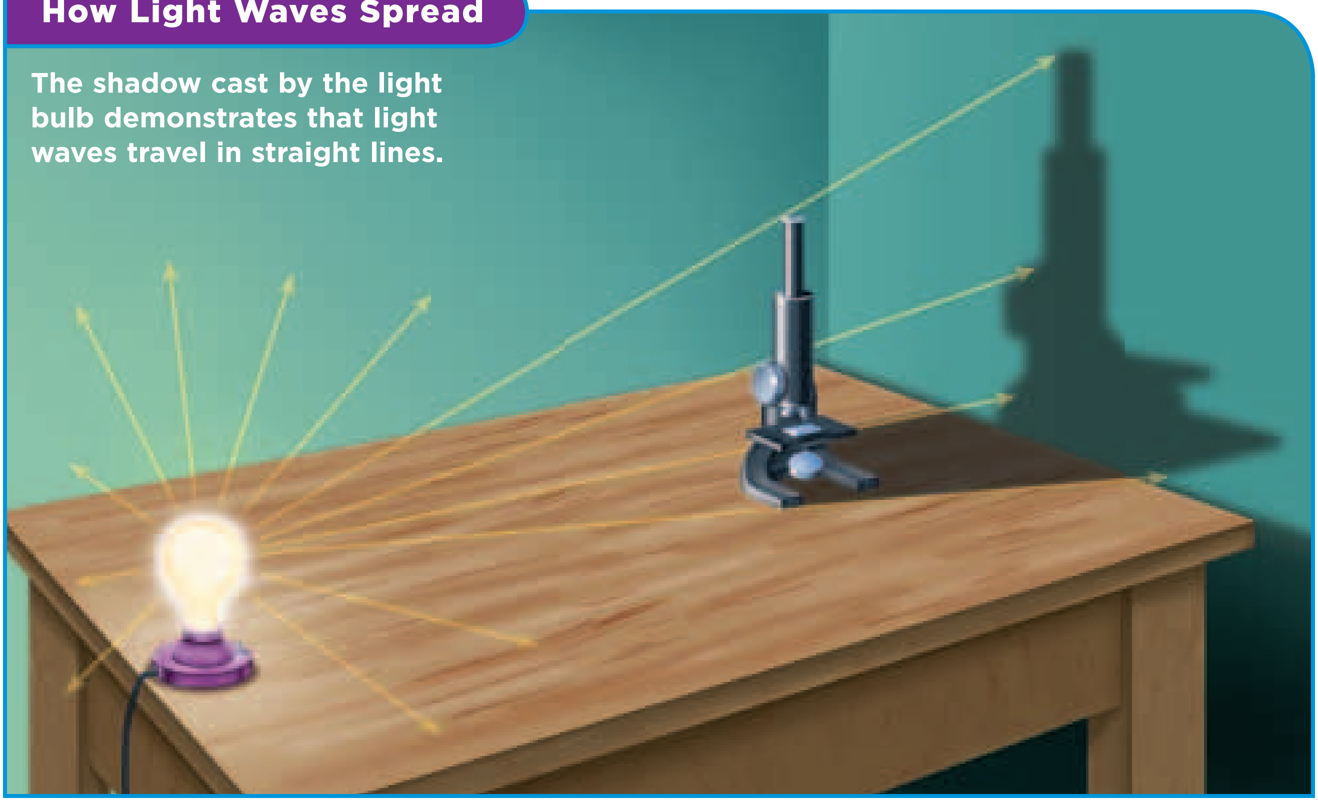
Quick Check

Sequence When does a light ray stop traveling in a straight line?

Critical Thinking What is the difference between transparent and translucent matter?

How Light Waves Spread

The shadow cast by the light bulb demonstrates that light waves travel in straight lines.



How does light act with mirrors?

In order for us to see an object, the object must either produce its own light or reflect the light from a light source. Reflection is the bouncing of waves off a surface. The angle between an incoming light ray and a surface is equal to the angle between the reflected light ray and the same surface. This relationship is called the **law of reflection**.

The law of reflection explains how mirrors work. A **mirror** is an object with a polished surface that forms reflected images. Light rays that bounce off a mirror can form an image of an object. The things you see in a flat mirror look almost as if they exist on the other side of a window, with one important exception. The image that appears in the mirror is reversed.

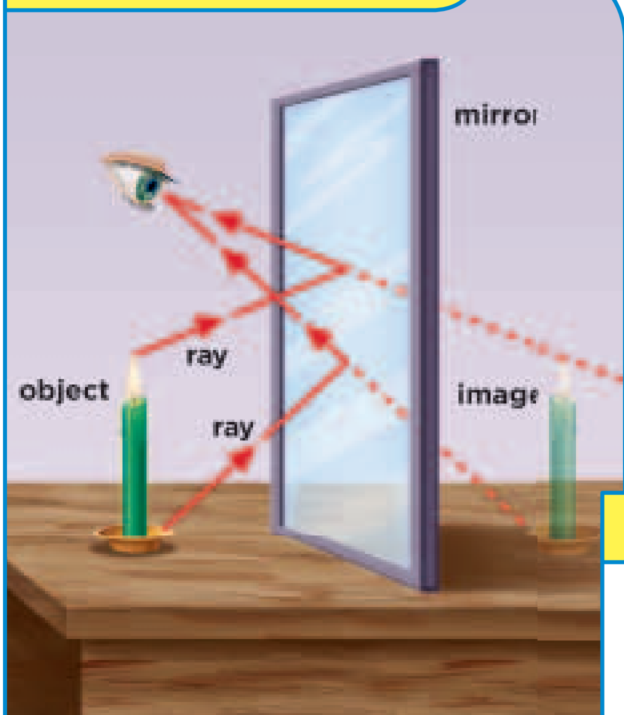
▲ A convex mirror provides a wide-angle view.

For example, if you raise your left hand in front of a mirror, in your reflection it appears that your right hand is raised.

When light rays strike a dull or rough surface, they do not form an image. The law of reflection still applies to the light rays, but the roughness of the surface causes the rays to reflect in different directions. The rays still travel in straight lines, but the lines point in many directions.

The shape of a mirror affects the appearance of the image it reflects. A *plane mirror* has a flat surface. Plane-mirror images appear as exact copies, though they are reversed. Most everyday mirrors are plane mirrors.

The Law of Reflection



Read a Diagram

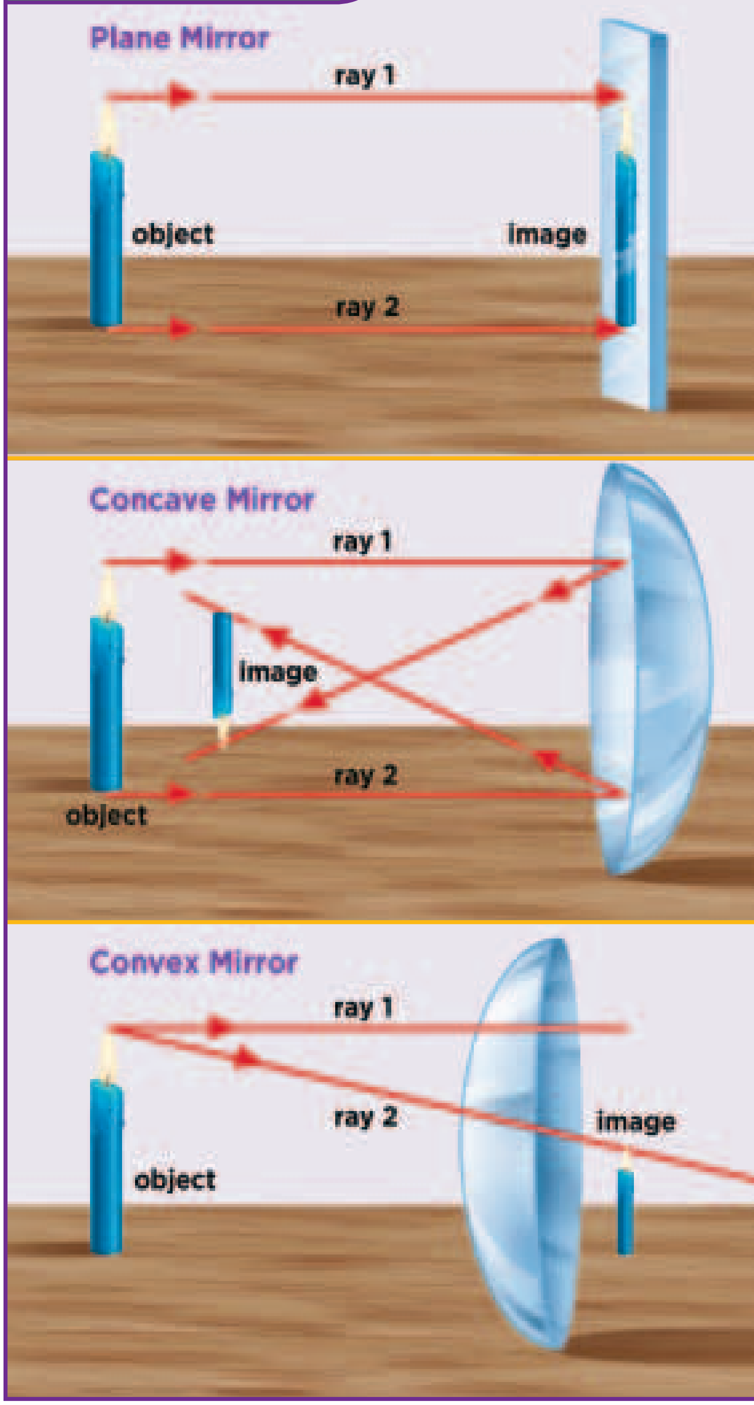
How does the diagram illustrate the law of reflection?

Clue: How does this candle look to the eye of the observer?

A mirror that is **concave** has a surface that curves inward. Light rays are reflected from the surface of a concave mirror and meet at a point located in front of the mirror. The place where the light waves meet depends on the curve of the mirror. An object you placed close to a concave mirror would produce a large image that was right-side-up. As you moved the object away, the image would become blurry and eventually appear upside down. The image would stay upside down and become smaller as you continued to move the object away from the mirror. Concave mirrors are used to gather light inside telescopes. Makeup and shaving mirrors are often concave mirrors, because they make the face appear larger and allow people to see greater detail.

A mirror that is **convex** has a surface that curves outward, like the curve of the outside of a sphere. A convex mirror produces an image that is right-side-up and much smaller than the object. When light rays are reflected from the surface of a convex mirror, they spread out, producing a wide-angle view. This wide-angle view makes convex mirrors useful for security in stores and also for providing a better view for drivers of vehicles.

Types of Mirrors



Quick Check

Sequence What happens to the image of an object as the object is moved away from the surface of a concave mirror?

Critical Thinking Why can you see your image clearly in a mirror but not on a wall?

How does light act with lenses?

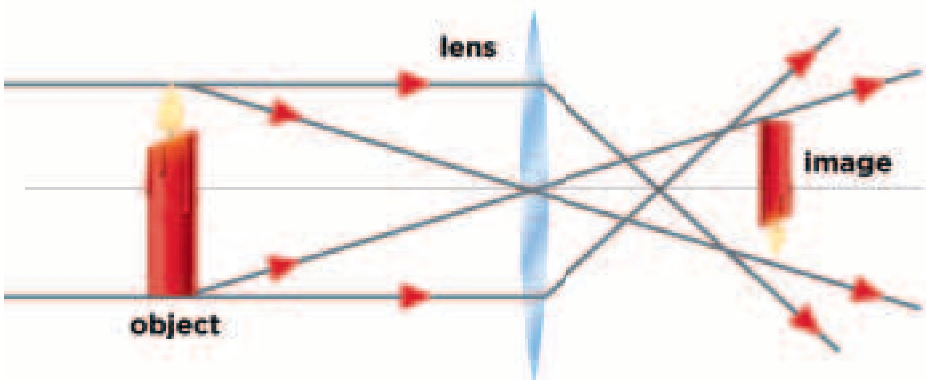
Have you ever observed what occurs when a drop of water falls onto a printed page? The letters beneath the drop seem larger than the letters on the rest of the page. This is similar to how a lens works. Light waves are refracted as they pass from the air to the lens. Refracted light rays still travel in straight lines, but the paths of the lines change as the light passes into the next material. You can observe how light refraction works by placing a pencil in a clear glass of water. Light waves are bent as they pass from the air to the water. As a result, the pencil appears as though it is broken right at the spot where it enters the water. Eyeglasses, telescopes, cameras, and microscopes all use lenses to produce images.

Convex lenses form images by refracting light rays together. A convex lens is thicker toward its middle, and this gives the lens a shape that bulges outward. Light rays pass through the lens and come together at a point on the other side. The *focal point* is the point at which the light rays meet. The distance between a convex lens and an object determines the type of image that forms. If the object is located between the lens and its focal point, the image that is formed is right-side-up and larger than the actual object. If the object is located beyond the focal point of the lens, the image that is formed is upside down and smaller than the actual object.

Convex and Concave Lenses

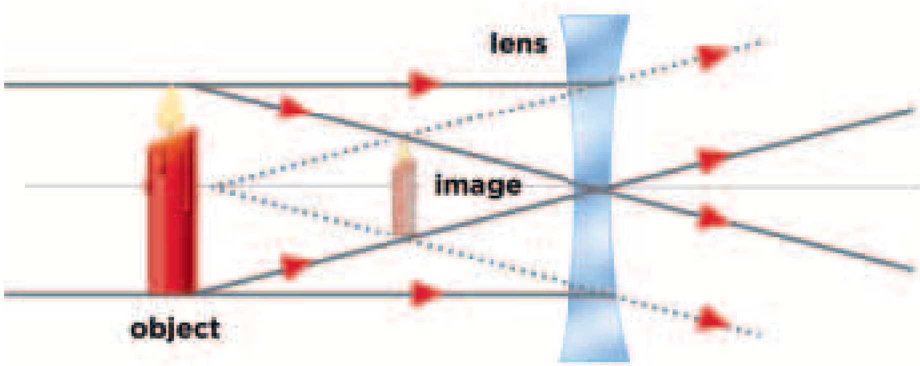
Convex Lens

Convex lenses form images by refracting light rays together. The size and position of the image depend on how far the object is from the lens.

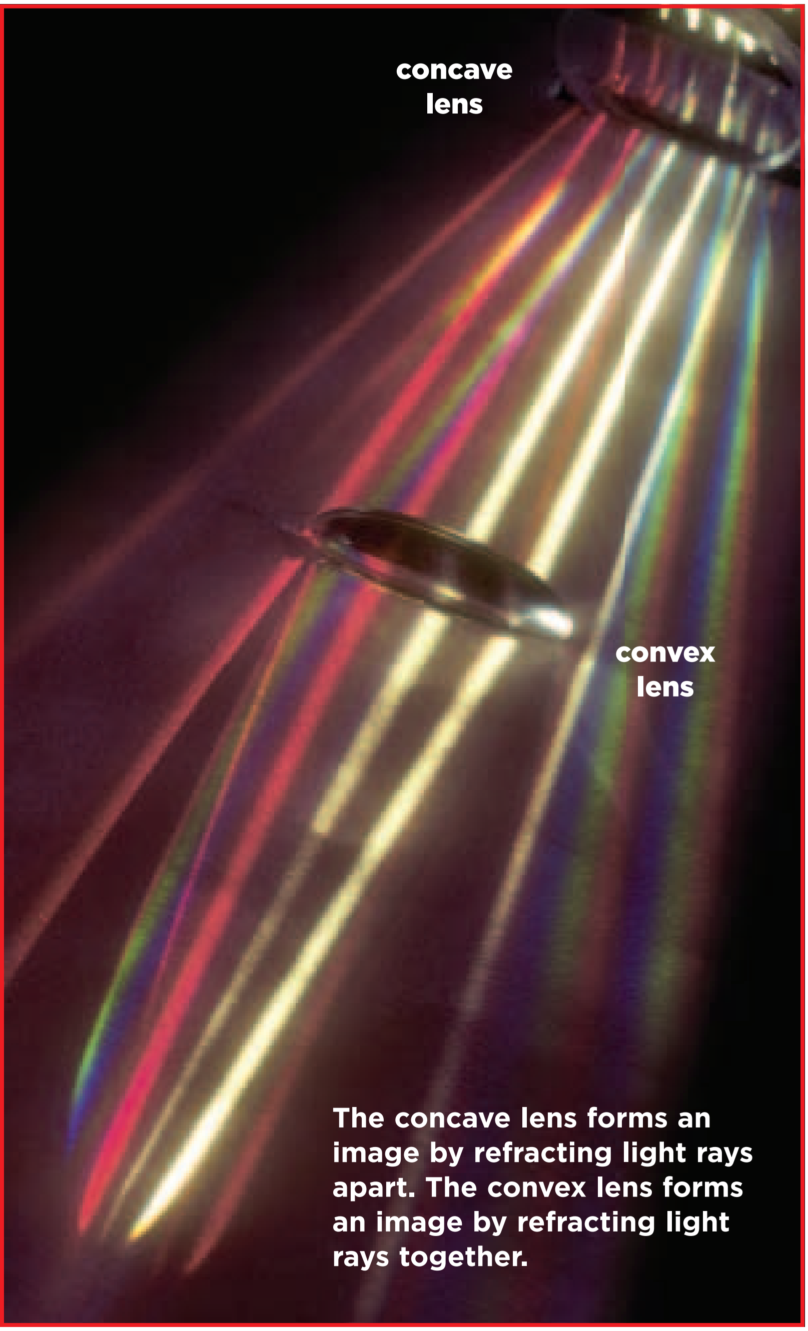


Concave Lens

Concave lenses form images by refracting light rays apart. These images are always right-side-up and smaller than the object.



A *concave lens* curves inward. This type of lens forms an image by spreading light rays apart. A concave lens is thinner in the middle than it is at the edges. An image that is formed by a concave lens is right-side-up and smaller than the actual object. Concave lenses are used mostly in eyeglasses to correct nearsighted vision.

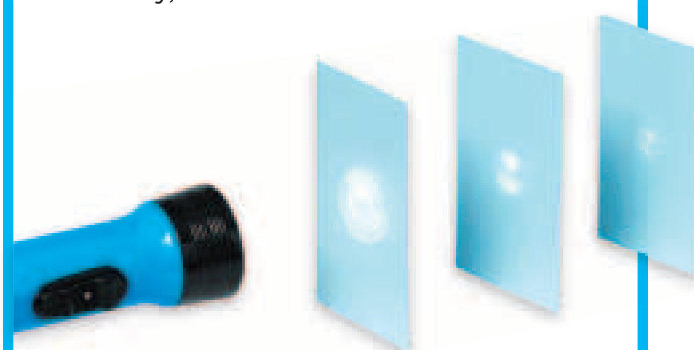


The concave lens forms an image by refracting light rays apart. The convex lens forms an image by refracting light rays together.

Quick Lab

Investigating Light

1. Make a small hole in the center of each of three index cards. Tape the cards upright in a row on a flat surface. Be sure that the holes are aligned.
2. **Observe** Place a flashlight behind the last card, and turn the flashlight on. Stand in front of the first card so that your eyes are level with its hole. Record your observations.
3. **Observe** Move the middle card 3 cm to the left. Return to your position in front of the first card. Record what you observe.
4. **Interpret Data** Compare your observations. Were they the same? Different? Explain.
5. **Infer** What caused the difference, if any, noted above?

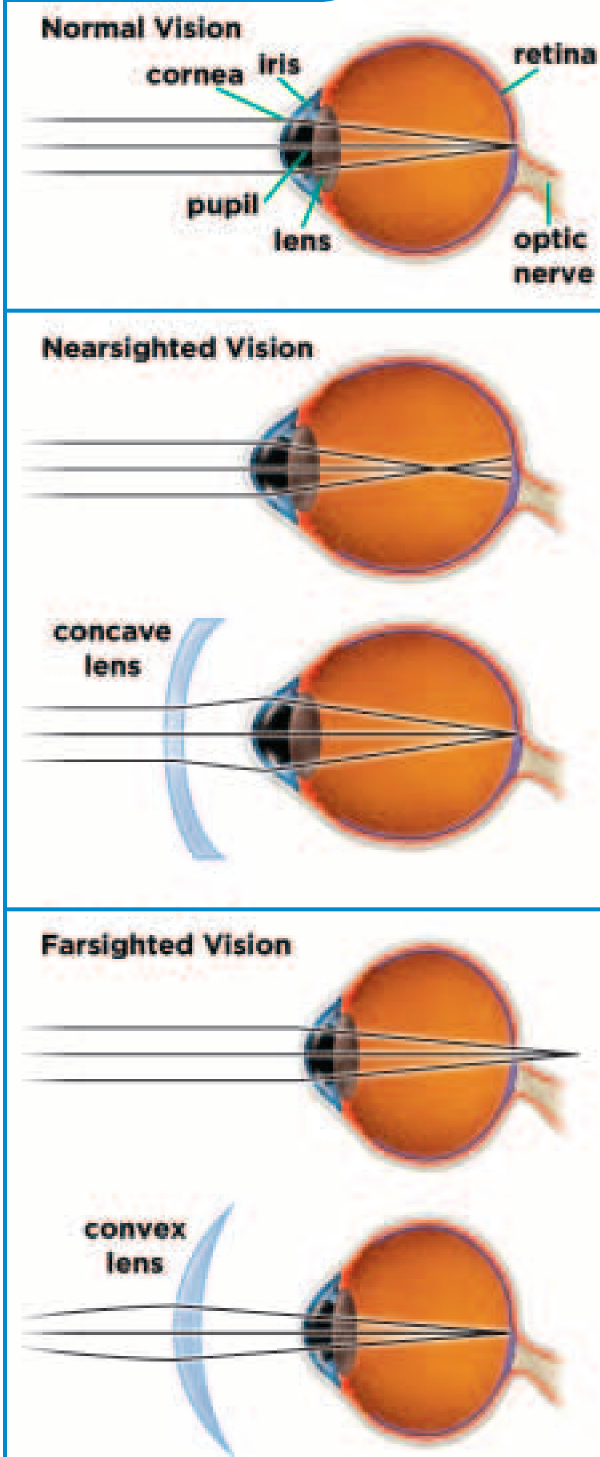


Quick Check

Sequence What happens to the path of a light ray when the light is refracted?

Critical Thinking Why does a straw appear bent or broken when it is in a glass of water?

The Human Eye



Read a Diagram

How does a convex lens help a farsighted person see better?

Clue: Notice the way that the lens bends light that passes through it.

How do we correct vision?

The internal shape of your eyes plays a large role in how they function. If your eye shape is even slightly off, your vision may be impaired.

For example, a *nearsighted* person has at least one eye that is longer than normal from front to back. This causes light rays from distant objects to be focused in front of the retina. As a result, nearby objects appear clear, but distant objects look blurry. Eyeglasses or contact lenses with concave lenses correct nearsighted vision. These lenses spread the light rays before they reach the eye. The rays then travel a longer distance and come to a focus at the correct spot: on the retina.

A *farsighted* person has at least one eye that is shorter than normal from front to back. This causes light rays from nearby objects to be focused behind the retina. Because of this, a farsighted person can see distant objects clearly but has difficulty viewing nearby objects. Eyeglasses or contact lenses with convex lenses correct this condition. These lenses bend light rays closer together before they reach the eye. As a result, the rays are focused properly on the retina.

Quick Check

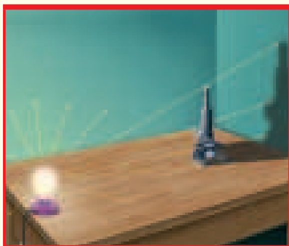
Sequence Where are light rays focused in a nearsighted person's eyes before he or she puts on eyeglasses? After he or she puts on eyeglasses?

Critical Thinking How are nearsightedness and farsightedness alike?

FACT Reading in dim light might cause eye fatigue, but it will not damage your eyes.

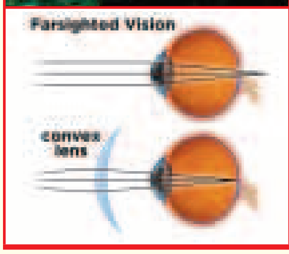
Lesson Review

Visual Summary



Light travels in straight lines that spread out as they move away from the source.

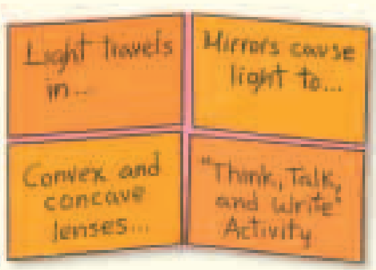
Mirrors cause light to be reflected in different ways. **Lenses** refract light.



Convex and **concave** lenses can be used to correct vision.

Make a FOLDABLES™ Study Guide

Make a Four-Door Book. Complete the statements shown, and include your work for the Sequence question on this page.



Think, Talk, and Write

1. **Main Idea** How does light travel?
2. **Vocabulary** A transparent, curved object that bends light is called a(n) ________.
3. **Sequence** What happens when a light ray is refracted?

   First → Next → Last

4. **Critical Thinking** Explain the difference between transparent materials and translucent materials.
5. **Test Prep** **When light rays strike the surface of a concave mirror, they are reflected and**
   - **A** grow dimmer.
   - **B** come closer together.
   - **C** lose energy.
   - **D** spread farther apart.
6. **Test Prep** **When light rays strike the surface of a convex mirror, they are reflected and**
   - **A** grow brighter.
   - **B** come closer together.
   - **C** gain energy.
   - **D** spread farther apart.

Writing Link

Explanatory Writing

You are an eye doctor explaining to a patient the path light takes as it moves through the eye. Write an explanation of what happens to light at each stage of its journey.

Health Link

Medical Technology

Doctors now use laser methods to correct vision permanently. Use reference materials to learn more about laser eye treatments. Share your findings with your class.

SEEING IN INFRARED

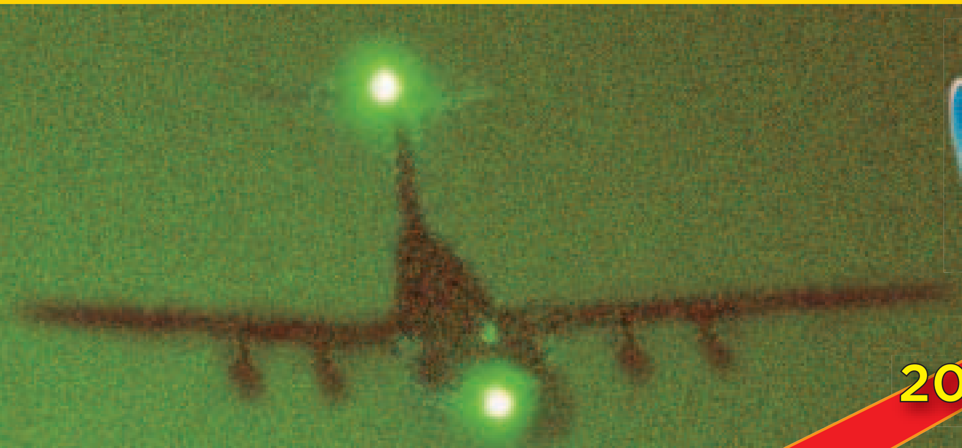
When you stand in front of a campfire, the glowing embers of the fire give off radiation that you can see. This visible radiation is like a train of waves that begins at the fire and travels to your eyes. There is another wave train, or type of radiation, coming from the fire, but you are not able to see it. These waves are longer than those of the visible spectrum. These waves heat up the air, and you can feel their heat when you stand next to the fire. These waves are called infrared radiation.

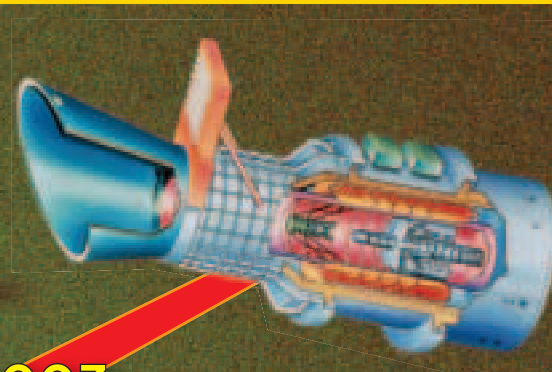
You cannot see a person in a dark room, because people do not give off radiation that our eyes can pick up. However, if you could see the longer waves of infrared radiation, you would see the person very well, even if the room were pitch black! Because this is so useful, people have invented machines that can help us detect levels of infrared radiation.

1880

Bolometer

Samuel Langley invents a tool called a bolometer to measure infrared radiation. Infrared radiation heats a metal coil inside the bolometer and produces measurable physical changes to the coil. The bolometer can detect a cow from 400 meters (1,320 feet) away.





2003

Spitzer Space Telescope

NASA's Spitzer Space Telescope uses infrared detectors to take pictures of the universe. It takes the first pictures of planets outside our solar system. These planets emit very little visible light, but they emit enough infrared radiation to be picked up by the telescope.

1940s

Night-Vision Goggles

The U.S. Army produces the first night-vision devices. Infrared night-vision goggles use an infrared detector to convert infrared waves into visible ones. The advantage of these goggles is that they allow people to search for things at night without using light.

Write About It

Compare and Contrast

1. How is infrared radiation different from visible radiation?
2. What do the bolometer, night-vision goggles, and the Spitzer Space Telescope have in common?

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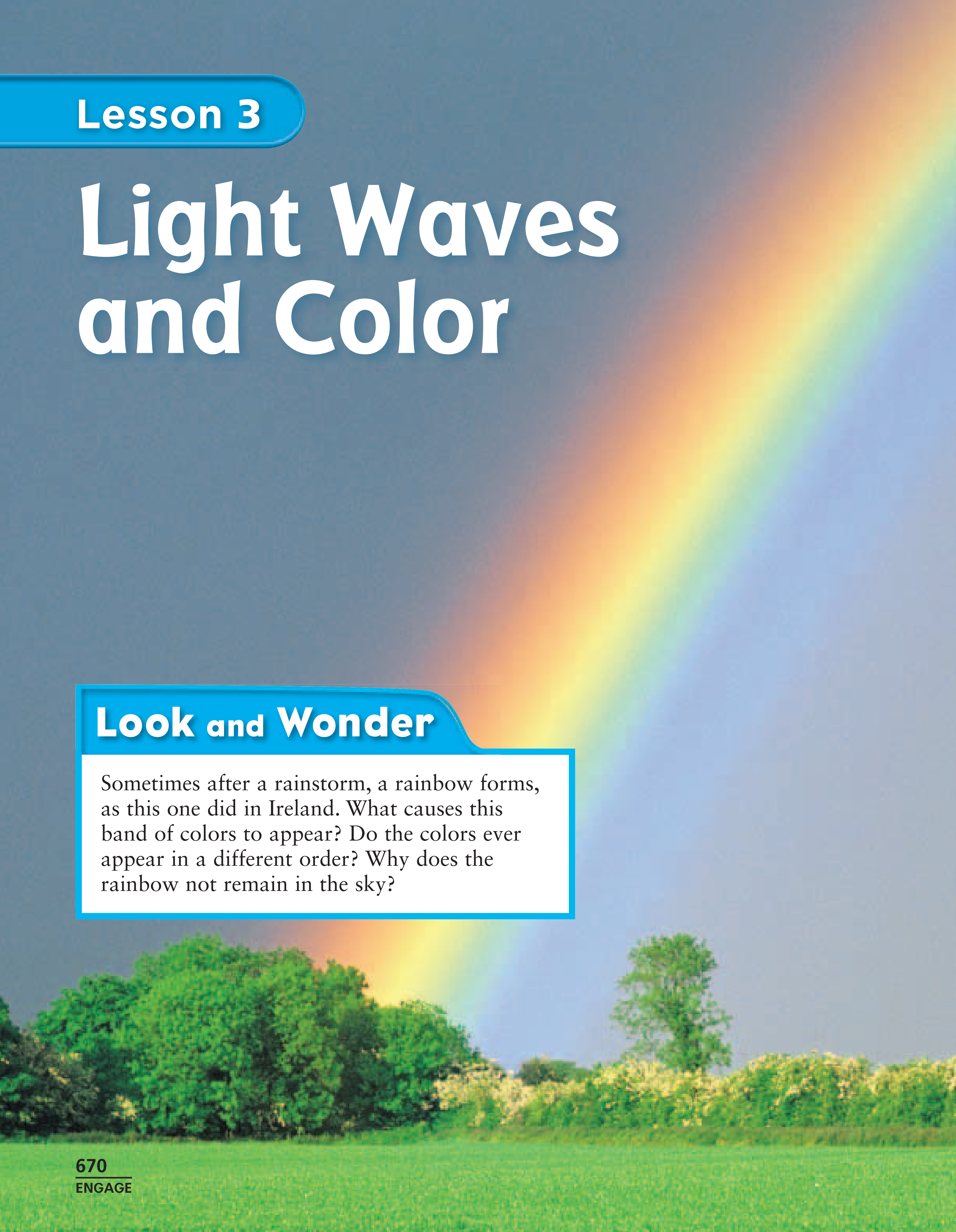
Compare and Contrast

- Look for similarities and differences.
- Use your own experiences to clarify comparisons.

American Museum of Natural History

Lesson 3

Light Waves and Color



Look and Wonder

Sometimes after a rainstorm, a rainbow forms, as this one did in Ireland. What causes this band of colors to appear? Do the colors ever appear in a different order? Why does the rainbow not remain in the sky?

Explore

Inquiry Activity

What makes up white light?

Make a Prediction

You can use a specially-shaped piece of glass or plastic called a prism to make a rainbow out of sunlight. What colors will you see? What order will they be in? Write your answer in the form of a prediction: “The colors formed by a prism will be . . .”

Test Your Prediction

1. **Experiment** Place the prism on an elevated, flat surface that receives direct sunlight.
2. **Record Data** Hold the white paper in front of the prism. Move the prism slowly at different angles and in different locations until you see bands of colored light on the paper. Make a sketch of your observations, labeling the colors that you observe.
3. **Sequence** What is the order of the colors, beginning with red?

Draw Conclusions

4. **Interpret Data** What color light entered the prism? What did the prism do to the sunlight?
5. **Communicate** Compare your color-sequence data from step 3 with the data of others in your class. What do you notice?
6. **Infer** Do you think that you can change the order of the colors by turning the prism? Try it, and then compare your results with others in your class.

Materials

- prism
- white paper

Step 2

Explore More

Would using a blue light source change your data? Make a prediction, and then design an experiment to test it.

Read and Learn

Main Idea

The electromagnetic spectrum contains visible light, which is responsible for how we view color.

Vocabulary

visible light, p. 672
prism, p. 672
diffraction grating, p. 672
electromagnetic spectrum, p. 674
primary color, p. 676
secondary color, p. 676
pigment, p. 676

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Reading Skill

Infer

Clues	What I Know	What I Infer

Technology

SCIENCE QUEST

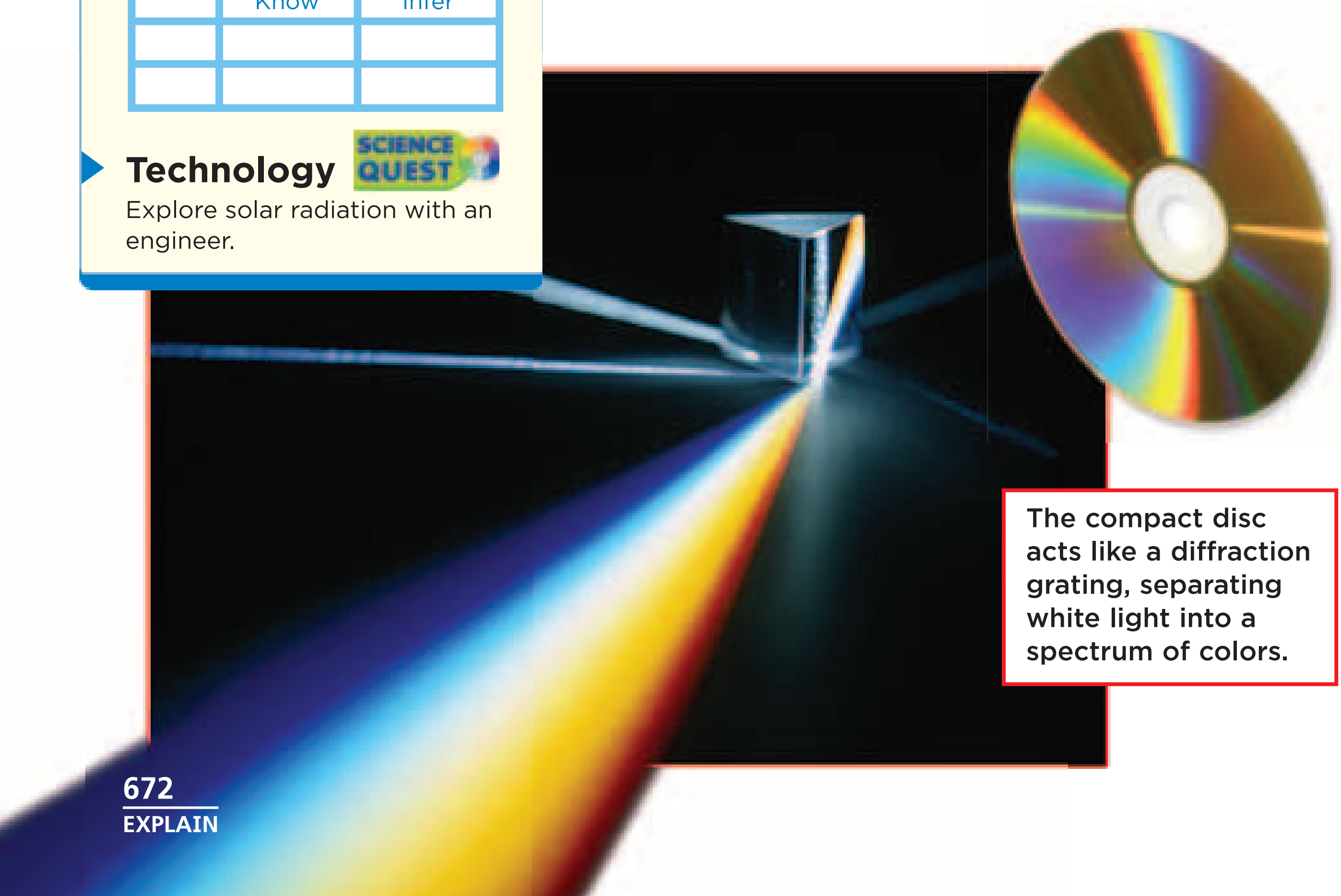
Explore solar radiation with an engineer.

Why do we see colors?

Why is a red flower red? What makes the sky blue? The study of color and the way to answer questions such as these begins with the study of light.

Visible light from the Sun comes to Earth as white light, traveling through space in the form of waves. **Visible light** contains a mixture of wavelengths that the human eye can detect. When these wavelengths are separated, we see them as different colors. This happens when light waves are refracted as sunlight passes through raindrops. Different wavelengths are refracted in different amounts. Long, red wavelengths are bent the least, and short, violet wavelengths are bent the most. Recombining all the wavelengths of visible light produces white light.

A **prism**, a triangular piece of glass or plastic, bends light. This refraction separates visible light into the red, orange, yellow, green, blue, and violet wavelengths that make up white light. Another way to bend light waves is to use a **diffraction grating**. A diffraction grating is usually made of glass, plastic, or metal, and it contains many thin, parallel slits.



The compact disc acts like a diffraction grating, separating white light into a spectrum of colors.

White light contains the entire visible spectrum. This leaf absorbs all the colors of white light except green. Because green light is reflected, the leaf appears green when we look at it.

Light rays passing through these slits interfere with each other, separating the white light into colors. Diffraction gratings, like prisms, enable scientists to study properties of light.

In the late 1600s, Sir Isaac Newton observed that sunlight passing through a prism emerged as bands of different colors. Newton hypothesized that sunlight was naturally made of different colors of light. He called these colors a *spectrum*, Latin for "appearance" or "apparition." We now know that each wavelength is refracted at a different angle and that this is what produces the different bands of color.

Sunlight striking an object may be reflected, refracted, or absorbed. The light that is reflected determines the color of an object. For example, when sunlight strikes a leaf, many wavelengths are absorbed and used in photosynthesis. Green light is reflected, so the leaf appears green. An object that reflects all visible light appears white. An object that absorbs all visible light appears black.

Quick Lab

Colors from Light

1. **Predict** What color will different-colored objects become if lighted with red light? Blue? Green?
2. **Observe** Tape a piece of red cellophane to a flashlight. Darken the room, and shine the red light on objects of different colors. Observe how the red light changes the appearance of each object.

3. **Use Variables** Repeat step 2 using cellophane of other colors, such as blue, green, and yellow. Shine the different colors of light on the same group of objects. Record your findings in a data table.
4. **Predict** What will happen if you place two or more colors of cellophane on the flashlight at once? Test your prediction.
5. **Interpret Data** How many different colors of light can you make? How do these colors interact with objects of various colors?

Quick Check

Infer What makes a flower appear yellow?

Critical Thinking Does the order of colors in a rainbow ever change? Explain.

How many kinds of light are there?

Are there waves other than visible light within sunlight? In 1800, a scientist named William Herschel answered this question with an experiment. He placed thermometers in the different bands of light from a prism. He also placed a thermometer just outside the red band of light, where there was no visible light at all. The red light had the highest temperature of the colored bands. However, to Herschel's surprise, the area just beyond the red band had an even higher reading. Herschel correctly concluded that there was another form of energy in sunlight that the human eye could not see.

Today, we know that energy from the Sun travels in many types of waves. Visible light makes up only a small portion of these waves. The **electromagnetic spectrum** contains the full range of wavelengths. The spectrum is arranged from long waves, with the lowest amount of energy, to short waves, with the highest amount of energy. It consists of radio waves, microwaves, infrared waves, visible light, ultraviolet rays, X rays, and gamma rays.

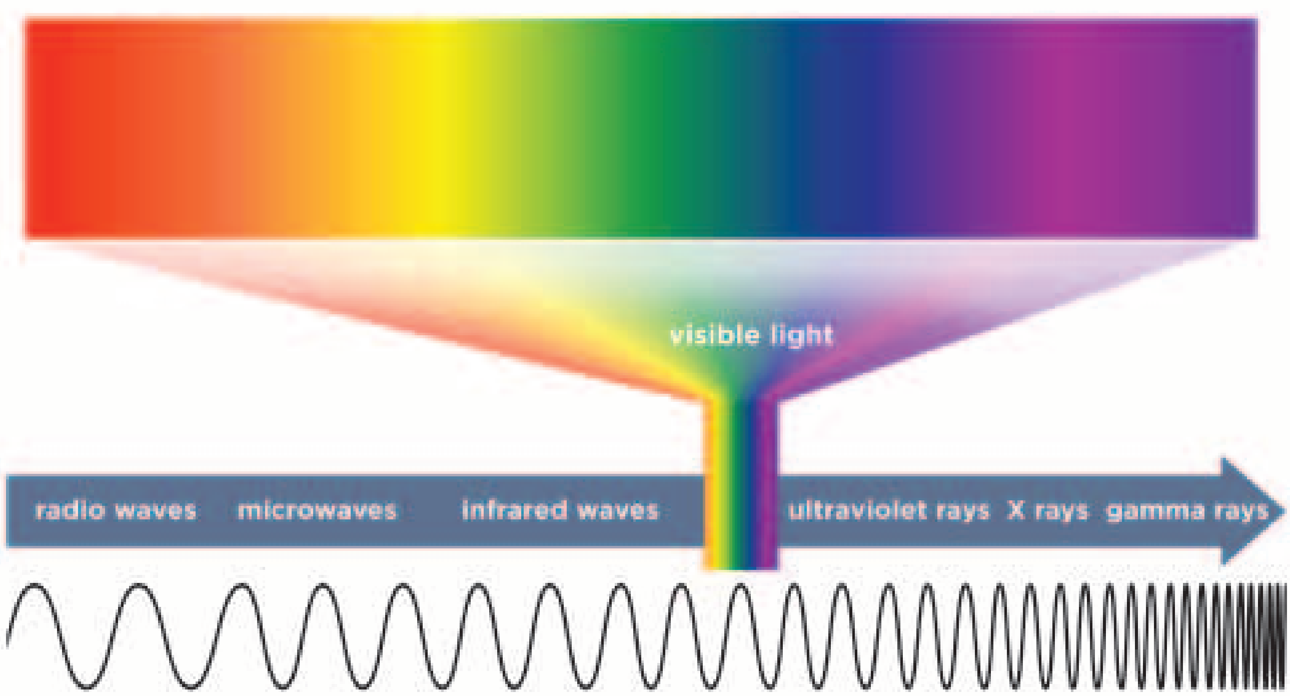
Radio waves have the longest wavelengths and include transmissions of AM radio, shortwave radio, television, and FM radio. In the next part of the spectrum are microwaves.

Read a Diagram

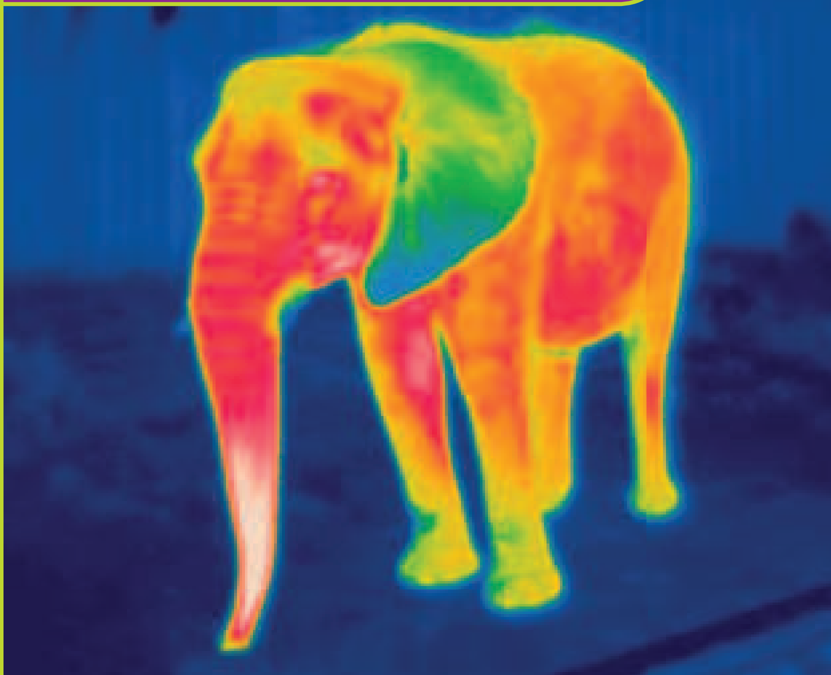
Which has the longer wavelength: visible light or radio waves?

Clue: Look at the distance between crests for both light and radio waves.

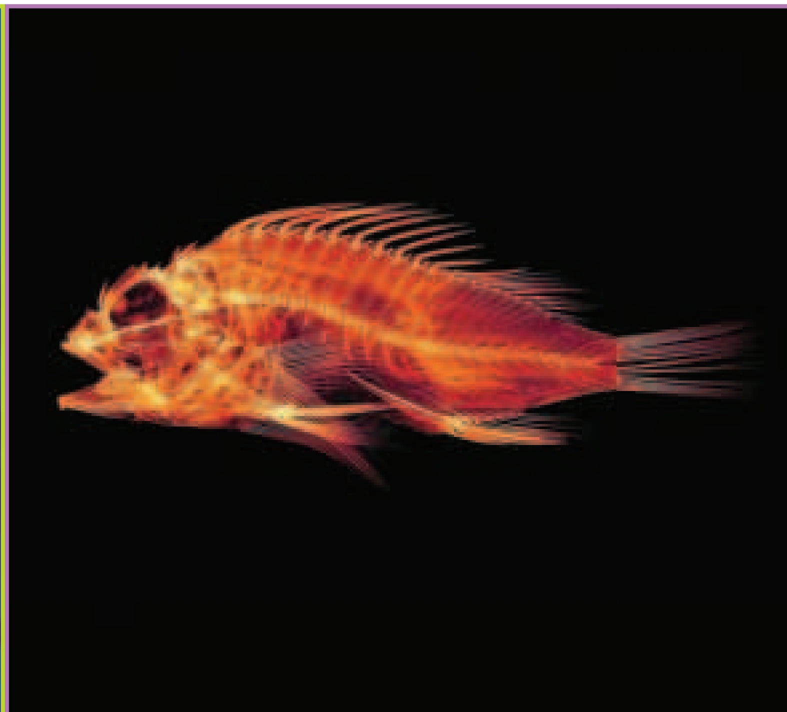
The Electromagnetic Spectrum



Electromagnetic Images



thermogram (infrared) image of an elephant



X-ray image of a scorpion fish

Microwaves are used in radar and satellite systems as well as ovens that cook food quickly. Infrared waves, next in the spectrum, are typically felt as heat. Infrared waves are given off by the Sun and other sources of heat, such as electric-stove burners and active volcanoes. The waves that Herschel discovered were infrared waves.

Near the middle of the spectrum are the wavelengths of visible light. We see these wavelengths as colors that range from red to violet.

After visible light in the spectrum are ultraviolet rays. Ultraviolet, or UV, rays carry more energy than visible-light waves do. Overexposure to ultraviolet rays and other high-energy waves can damage people's skin and eyes. The ozone layer in Earth's upper atmosphere provides some protection against these electromagnetic waves.

After ultraviolet rays in the spectrum are X rays and gamma rays. X rays can pass through many substances, including soft human tissue. Because of this property, X rays are used to make images of hard parts of the body, such as teeth and bones. X rays are also used in airports to screen luggage and other cargo. Gamma rays have very short wavelengths and have so much energy that they can even pass through some metals and concrete. Gamma rays have many applications in science.

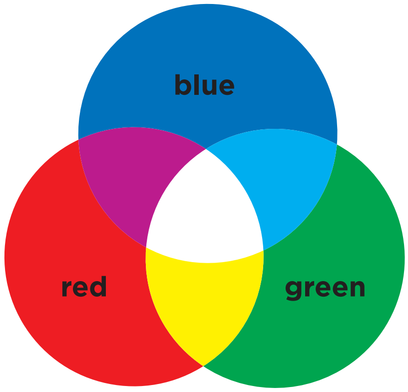
Quick Check

Infer What part of the electromagnetic spectrum has waves with the highest frequency?

Critical Thinking Which would be more damaging to human tissue: infrared waves or ultraviolet rays? Why?

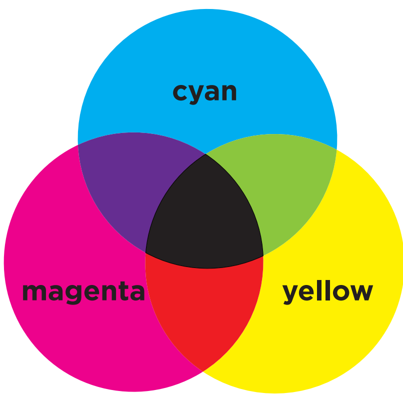
Color Models

RGB Color Model (primary colors)



Emitted light, such as that from light bulbs of different colors, can be used to produce a wide range of colors. This model uses additive color mixing.

CMY Color Model (primary pigments)



Reflected light produces the colors seen in a magazine or book illustration. This model uses subtractive color mixing.

Read a Diagram

Color printers have ink cartridges containing cyan, magenta, and yellow pigments. What secondary color could be produced if cyan ran out?

Clue: Look at the area where the magenta and yellow circles overlap.

How do colors mix?

Different color models are used to understand the relationships between colors. Each color model is named after its primary colors. **Primary colors** are not produced through the mixing process. **Secondary colors** are produced by blending primary colors.

The traditional color model is the *RYB (red, yellow, blue) color model*. While it is useful in art, this model does not include all colors, such as some shades of green, cyan (SIGH•an), and magenta. The RYB model is still referred to in art classes, but scientists now use more accurate color models.

In the *RGB (red, green, blue) color model*, primary colors of light combine and produce almost all colors. The RGB color model is an example of additive color mixing. In this color model, the three primary colors can combine, reflect all colors, and produce white.

The *CMY (cyan, magenta, yellow) color model* uses subtractive color mixing. The perceived color depends on the ability of the substance's **pigments**, tiny solid particles that provide color, to absorb wavelengths of light. The ink cartridges in color printers combine certain amounts of primary colors to produce other colors. When all three pigments combine, this produces black.

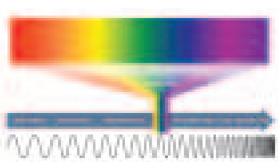
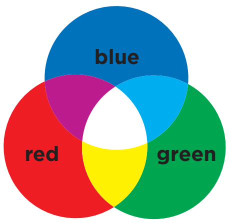
Quick Check

Infer Why might a computer screen not match a color printout?

Critical Thinking How do primary colors of light and primary colors of pigments differ?

Lesson Review

Visual Summary

	White light that passes through a prism separates into the colors of **visible light**.
	The **electromagnetic spectrum** is the wide range of electromagnetic radiation, organized by wavelength.
	When two **primary colors** are combined, a **secondary color** is formed.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide additional details.

Think, Talk, and Write

1. **Main Idea** What determines an object's color?
2. **Vocabulary** The range of different forms of electromagnetic radiation, arranged by wavelength, is called the ________.
3. **Infer** If you were provided with cyan, magenta, and yellow pigments, how could you make green?

Clues	What I Know	What I Infer

4. **Critical Thinking** What does an infrared sensor detect?
5. **Test Prep** **The primary colors of light are red, blue, and**
   - **A** cyan.
   - **B** yellow.
   - **C** magenta.
   - **D** green.
6. **Test Prep** **Which part of the electromagnetic spectrum has waves of the shortest wavelength?**
   - **A** X rays
   - **B** radio waves
   - **C** gamma rays
   - **D** microwaves

Math Link

Distance and the Speed of Light

Light travels through empty space at the speed of almost 300,000 km/s. If it takes about 8 minutes for light to travel from the Sun to Earth, approximately how far is Earth from the Sun?

Art Link

Color Wheels

Color wheels show relationships among colors. Make a poster that displays color wheels based on the different color models. Include on your poster an explanation of how color wheels work.

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Color This Old House

Our family moved into an old Victorian house that we all love. It was a jewel box of a house, but it was also a fixer-upper that needed lots of work.

Part of the visual delight of Victorian houses is that the outsides are painted many different colors. We needed to choose a color for the siding, two or more colors for the trim, and accent colors for the window frames, doors, and railings.

In art, all colors are based on mixing red, yellow, and blue. These are the primary colors an artist or painter might use. Suppose I wanted to produce the perfect shade of green paint—one that looked like the buds on trees in early spring. What would I do? First, I would find the two primary colors my basic color falls between on the color wheel. Since green falls between blue and yellow, I know I would need to start by mixing these colors. Then I would decide which of these two primary colors my green was closer to. In other words, would I want a green that had more yellow or more blue? To make that early-spring green, that fragile color that seems to last only a moment in nature, I would add more yellow to my mixture. If I wanted the shade to be a little lighter, I would add some white. How much white I added would depend on how light I wanted my color to be. If I wanted the green to be a little darker or muted, I would add some black.

Descriptive Writing

A good description

- tells how something looks, sounds, smells, tastes, or feels to the touch
- uses sensory words to describe something
- includes details to help the reader experience what is being described

Our family decided to paint the main part of our house yellow. We chose a bright yellow, an artist's or painter's primary color, instead of a mixture. The light bounces off this cheery color early in the day, and the late-afternoon light gives it a soft, warm glow. At first, we painted the roof tiles and the trim around the windows and doors orange, a secondary art color that is a mixture of yellow and red. However, orange seemed too glaring in bright sunlight. We added a few drops of black to the orange paint. This made it darker, because black absorbs light, and therefore less is reflected back to your eyes. We made another batch with a little less black and a third with a little more black. The resulting shades of rustlike orange fit well with the bright yellow. They stand out against the yellow siding and emphasize the decorative trim.

You will not believe what color we painted the doors and window frames! On a color wheel, the color that is opposite yellow is purple. This means that yellow and purple are complementary colors. Yes, we have purple doors and window frames. Our Victorian house is certainly flamboyant. It deserves the nickname of "painted lady."

A color wheel is a quick and easy way for artists to identify colors that complement one another.

Write About It

Descriptive Writing Carefully look at a painting or photograph. Describe what you see. Tell which colors are primary and which are secondary in art. Describe how they work together to create a pleasing effect.

LOG ON e-Journal Research and write about it online at www.macmillanmh.com

Lesson 4

Heat

Look and Wonder

At the Big Island of Hawaii, hot, molten lava flows into the sea. The temperature of the lava is much higher than that of the seawater. What happens to the water when the lava reaches it?

Explore

Inquiry Activity

How can you measure heat flow?

Make a Prediction

Does heat energy move between warm and cool objects? What will happen if a jar of water is placed in a bowl of water at a different temperature? Write your answer in the form of a prediction: "If a jar of warm water is placed in a bowl of room-temperature water, then . . . and if a jar of cool water is placed in a bowl of room-temperature water, then . . ."

Test Your Prediction

1. Fill one jar with water at 30°C. Fill a second jar with water at 10°C.
2. **Measure** Place each jar in a separate bowl of room-temperature water measuring between 22°C and 24°C. Record the starting temperatures of the water in the bowls and jars.
3. **Experiment** Record the temperatures of the four containers every 2 minutes for 20 minutes. What differences in the temperatures do you notice? Record your observations. When do you think the temperatures will stop changing? Thirty minutes after your last observation, check the thermometers again, and record the temperatures.

Draw Conclusions

4. **Interpret Data** Make a line graph that shows how the temperature of the water in each jar and each bowl changed over time. What happened to the temperature in the jar with warm water? How did the heat flow? How could you explain what you observed?

Explore More

What would happen if you placed a jar of warm water in a bowl of ice water? What would the graph of temperature and time look like? Make a prediction and test it. Present your results.

Materials

- 2 jars
- water
- 4 thermometers
- 2 large bowls
- watch or stopwatch

Step 2

Step 3

Read and Learn

Main Idea

Heat energy flows from a warmer object to a cooler object until both are the same temperature.

Vocabulary

heat, p. 682
calorie, p. 682
thermal expansion, p. 683
conduction, p. 684
convection, p. 685
specific heat, p. 688

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Reading Skill

Cause and Effect

Cause	→	Effect
	→	
	→	
	→	
	→	

Technology

SCIENCE QUEST

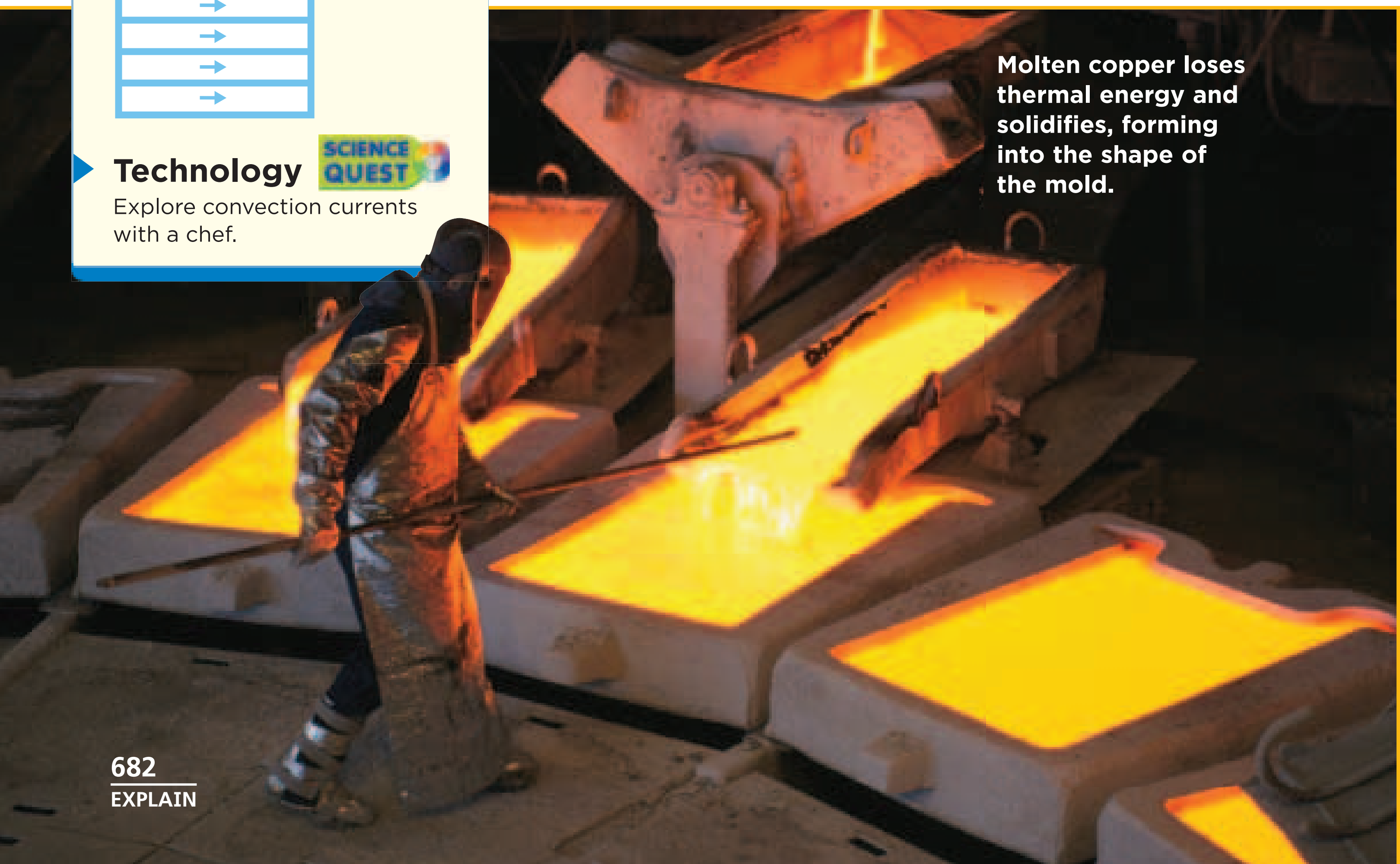
Explore convection currents with a chef.

What is heat?

If you hold a mug of hot cocoa, energy moves from the mug to your hand. Since the mug is hotter than your hand, your hand gets warmer as it absorbs energy from the mug. If you put ice cubes into your drink, energy flows from the hot liquid into the cold ice. The drink cools as transferred energy melts the ice.

Heat is the flow of energy from one substance to another. Heat is a form of kinetic energy caused by the movement of the molecules that make up all matter. If you warm something, such as a cup of soup, you increase the movement of its molecules. The substance then becomes hotter. As an object is heated, the total amount of kinetic heat energy, or thermal energy, within that object increases.

The total amount of thermal energy in a substance is measured using a calorimeter. The metric unit used to measure this energy is the calorie. A **calorie** is the amount of energy needed to raise the temperature of 1 gram of water by 1°C.



Molten copper loses thermal energy and solidifies, forming into the shape of the mold.

Energy and Temperature

A thermometer placed in boiling water registers about 100°C (212°F). The thermometer measures the temperature of the water. Temperature is a measurement of the average kinetic energy of the molecules in a substance.

As heat flows into a substance, the kinetic energy of the molecules in the substance increases. Some molecules in a substance may move faster or slower than other molecules, but overall the average speed of the molecules rises. This causes an increase in temperature.

This increase in energy can also cause molecules to move farther apart. As the molecules in a substance spread out, it usually increases in volume. An increase in volume that is caused by an increase in temperature is called **thermal expansion**. Scientists, engineers, and architects consider the effects of thermal expansion when choosing materials to build houses and other structures. Not all materials respond to changes in temperature in the same way—some expand more than others.

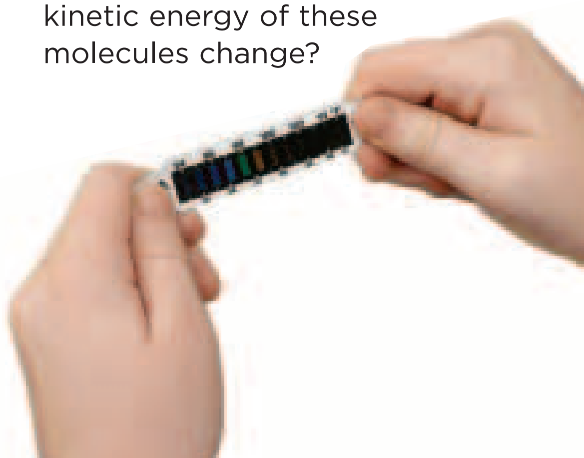
Temperature and Mass

The total amount of thermal energy in a substance depends on temperature and mass. A thimble filled with boiling water has a high temperature, but little mass. It has less thermal energy than a jug full of water that is warm but not boiling. Overall there is more energy in a gallon of warm water than there is in a thimble of boiling water. Although the temperature of the jug is lower, the total amount of energy is much higher.

Quick Lab

Heat from Friction

1. **Form a Hypothesis** Can friction from rubbing your hands together generate enough heat to raise the temperature of your hands? Record your hypothesis.
2. **Measure** Hold a thermometer in one hand so that your hand completely covers the bulb. Record the temperature after the liquid stops moving.
3. **Experiment** Remove the thermometer, and rub your hands together vigorously for about a minute. Repeat step 2.
4. **Interpret Data** Did the temperature of your hand change? How might you explain this?
5. **Infer** Relate the change in temperature to the molecules of your hand. Did the average kinetic energy of these molecules change?



Quick Check

Cause and Effect What effect does heat have on a substance?

Critical Thinking How is temperature different from thermal energy?

How does heat travel?

Heat energy always flows from a higher-temperature material to a lower-temperature material. That is why, in the diagram below, the water in the plastic bag increases in temperature when it is placed in the beaker of warmer water. As the warm water cools, some of its thermal energy is transferred to its surroundings.

Conduction

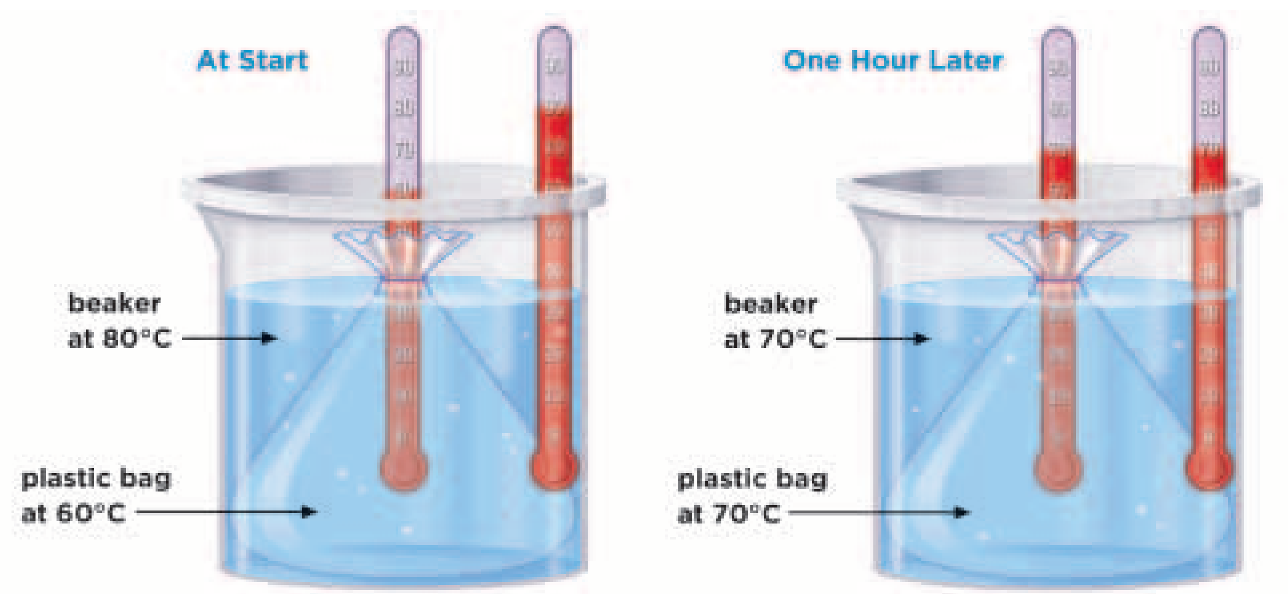
Heat energy can move in three ways. **Conduction** is the movement of energy through direct contact. This means that two materials touch, and energy flows directly from one material to the other. Conduction is the only way that heat energy can travel through solids.

Conductors are materials that absorb heat and distribute it evenly throughout an object. Most metals are good conductors. Insulators are materials that absorb some heat but do not transfer it very well. If you placed your hand on a piece of wood, the area under your hand would warm, but the temperature of the rest of the wood would not change. *Insulation* (in•suh•LAY•shuhn) is any material used to prevent heat from flowing into or out of a substance.

Convection

When you heat a pot of soup, some heat energy is transferred through direct contact between the pot and the soup. However, most of the heat is transferred as the heated soup located near the bottom rises and moves around the pot.

Measuring Heat Flow

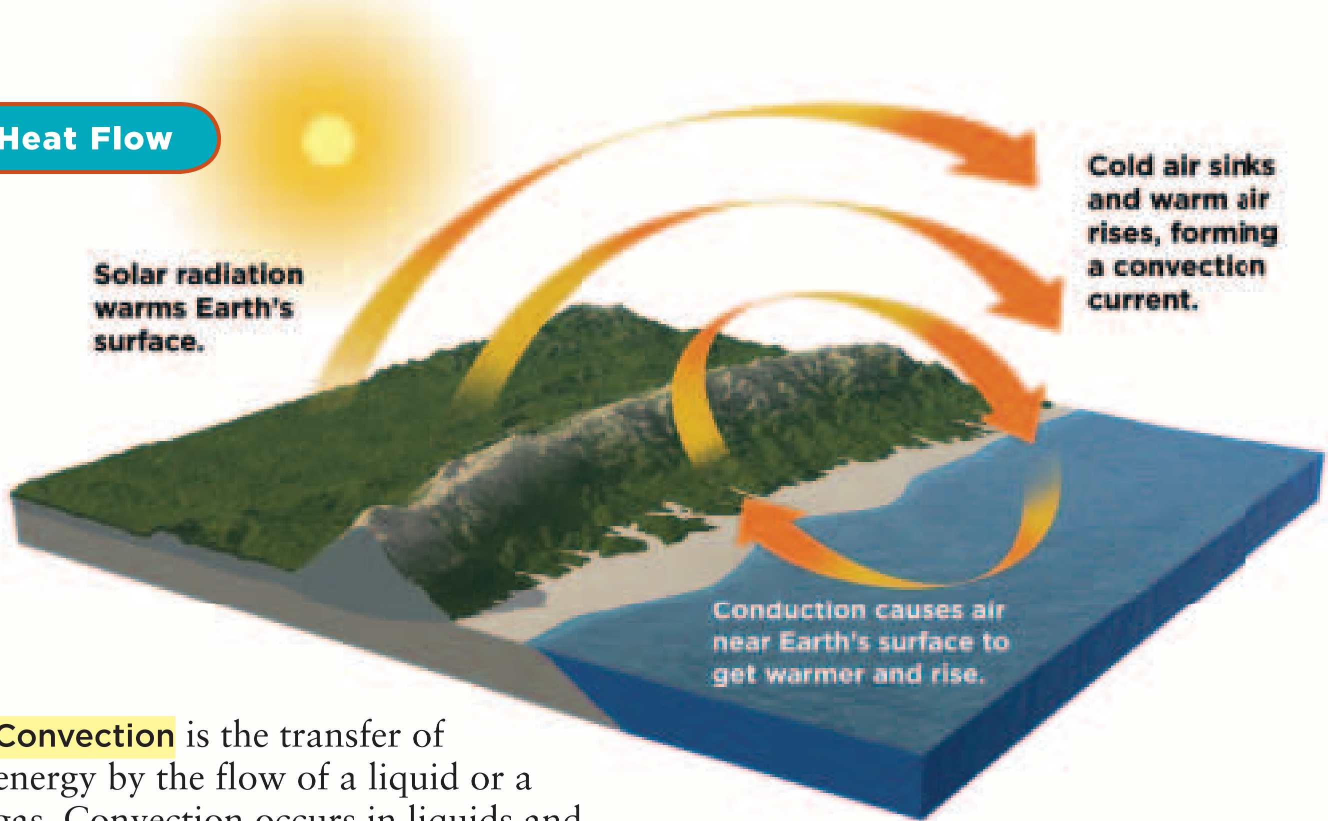


Read a Diagram

How did heat flow between the water in the bag and the water in the beaker?

Clue: Compare the temperatures of the water in the bag and in the beaker at the beginning and at the end of the experiment.

Heat Flow



▲ Heat is transferred within Earth's atmosphere by radiation, conduction, and convection.

Convection is the transfer of energy by the flow of a liquid or a gas. Convection occurs in liquids and gases but not in solids. Convection occurs because most liquids and gases become less dense when heated. Their particles move faster and farther apart. Convection cycles are responsible for transferring energy throughout Earth's atmosphere and oceans.

Radiation

Energy from the Sun reaches Earth by radiation. Radiation is the transfer of energy by electromagnetic waves. Radiation can travel through gases and the vacuum of space. Objects that absorb radiation gain energy. The Sun is not the only source of radiation. All objects give off a range of electromagnetic waves. Objects that are near or below room temperature give off infrared radiation, which our eyes cannot see. However, when objects are heated to about 600°C (1,112°F), they give off a great deal of visible light. We see this visible light as a dull red glow, like that of a stove-top burner.

Heat Flow and Clothing

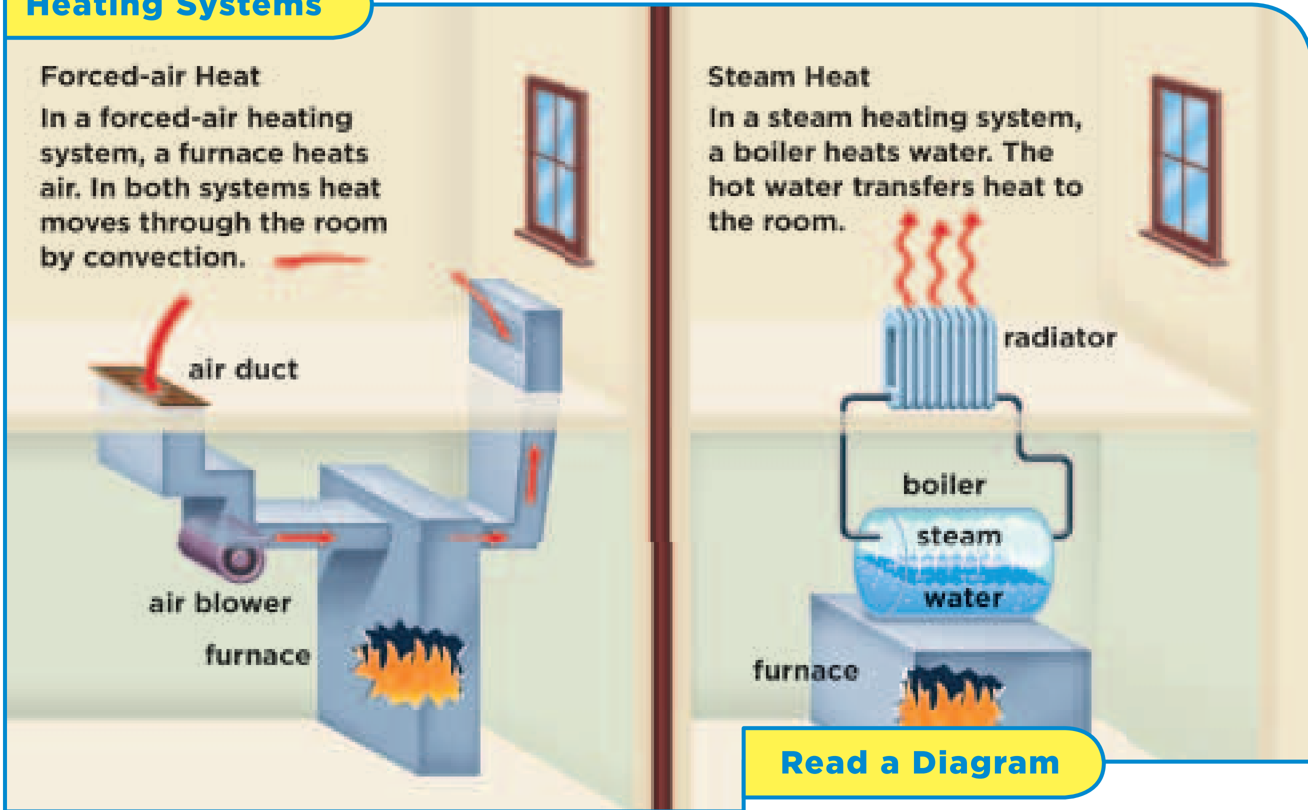
When we are cold, we try to trap heat energy around the body. This is why winter clothes are often made of materials that are good insulators, such as wool. Dark colors absorb more energy, so cold-weather garments are often dark, as well. In contrast, summer clothing is often light in color and made of thin, lightweight materials. They absorb less energy and allow heat to flow away from the body easily.

Quick Check

Cause and Effect How does convection cause an increase in temperature?

Critical Thinking Compare and contrast conduction and radiation.

Heating Systems



Read a Diagram

How is air in the room heated by the vents?

Clue: Identify whether the air is warmed by convection or conduction.

How do we use heat?

Buildings are heated by systems designed to transfer heat energy. In a hot-water heating system, water is used to transfer energy from a boiler to the air in a room. The boiler heats water, which is forced through pipes by pumps. The pipes lead to convectors in the rooms, and the air around the convectors becomes warmer. Convection currents circulate air throughout the room, and the room is warmed as a result. Heated air is less dense than cooler air, so it rises in the room. As the air cools, it sinks back down and is eventually heated again.

In a forced-air heating system, a room is heated with air alone. Hot air, forced up by fans from the furnace, heats the air in the room. Convection currents circulate the air in the room.

Thermostats

If boilers and furnaces operated all the time, buildings would soon become too warm, and we would use more fuel than necessary. Therefore, heating systems have a way to turn on and off automatically. A thermostat switch controls the process. The switch in a thermostat is often a bimetallic strip, made of two different kinds of metals. Different materials expand or contract at their own particular rates. When the bimetallic thermostat strip is heated, one of the metals expands more than the other. This expansion causes the strip to bend. The bending of the strip turns the system off when the air in the room reaches a certain temperature.

When the strip cools, it straightens out, and this turns the boiler or furnace on once again.

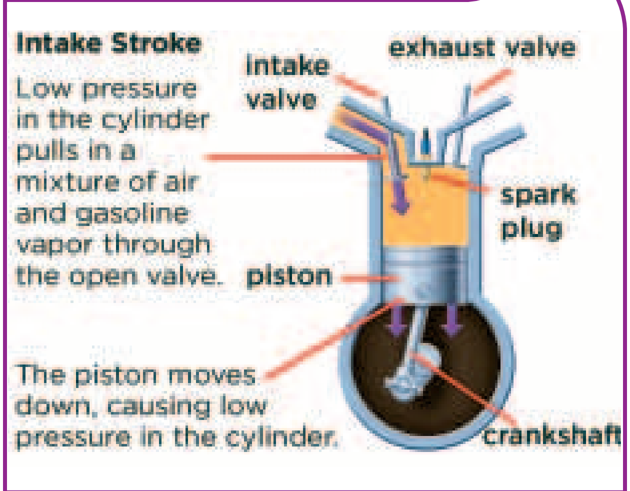
Combustion Engines

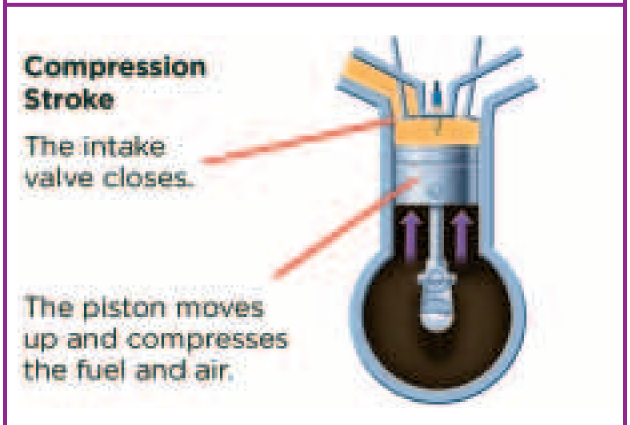
Gasoline is the fuel that is burned in the engine of a car, but heat energy actually makes the engine move. Heat causes the gases from the burning fuel to expand. The gases push on pistons, which then move downward. The motion of the pistons triggers a chain of actions that turns the crankshaft and propels the vehicle forward. Coolant in the engine's radiator prevents overheating.

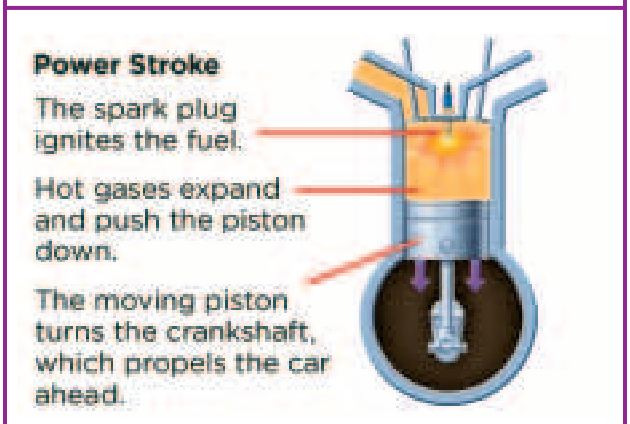
As a car moves along a road, there is friction between the tires and the road. Friction produces heat. If enough heat flows into the material of the road, the road may expand. On hot, sunny days, radiation also causes the temperature of the road to rise and thermal expansion to occur. This expansion could cause a roadway to buckle or bend.

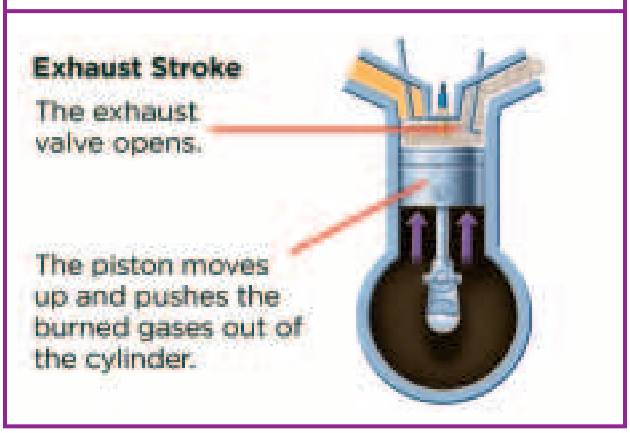
To prevent this kind of damage, separators are placed between sections of road. They are made of materials that are good conductors. These sections expand and contract as the road warms and cools to help protect the road from damage.

How Heat Propels a Car









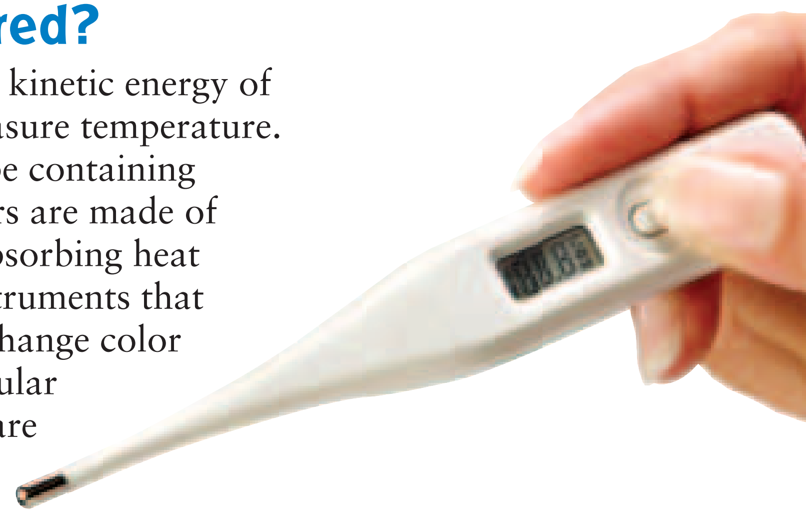
Quick Check

Cause and Effect How does burning gasoline cause a car to move?

Critical Thinking Why are steel separators often placed in roads?

How is temperature measured?

Temperature is a measure of the average kinetic energy of a substance's molecules. Thermometers measure temperature. Some thermometers are made of a clear tube containing a liquid that expands when it warms. Others are made of coiled bimetallic strips that expand from absorbing heat energy. There are also different types of instruments that measure this energy using substances that change color or another property upon reaching a particular temperature. Many modern thermometers are digital. When any type of thermometer is placed in a warmer material, heat flows from the material to the thermometer, causing its temperature to change.



Specific Heat

Physical properties such as shape, size, color, and texture vary depending on the type of matter. Another physical property of matter is the rate at which the substance warms up upon absorbing heat. The **specific heat** of a substance is the amount of energy, often measured in joules (J), needed to raise the temperature of 1 gram of the substance by 1°C. Most metals have a low specific heat, so little energy is needed to increase their temperatures. Water has a high specific heat, so more energy is needed to raise its temperature. That is why you can burn your finger by touching the metal handle of a pot on the stove when the water in the pot is only lukewarm.

Specific Heats of Substances

Substance	Specific Heat (in joules per gram per degree Celsius)
aluminum	0.90
copper	0.39
iron	0.45
mercury	0.14
water (liquid)	4.19

This lizard can stand on sand that has been in bright sunlight. The scorching sand's specific heat is so low, the lizard alternates feet so that they do not get too hot.

Quick Check

Cause and Effect Why does a pot heat faster than water inside the pot?

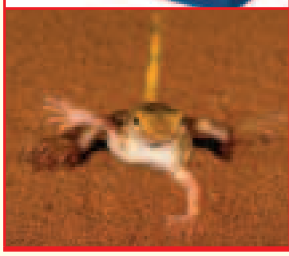
Critical Thinking Which substance in the chart above is the best conductor of heat? Why do you think so?

Lesson Review

Visual Summary

Heat flows from warmer substances to cooler substances.

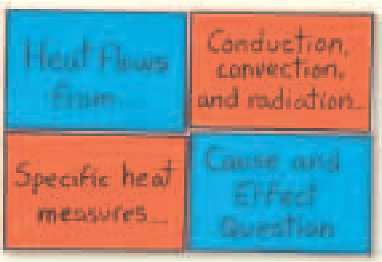
Conduction, convection, and radiation are three types of **heat transfer**.



Specific heat measures how much energy is required to warm a particular substance.

Make a FOLDABLES™ Study Guide

Make a Four-Door Book. Complete the statements shown, and include your work for the Cause and Effect question on this page.



Think, Talk, and Write

1. **Main Idea** How are heat and temperature related?
2. **Vocabulary** The amount of heat needed to raise the temperature of 1 gram of a substance by 1°C is its ________.
3. **Cause and Effect** What causes ice cream to melt in sunlight?

Cause	→	Effect
	→	
	→	
	→	
	→	

4. **Critical Thinking** Would the liquid inside a thermometer be more likely to have a high specific heat or a low specific heat? Explain your answer.
5. **Test Prep** **A lit fireplace at one end of a large room warms people standing on the opposite end of the room by**
   - **A** conduction and convection.
   - **B** radiation and thermal expansion.
   - **C** radiation and convection.
   - **D** conduction and thermal expansion.
6. **Test Prep** **What causes thermal expansion?**
   - **A** chemical changes
   - **B** an increase in motion of molecules
   - **C** changes in pressure
   - **D** a decrease in specific heat

Writing Link

Personal Narrative

Suppose you had to spend a day without any type of heat transfer. How would your daily life activities be affected? Write a narrative about that day.

Math Link

Calculate Calories

One gram of low-calorie cheese provides 1.5 Cal. How many food calories would 17.5 g of this cheese provide?

How Is Electrical Energy Use Calculated?

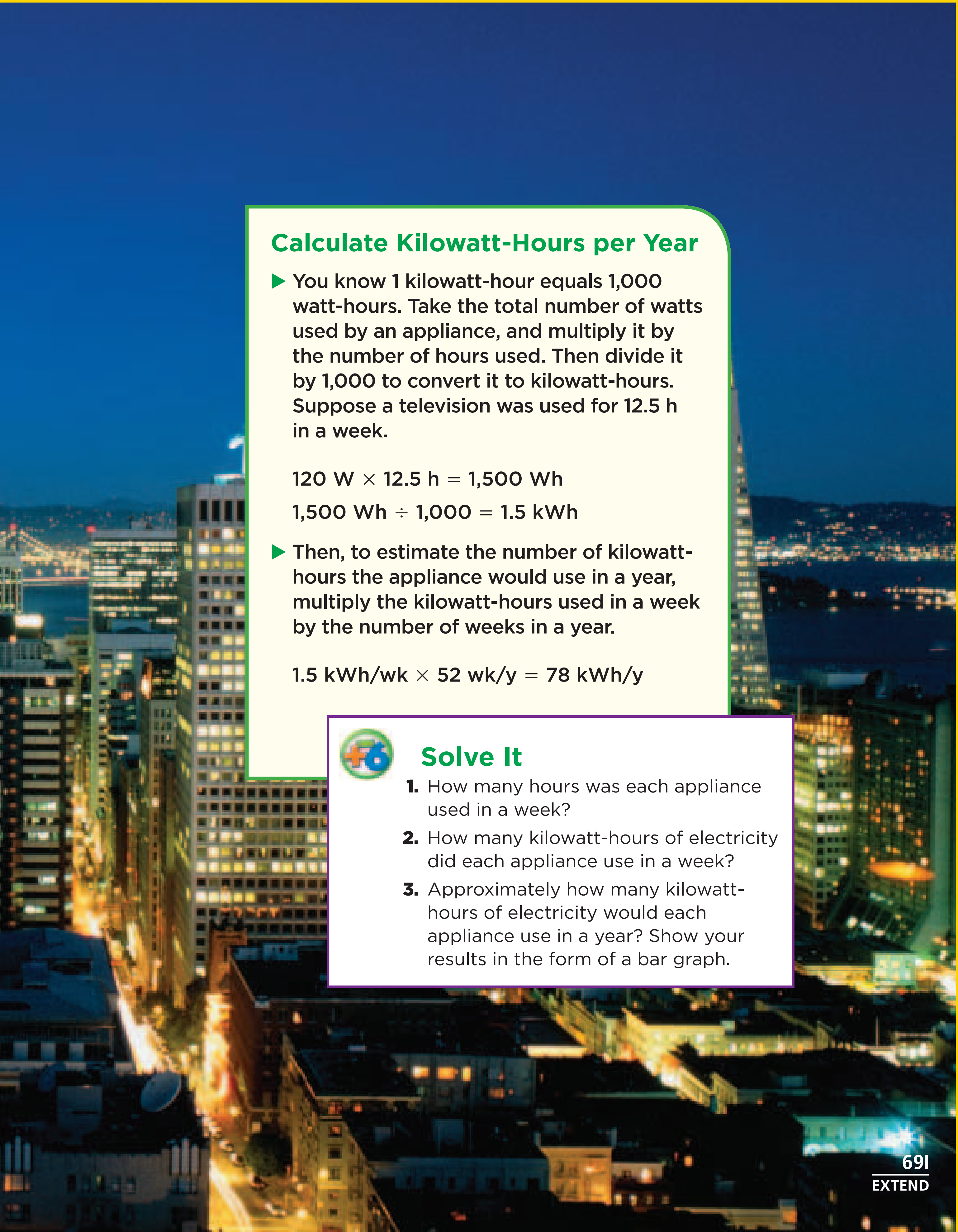
The power, or rate of energy use, of electrical appliances is measured in watts. One watt is one joule per second. Electricity companies charge consumers for the amount of energy that they use. Because a joule—and a second—are very small units of measurement, companies measure energy in kilowatt-hours (kWh). One kilowatt-hour equals 1,000 watt hours (Wh).

You can find the energy used in kilowatt-hours by multiplying the power in watts by the time in hours the appliance was used, then dividing the product by 1,000.

The table below shows the power of some common appliances in watts. Choose five appliances, and for one week record the number of hours that anyone in your household uses each appliance. You can then use this information to estimate how many kilowatt-hours of electricity these appliances use in a year.

Power of Select Appliances

Appliance	Watts
clothes dryer	3,000
dishwasher	1,800
hair dryer	1,200
iron	1,200
microwave	1,080
toaster	900
washing machine	480
stereo	400
personal computer	270
television	120



Calculate Kilowatt-Hours per Year

- You know 1 kilowatt-hour equals 1,000 watt-hours. Take the total number of watts used by an appliance, and multiply it by the number of hours used. Then divide it by 1,000 to convert it to kilowatt-hours. Suppose a television was used for 12.5 h in a week.

$$120 \text{ W} \times 12.5 \text{ h} = 1{,}500 \text{ Wh}$$

$$1{,}500 \text{ Wh} \div 1{,}000 = 1.5 \text{ kWh}$$

- Then, to estimate the number of kilowatt-hours the appliance would use in a year, multiply the kilowatt-hours used in a week by the number of weeks in a year.

$$1.5 \text{ kWh/wk} \times 52 \text{ wk/y} = 78 \text{ kWh/y}$$

Solve It

1. How many hours was each appliance used in a week?
2. How many kilowatt-hours of electricity did each appliance use in a week?
3. Approximately how many kilowatt-hours of electricity would each appliance use in a year? Show your results in the form of a bar graph.

Lesson 5

Electricity and Magnetism

Look and Wonder

This maglev train zips along without even touching the railway. This is because it rides along on top of an electromagnetic field. What is electromagnetism? How are electricity and magnetism related?

Explore

Inquiry Activity

What happens to charged objects that are brought together?

Make a Prediction

What happens when a balloon is rubbed with cloth and then brought near your hair? The balloon seems to have a type of energy that can make other objects move closer or farther away. This is called a charge. Can pieces of clear tape show similar effects when brought together? Write your answer in the form of a prediction: "If clear tape can hold a charge, then the pieces of tape will . . ."

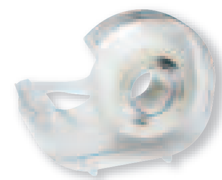
Test Your Prediction

1. **Experiment** Press two pieces of clear tape tightly to your desk, folding over one side of each piece to make a small tab. Pull the strips of tape off the desk, and hold the ends of the tape close together. Observe what happens.
2. **Experiment** Tightly press two new strips of tape to your desk, but this time, stick one of the pieces on top of the other. Pull both strips off the desk, and then pull them apart. Hold the ends of the tape close together, and observe what happens.
3. **Record Data** What happened in step 1 when you brought the ends of the tape near each other? What happened in step 2 when you brought the ends of the tape near each other?

Draw Conclusions

4. **Interpret Data** What seems to have caused the difference between step 1 and step 2?
5. **Compare** What other substances have you observed interacting in a similar manner?
6. **Infer** What do you think pulling the strips of tape off the desk may have done to them?

Materials



- clear tape

Step 2

Explore More

Is there something that you can do or apply to the pieces of tape that will prevent this from happening? Make a prediction, test it, and share your results with others in your class.

Read and Learn

Main Idea

Electricity refers to electric charge and electrical energy.

Vocabulary

electricity, p. 694
static electricity, p. 695
induced charge, p. 696
current electricity, p. 698
resistor, p. 699
series circuit, p. 700
parallel circuit, p. 701
magnetic field, p. 702
electromagnet, p. 703
generator, p. 704

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Reading Skill

Problem and Solution

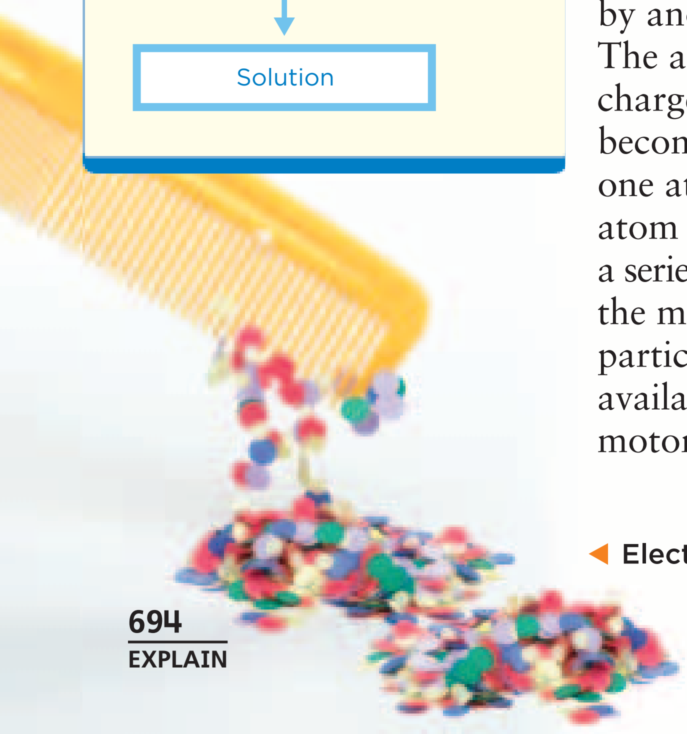
Problem → Steps to Solution → Solution

▲ Have you ever seen a plasma globe? An electric charge produces a lightninglike effect inside the sphere.

What is electricity?

All matter is made up of atoms. All atoms, in turn, are made of different numbers of protons, neutrons, and electrons. Although electrons are much smaller than protons, they carry the same amount of electric charge. When positively charged particles (protons) and negatively charged particles (electrons) are equal in number, the charges cancel one another out.

Electrons spin around the outside of an atom's nucleus, and they can sometimes separate from it. If a "stray" electron is lost by one atom and picked up by another, then the charges of both atoms change. The atom that lost the electron becomes positively charged, and the atom that gained the electron becomes negatively charged. As electrons move from one atom to another, this charge moves from atom to atom as well. The transfer of charged particles builds a series of electrically charged atoms. **Electricity** refers to the movement and transfer of the energy of charged particles. The flow of electricity is energy that is available for doing work. This energy is used to power motors, lights, appliances, and many other devices.



◀ Electrical charges cause confetti to cling to a comb.

Static Electricity

When two materials touch one another, electrons can move from one material to the other. This causes one material to become more negatively charged than the other. The material that gains electrons becomes negatively charged, because it has more electrons than protons. The material that loses electrons becomes positively charged.

The transfer of electrons from one place to another causes an imbalance of positive and negative charges. This results in static electricity. **Static electricity** is the buildup of a positive or negative electric charge on a material's surface. Static electricity can be produced by many different nonmetallic materials. Some materials lose electrons easily, and others tend to attract electrons.

For example, the atoms in your skin tend to lose electrons more easily than the atoms in a cat's fur do. If you were to pet a cat, your hand would gain a net positive charge, and the cat's fur would have a net negative charge. Petting causes a cat's fur to stand on end, because so many strands of hair have the same negative charge. The negatively charged hair strands repel one another.

Objects with the same electric charge repel one another, and objects with opposite charges attract one another. If a negatively charged material touched a positively charged material, the opposite charges would attract one another, and the materials would stick together. This is sometimes referred to as "static cling."

A difference in electric charge produces an attractive force which is similar to gravity, only stronger.

How Static Electricity Forms

Static charge on a comb can make a substance such as confetti move against the pull of gravity and jump to the comb. Using the comb can affect the overall charge of your hair as well.

Quick Check

Problem and Solution How could you reduce the buildup of static electricity in your hair?

Critical Thinking A student rubs two balloons against her hair and then puts the balloons next to each other. The balloons move away from each other. Why?


This bolt of lightning over Las Vegas is actually a discharge—a rapid movement of electrons.

How can electricity jump?

Have you ever shuffled your feet across a carpet? If so, you may have noticed that, if you then reached for a doorknob, a spark jumped and caused a small shock. The contact between the soles of your shoes and the carpet caused electrons to move from the carpet to you.

An electric charge flowed over your body, and electrons jumped from your hand to the doorknob as soon as your hand was close enough to the knob. This spark equalized the difference between the ratio of positive charges and negative charges. A *discharge* corrects an imbalance, or difference, in charge through the rapid movement of electrons. Discharges are responsible for static shocks.

When a charged object is placed near a neutral object—an object with no net charge—the charged object can affect the overall charge of the neutral object. Like charges within the neutral object are repelled, and unlike charges are pulled toward it. This movement can cause an induced charge to form.

An **induced charge** is a static charge caused by the presence of an object that itself has a net positive or negative charge. If a neutral object is affected by the charge of another object and is then touched to the ground, a discharge occurs, and like charges rapidly drain away. Then, when the original object is away from the charged object and is no longer affected by its force, the formerly neutral object is left with a net positive or negative charge.

When you rub a balloon on your hair, some electrons leave your hair and are transferred to the balloon. The balloon then has a net negative charge. When you place that balloon near a wall with no net charge, the negative particles in that area of the wall are repelled. This leaves a net positive charge on the surface of the wall. The balloon and wall then attract each other, and the balloon sticks to the wall. This example illustrates how a charged object can induce a separation of charges in another object.

Evidence suggests that lightning can also be produced as a result of induced charges. Storm clouds can accumulate a negative charge near the bottom of the cloud. This can induce a positive charge in the ground below the cloud. This imbalance of charges can result in the discharge called lightning, which can reach 5 kilometers (3 miles) in length.

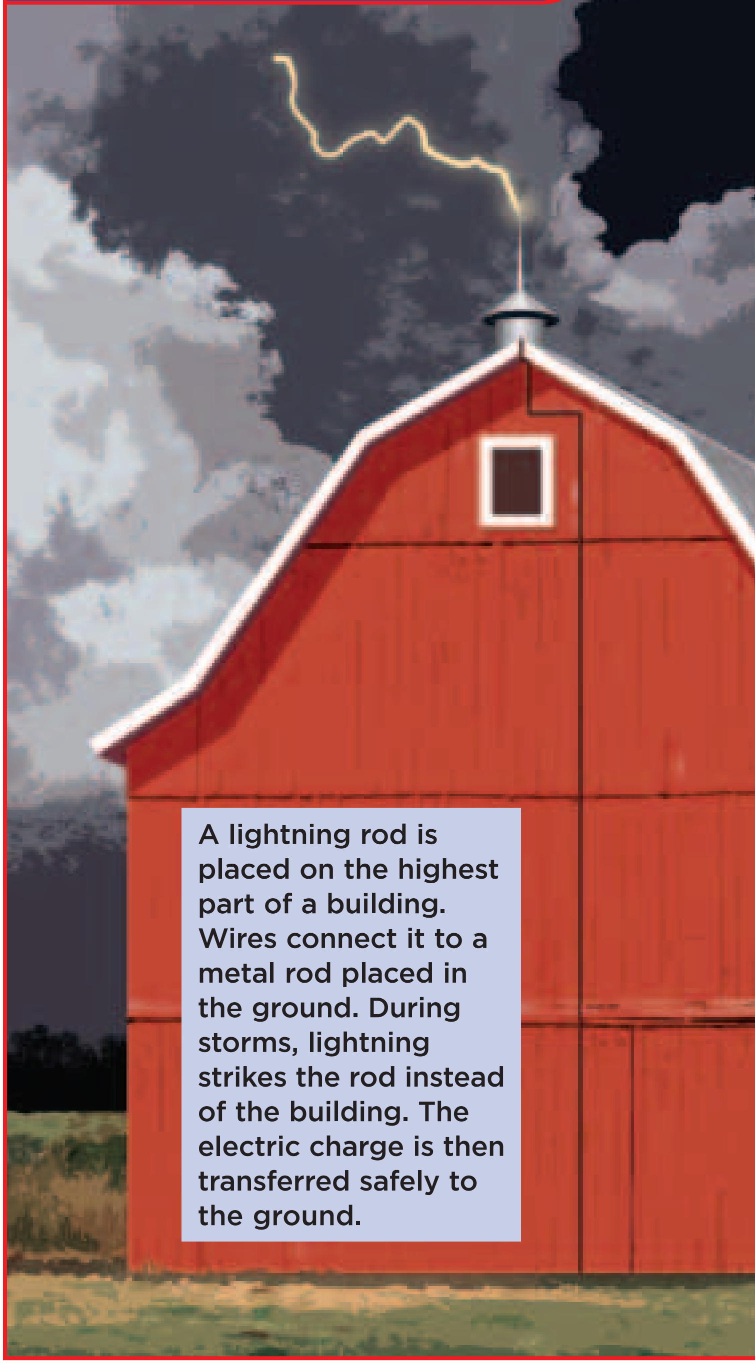
Conductors and Insulators

A *conductor* is a material through which an electric charge flows easily. Most conductors are made of atoms from which some electrons are likely to become unattached. Metals such as copper are the best conductors. Your skin is not a good conductor. If it were, even a small shock could be dangerous. An *insulator* is a material that does not allow an electric charge to transfer easily. Conductors and insulators of electric charge are very similar to conductors and insulators of heat energy.

Grounding Wires

Insulation on the wires of appliances can become worn, exposing the bare wires. If a bare wire touched the metal case of an appliance, it could become electrified. To avoid this problem, a *grounding wire* is connected to the metal case. The grounding wire connects the case to the ground through the household wiring. The ground, especially if moist, is a good conductor. If a charge builds up, the grounding wire enables it to share the charge with the ground. Because the ground distributes charge over much of Earth, the charge on the case is then too small to cause problems.

How a Lightning Rod Works



A lightning rod is placed on the highest part of a building. Wires connect it to a metal rod placed in the ground. During storms, lightning strikes the rod instead of the building. The electric charge is then transferred safely to the ground.

Quick Check

Problem and Solution How does a grounding wire help keep you safe?

Critical Thinking What kinds of appliances might have grounding wires for protection?

FACT Lightning often strikes the same place twice.

How can electricity flow?

The charges that make electrical energy available to do work can flow through conductors along different paths. Each path for electric charge is an example of a *circuit*. In circuits, electric charges move within wires, bulbs, and other devices.

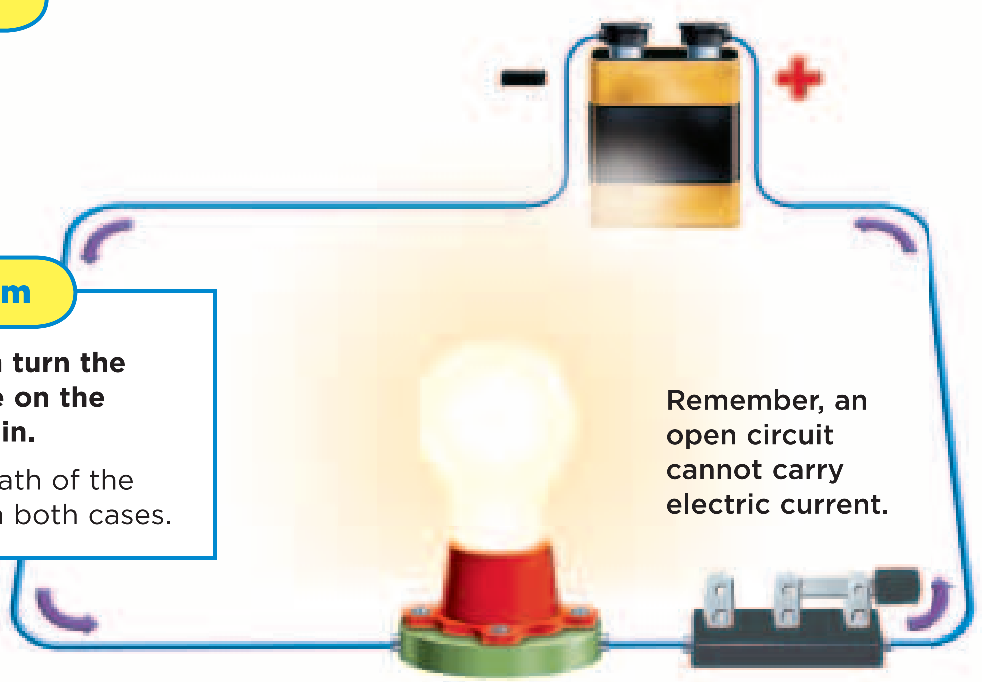
A simple circuit consists of an energy source such as a battery, a device such as a lamp, and connecting wires. The flow of an electric charge through a circuit is called **current electricity**. Light bulbs light up because an energy source pushes an electric charge through them. How does this happen?

The movement of charges through a circuit is similar to the way your heart moves blood through the circulatory system. In a circuit, energy from a source such as a battery causes an electric charge to flow through the wire. Electrons that are not strongly attached to the atoms inside the wire move, causing current electricity. Batteries stop working when the chemical reactions inside them can no longer transfer energy to electrons and move them through the wire in this manner.

Although the movement of negatively charged electrons is most often referred to when studying current electricity in wires, current is always said to flow from the positive to the negative terminal in a circuit. This is called *conventional current*. This way of describing the movement of electric current originated before scientists fully understood electricity. However, it is still the way used to describe how circuits operate.

A *switch* can control the flow of a charge in a circuit. When the switch is opened, the flow is halted. The circuit is incomplete and is then called an *open circuit*. When the switch is closed, the electric charge resumes its motion. When current flows once again, the circuit is called a *closed circuit*.

A Simple Circuit



Read a Diagram

Would the switch turn the light off if it were on the other side? Explain.

Clue: Trace the path of the wire's electrons in both cases.

Switches come in many varieties, such as the on-off button on a flashlight or circuit breakers in your home. Switches help conserve energy by turning off devices that are not in use.

Direct and Alternating Current

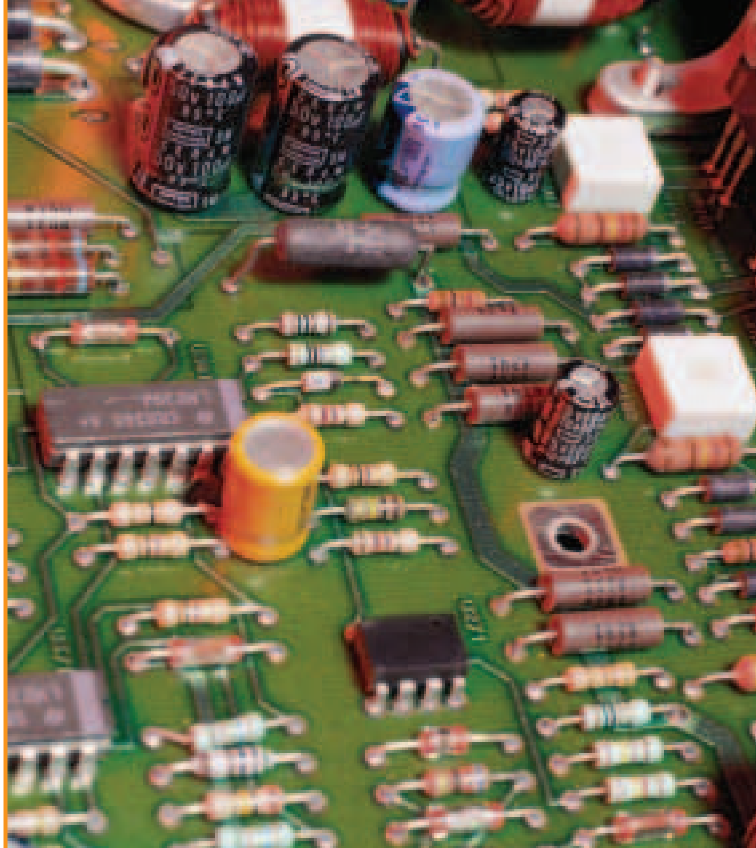
The simple circuit in the diagram on the opposite page uses direct current. *Direct current*, or DC, refers to current that flows in one direction. Batteries provide DC, as do solar-powered cells. The very first commercial electric power stations also used DC.

Inventor Thomas Edison was a strong advocate of DC. Rival scientists such as Nikola Tesla and George Westinghouse promoted the use of a different type of current. These scientists advocated systems that produced *alternating current*, or AC. In AC, the electric charge does not flow through the circuit in one direction. AC power is transmitted when the charge changes direction, moving back and forth at regular intervals.

It might surprise you to learn that the power in the outlets in your home is not the type that Thomas Edison promoted. Although each type of current has both advantages and disadvantages, AC power was the better choice. The main advantage of AC is that this type of current can be transported over long distances with far greater efficiency.

Resistors

Sometimes, people want to reduce the amount of electric charge that flows through a circuit. Current can be reduced by adding a resistor to the circuit.



Circuit boards in computers contain many resistors.

Resistors lower the amount of electric charge that flows through a device. Frequent collisions of atomic particles transfer some of the energy to the atoms of the resistor. These collisions cause the resistor to become warmer, and this reduces the energy available to move electric charge. Lights and other devices connected in a circuit act as resistors, because they too reduce current flow. A light bulb converts electrical energy to both heat and light.

Quick Check

Problem and Solution If electrical devices are always on, they will burn out quickly. How can this problem be solved in a simple circuit?

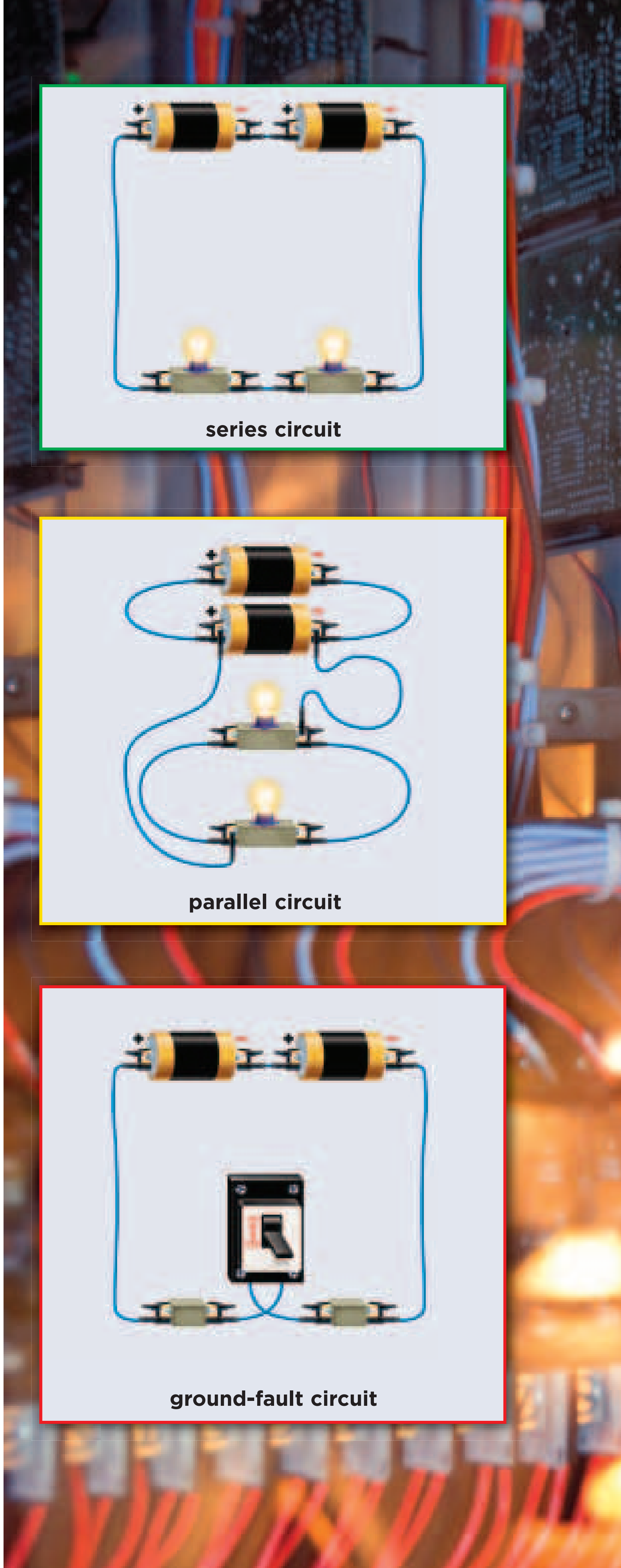
Critical Thinking What happens when a battery is recharged?

What are some kinds of circuits?

In a **series circuit**, there is only one path along which current electricity can flow. In a flashlight, electric charge flows along a single path from the batteries to the light bulbs and back. Each battery supplies more energy that causes electric charge to flow. The light bulbs receive the sum of the energy that comes from the two batteries. This energy is measured in volts (V). Because each battery has 1.5 volts, the two batteries together deliver a total of 3 volts. A higher voltage causes more electric charge to move through the light bulbs.

Remember, light bulbs and many other devices act as resistors. In a series circuit, the total resistance is the sum of the resistances of the individual devices. For example, two identical light bulbs together in a series circuit will have twice the resistance of either bulb by itself.

Strands of decorative lights are usually not wired in a long, extended series circuit. Why? The voltage of current electricity from a normal wall outlet is about 120 volts. Each small bulb on a strand of lights operates on about 2.5 volts. This means that the voltage from a wall socket is about 50 times the voltage that a single bulb requires. To provide the correct voltage to each bulb, each strand could only have 50 bulbs. If there were more, then each bulb would not receive enough voltage to light up.



Different types of circuits are used for different needs. ▶

series circuit

parallel circuit

ground-fault circuit

Parallel Circuits

In a **parallel circuit**, there are multiple paths along which current electricity can flow. For example, in a string of lights wired in a parallel circuit, when one bulb burns out, there are other paths along which electric charge can flow to all the other bulbs.

Parallel circuits are used everywhere that we use electricity, including homes, stores, and offices. If any one device on the circuit burns out, the other devices on the circuit will keep working. The structure of a parallel circuit also provides a backup, in case a device being powered by the circuit burns out. Parallel circuits make it possible for us to use electricity the way we do today.

Short Circuits

Sometimes, an additional type of backup is added to protect against high levels of current electricity. A *short circuit* is a path for current electricity that has little or no resistance. Current flowing in a short circuit can reach dangerously high levels and will also generate heat. A *fuse* is a device that prevents dangerous levels of current from continuing to flow through a circuit. A fuse contains a piece of metal that melts if it is heated. This melting breaks, or opens, the overloaded circuit.

Quick Check

Problem and Solution What problems do fuses solve?

Critical Thinking How are parallel circuits better than series circuits?

Electromagnets

▲ As the number of coils increases, so does the strength of the magnetic pickups in an electric guitar. The guitar strings vibrate, and the pickups transform this vibration into electrical energy.

What are magnets?

You may have used magnets at home or school to attract and pick up objects made of metals such as iron or steel. You can use a magnet to push and pull these objects without even touching them. How is this possible?

Magnets are surrounded by a **magnetic field**, an invisible area where the forces of magnetic attraction or repulsion can be detected. Scientists think that magnetism comes from the spinning motion of electrons in a magnet's atoms. Each atom behaves like a tiny magnet. Because atoms of iron, nickel, and cobalt tend to point their magnetic fields in the same direction, these elements form strong magnets.

Properties of Magnets

All magnets have two *poles*: a north-seeking pole (N) and a south-seeking pole (S). Picture a magnet that is suspended so that it can spin freely. The magnet's north-seeking pole will move and turn toward Earth's North Magnetic Pole. The south-seeking pole of the magnet will point toward Earth's South Magnetic Pole. A compass needle is a magnet that rotates to point to the North Magnetic Pole.

The south pole of one magnet repels, or pushes away, the south pole of another magnet. Two north poles interact in the same way. A north pole and a south pole, however, will attract each other. Attraction or repulsion is strongest right at the poles, but it can be observed all around a magnet and throughout the magnetic field.

It is impossible to isolate one pole from the other, because anything that is magnetized has two poles. Even if a magnet is cut in half, each half will still have a north-seeking pole and a south-seeking pole.

Electromagnets

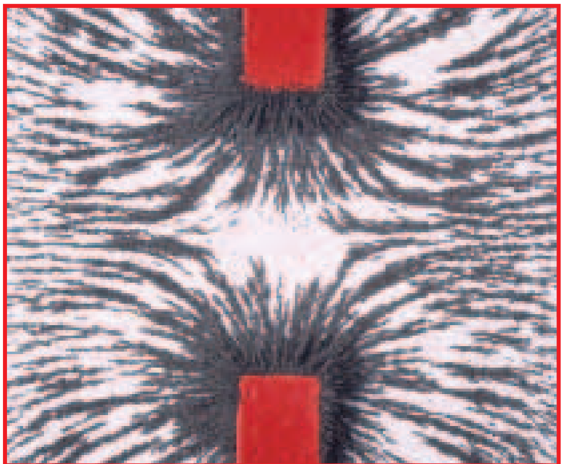
The flow of electric current produces a magnetic field. A wire carrying electric charge has a magnetic field surrounding it. It can even pick up certain metal objects, just as a common magnet can. The magnetism around a wire carrying an electric current becomes much stronger when the wire is wrapped into a tight coil. Each turn of the coil makes the magnet stronger.

If an iron core is placed within the wire coils, the magnet becomes even stronger. A device that is magnetized by current electricity is called an **electromagnet**. Electromagnets are convenient, because their magnetism can be turned on and off by stopping or starting the flow of electric charge.

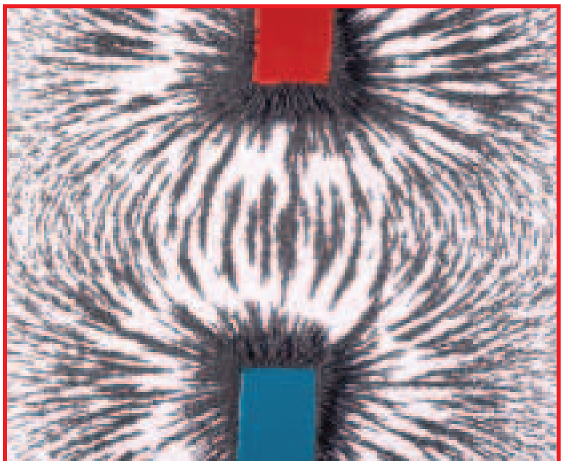
Applications of Electromagnetism

Electromagnets can be found in motors and even in sound equipment such as speakers and electric-guitar pickups. The strings of an electric guitar vibrate within a magnetic field. The pickup "picks up" these vibrations and converts them into a signal, which you then hear as an amplified sound.

Electromagnets play an important role in medicine. Doctors use a technique called magnetic-resonance imaging, or MRI, to produce images of human tissue. In an MRI, the patient lies inside a long tube and is surrounded by electromagnets. In the patient's body, the nuclei of certain atoms tend to line up with the magnetic field. When radio waves are beamed at the patient's body, the hydrogen nuclei gain energy and send out signals that a computer detects. The computer converts the data into detailed images of the body's tissue. These images are much clearer than images from X-ray machines and offer much more information to doctors.



The south poles of the magnets repel each other.



The north pole of one magnet is attracted to the south pole of the other magnet.

Quick Check

Problem and Solution How could you make your own electromagnet?

Critical Thinking Would current electricity affect a compass needle? Explain.

How do we use generators?

Electromagnets play an important role in producing the electricity that we use. A **generator** is a device that converts mechanical energy—supplied by a hand crank, turbine, magnets, or motors—into electricity. A generator uses energy to cause electric charge to flow. Electric power plants use generators to produce electric power for homes and businesses. The electric power that is produced by these generators is AC that completes 60 back-and-forth cycles each second.

Steam turbines are commonly used to produce current electricity. The turbines are powered by high-pressure steam produced inside giant boilers. Most electrical energy produced in the United States comes from coal, oil, or natural gas. These fuels are burned in order to turn liquid water into steam. Hydroelectric power plants spin their turbines with water that is stored behind dams and therefore has a great deal of potential energy.

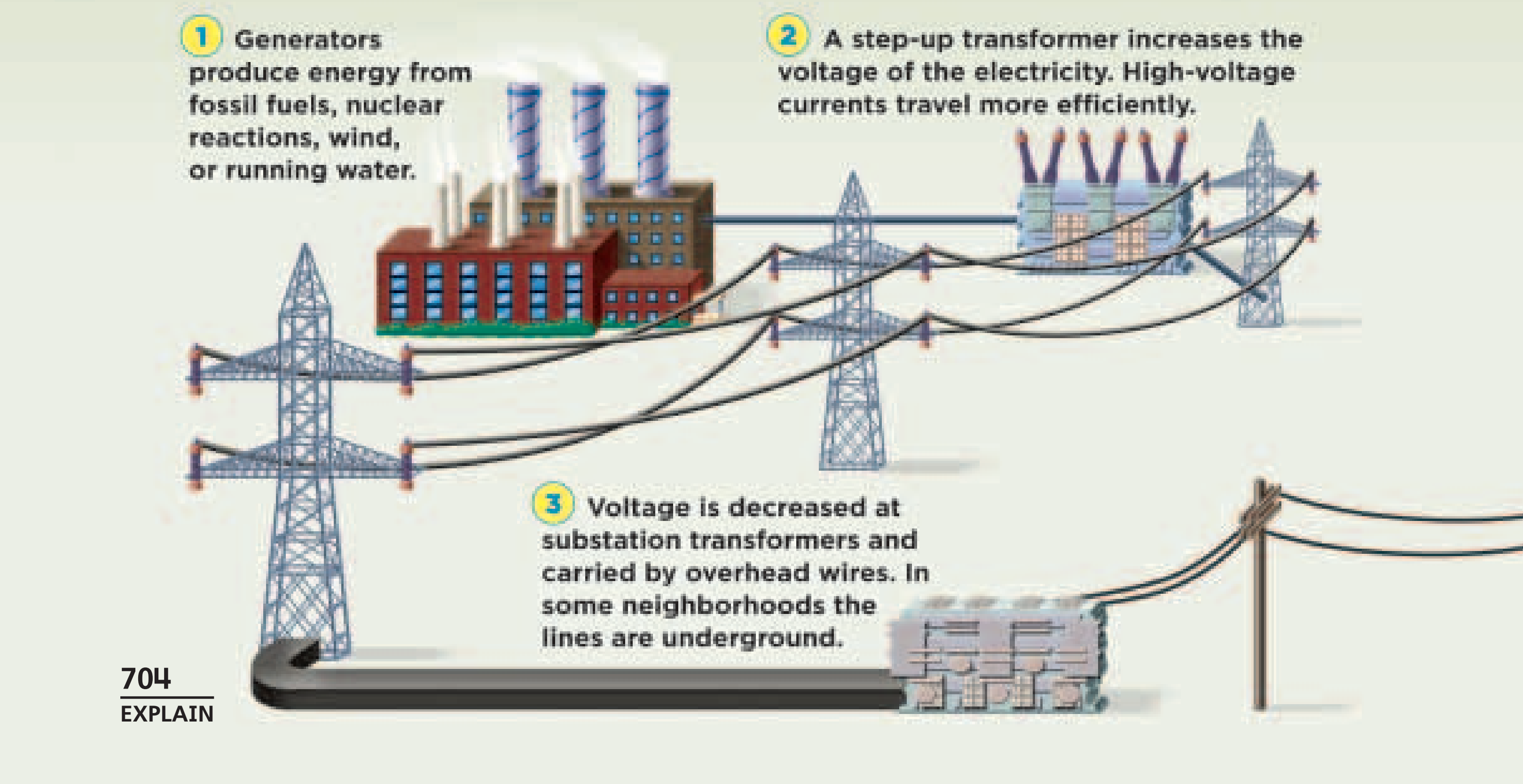
From Generators to Homes

Generators at power plants produce current electricity. How does this energy make its way into your home?

Current electricity is first conducted to a transmission substation. The substation has many towers with power lines leaving them. *Step-up transformers* in the substation increase the voltage of the current electricity. This allows the electric charge to be transmitted over long distances more efficiently.

Power lines can span great distances, from power plants to cities. Some energy is wasted on the way as heat, but step-up transformers help make the transmission process safer and more efficient so that less energy is wasted.

From Generators to Homes



The high voltages that are used in transmitting current electricity over distances are dangerous. Therefore, before current electricity enters your home, the voltage is decreased at several stages. Transformers are again used to change the voltage of the current electricity. *Step-down transformers* decrease the voltage of the electric charge. Another local substation reduces the voltage from more than 155,000 volts down to about 10,000 volts. Additional reductions take place in transformers on power lines and outside homes.

By the time the electric current reaches your home, the voltage is 240 volts. A regular wall socket in your home delivers 120 volts, and this is what most appliances need to operate. However, some sockets found in people's homes do deliver 240 volts.

Quick Lab

Make Your Own Compass

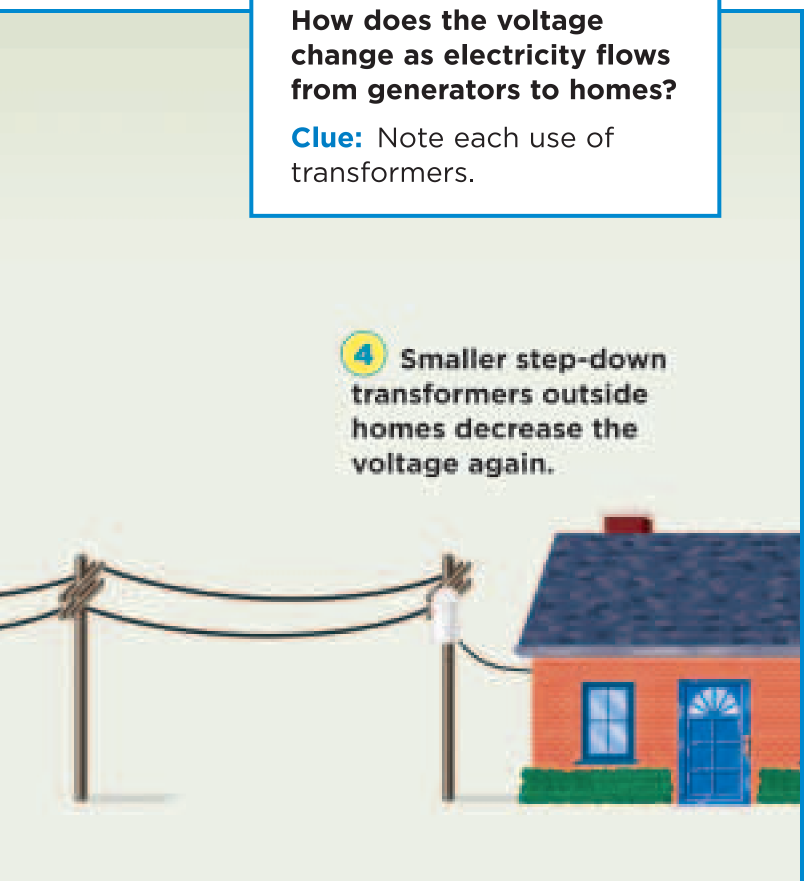
1. Rub a bar magnet many times in one direction over a needle. Place the needle on a thin slice of cork that is floating in water.

2. **Experiment** Place the south end of the bar magnet near the needle, and observe what happens.
3. **Infer** Which end of the needle points to Earth's North Magnetic Pole? How can you verify this?

Read a Diagram

How does the voltage change as electricity flows from generators to homes?

Clue: Note each use of transformers.

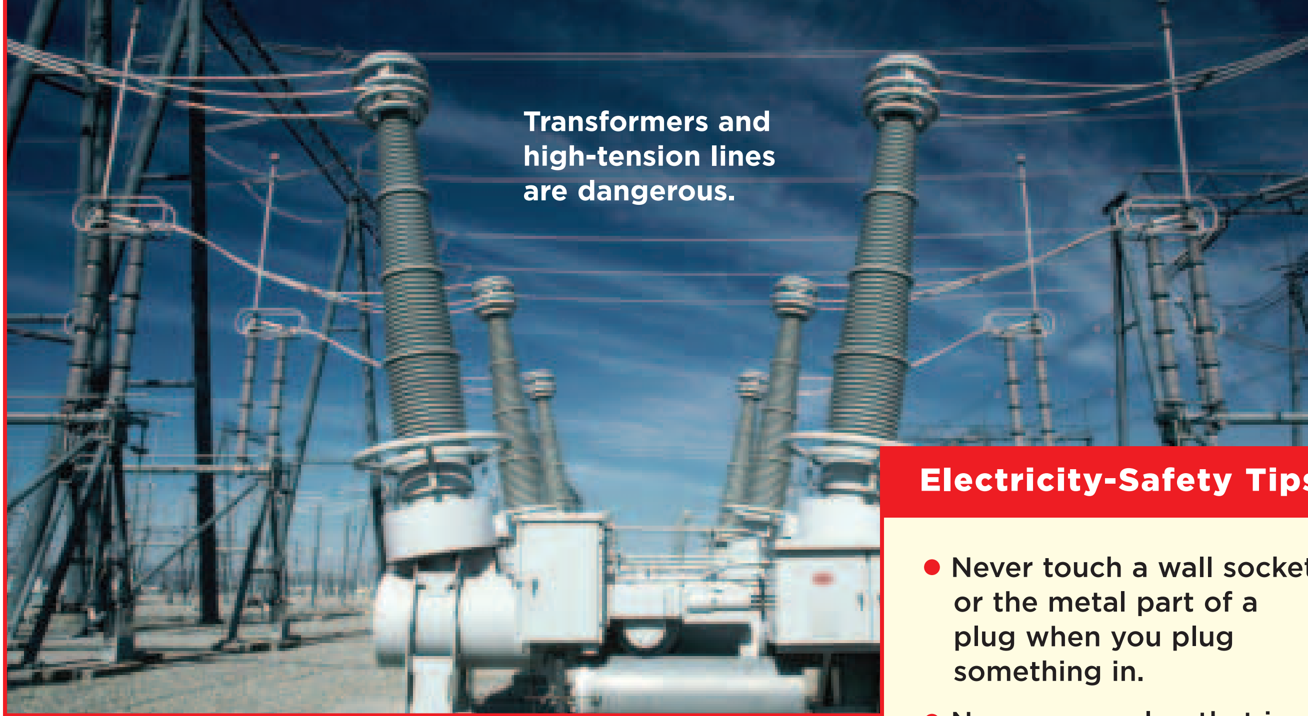


Sockets that deliver higher voltage are used for specially designed appliances, such as certain types of clothes dryers or air conditioners. A regular appliance plugged into a higher-voltage socket will short out, because a regular appliance cannot function using electric charge with such a high voltage level.

Quick Check

Problem and Solution How is current electricity transported over long distances?

Critical Thinking What ways of generating electricity seem to have the least effect on the environment?



Transformers and high-tension lines are dangerous.

What are some tips on using electricity?

Electric devices are helpful, but they must be used properly. Here are some rules to follow when using electricity. The two ideas to keep in mind when you use electricity are to use it safely and to save energy whenever possible.

Saving Energy

Electricity costs money. In addition, producing electricity uses up fuel and may pollute the environment. Many generators are run by steam. The steam is produced by burning fossil fuels such as coal and oil.

You can save fuel and save money by conserving energy. Wearing warm clothes instead of turning up the heat saves energy. Opening a window instead of using a fan saves energy. Turning off lights and appliances when they are not in use also saves energy.

Electricity-Safety Tips

- Never touch a wall socket or the metal part of a plug when you plug something in.
- Never use a plug that is torn or damaged; it can cause a short circuit.
- Never pull a plug out by the cord; it can damage the cord.
- Do not overload an outlet with many plugs; this could overload the circuit.
- Stay away from high-voltage wires. If you see a downed power line, report it to your power company.
- Never use electric devices when you are wet or standing in water.

Quick Check

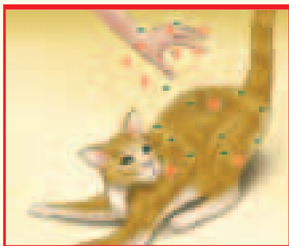
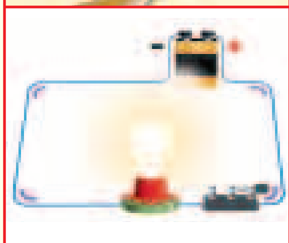
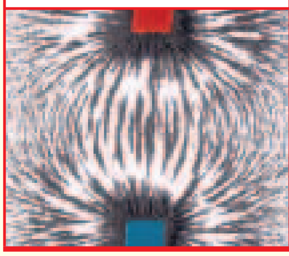
Problem and Solution How can you reduce the use of electricity in your home?

Critical Thinking Why should you avoid electrical-transmission wires?

Overloaded outlets are a safety hazard.

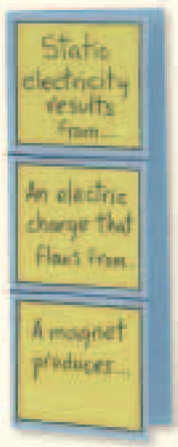
Lesson Review

Visual Summary

	**Static electricity** results from an imbalance of positive and negative electric charges.
	An electric charge that flows from an energy source through a circuit is called **current electricity**.
	A magnet produces a **magnetic field**, which can then be used to generate electric current.

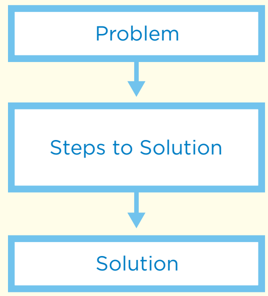
Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Copy the statements shown. On the inside of each tab, complete the statement and provide additional details.



Think, Talk, and Write

1. **Main Idea** What is electricity?
2. **Vocabulary** A substance through which an electric charge moves easily is a(n) _________.
3. **Problem and Solution** How do power companies transport current electricity over long distances?



4. **Critical Thinking** Would a magnet lose its magnetism if you cut it in half?
5. **Test Prep** **A simple circuit containing a light switch in the "on" position is**
   - **A** an open circuit.
   - **B** a closed circuit.
   - **C** a series circuit.
   - **D** a parallel circuit.
6. **Test Prep** **A device that is magnetized by current electricity is**
   - **A** a transformer.
   - **B** a generator.
   - **C** a battery.
   - **D** an electromagnet.

Writing Link

Personal Narrative

Keep a log documenting your usage of electrical energy for an entire week. Analyze your energy usage, and write about how you could reduce your usage and save energy.

Social Studies Link

Electricity Around the World

How do other countries provide electrical energy? Compare systems of power generation in at least two other countries to those used in the United States.

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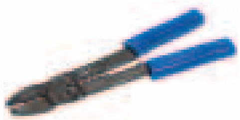
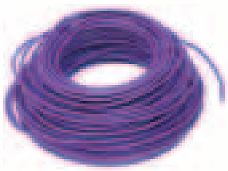
Be a Scientist

Materials


wire-cutting and wire-stripping tool


measuring tape


insulated wire


large nail


2 battery clips


2 D-cell batteries

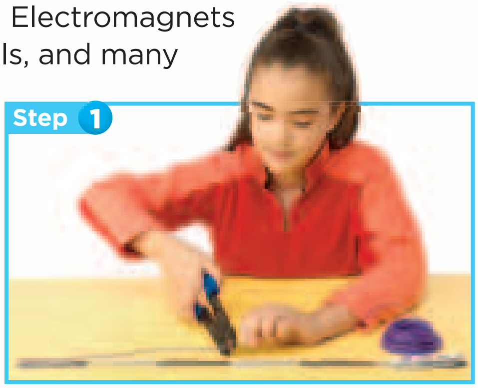

paper clips

Structured Inquiry

How can you make an electromagnet stronger?

Form a Hypothesis

Electromagnets work by using electric current to magnetize a metal object. Wire is wrapped around a metal object and then hooked to a source of electrical energy. The current in the wire causes the metal object to become magnetized. Electromagnets can be found in stereo speakers, doorbells, and many other household objects. How can you make an electromagnet stronger? Will an increase in electrical energy cause an increase in magnetism? Write your answer in the form of a hypothesis: "If the number of batteries in an electromagnet is increased, then the strength of the electromagnet will . . ."

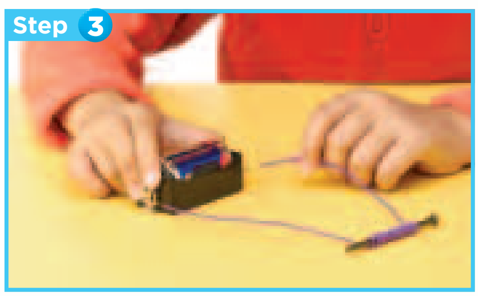

Step 1

Test Your Hypothesis

1. **Measure** Use a wire-cutting and wire-stripping tool to cut a 30 cm piece of insulated wire. Strip about 2 cm of plastic insulation off the ends of the wire. **Be Careful.**


Step 2

2. Tightly and neatly wrap the wire around a large nail. Draw a picture of the setup on a piece of paper.


Step 3

3. **Experiment** Connect the ends of the wire to one battery clip containing a battery. Pick up the nail. Make sure not to disconnect the battery. Hold the nail near some loose paper clips. See how many paper clips the nail will pick up and hold. Record this number on your paper. Disconnect the wires from the battery.


Step 4

4. **Use Variables** Use a second battery clip to connect two batteries in a series. Then repeat step 3.

Draw Conclusions

5. **Interpret Data** How did adding a second battery affect the strength of your electromagnet? How do you know?

6. **Form a Hypothesis** In what other ways might you make your electromagnet stronger, without changing the number of batteries?

Guided Inquiry

What other variables can be changed to make an electromagnet stronger?

Form a Hypothesis

How else can you increase the strength of your electromagnet? Will adding more wire coils improve its strength? Write your answer in the form of a hypothesis: "If more wire coils are added to an electromagnet, then the strength of the magnet will . . ."

Test Your Hypothesis

Design an experiment to determine how additional wire coils will affect the electromagnet. Write out the materials you will need and the steps you will follow. Record your results and observations.

Draw Conclusions

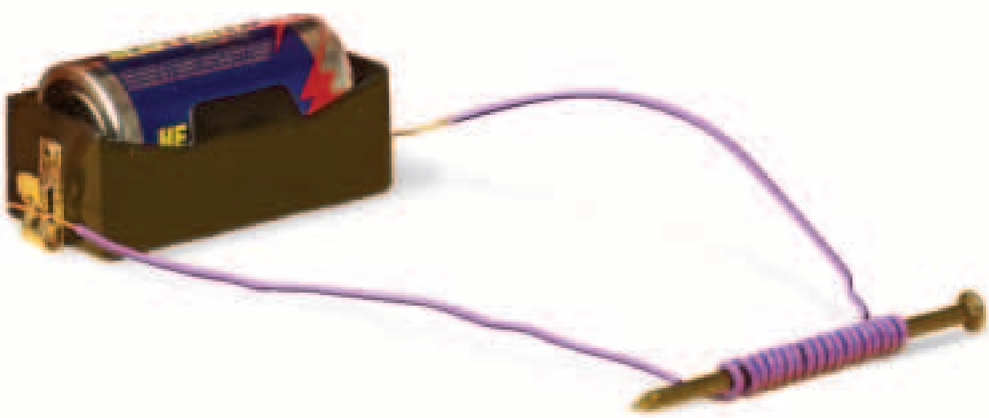
Did your results support your hypothesis? Why or why not? How did you achieve your best results? Present your electromagnet design to your classmates.

Open Inquiry

What more can you learn about electromagnets? For example, what happens when other materials are used in place of a nail? Design an experiment to answer your question. Write your experiment so that another group could repeat it by following your instructions.

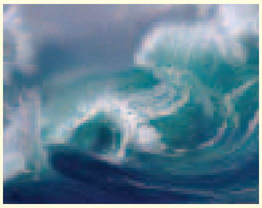
Remember to follow the steps of the scientific process.

Ask a Question
↓
Form a Hypothesis
↓
Test Your Hypothesis
↓
Draw Conclusions



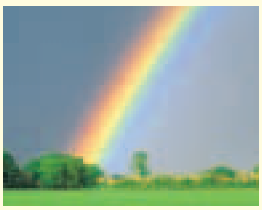
CHAPTER 12 Review

Visual Summary



Lesson 1 Waves transfer sound energy from a source through a medium.

Lesson 2 Light travels from its source in straight lines that move out in all directions.



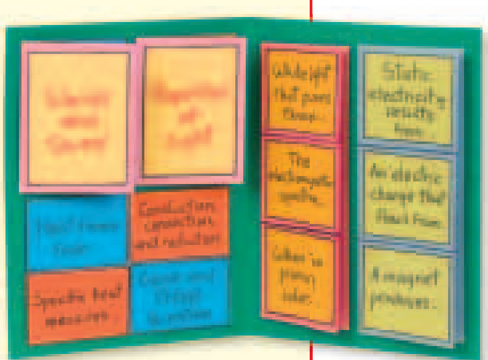
Lesson 3 The electromagnetic spectrum contains visible light, which is responsible for how we view color.

Lesson 4 Heat energy flows from a warmer object to a cooler object until both are the same temperature.

Lesson 5 Electricity refers to electric charge and electrical energy.

Make a FOLDABLES™ Study Guide

Assemble your lesson study guides as shown. Use your study guide to review what you learned in this chapter.



Vocabulary

Fill each blank with the best term from the list.

convection, p. 685	**opaque**, p. 661
electricity, p. 694	**primary color**, p. 676
generator, p. 704	**refraction**, p. 651
heat, p. 682	**visible light**, p. 672

1. The mixture of different wavelengths seen by the eye is called ________.

2. The transfer of energy by the flow of a liquid or a gas is ________.

3. The flow of energy from one substance to another is called ________.

4. Light will not pass through a material that is ________.

5. You can convert mechanical energy to electricity using a(n) ________.

6. A change in the direction of a wave because of a change in medium is called ________.

7. The transfer of the energy of charged atomic particles is called ________.

8. A color that is not produced by mixing other colors is called a(n) ________.

Skills and Concepts

Answer each of the following in complete sentences.

9. **Cause and Effect** A metal object moves toward another metal object on its own. What is the most likely cause?

10. **Expository Writing** Explain what happens to white light when it passes through a prism.

11. **Experiment** You are conducting an experiment to determine the effect of frequency on the pitch of sounds in air. What variable would you change during your experiment?

12. **Critical Thinking** A worker lifts a crate up to a truck. Another worker uses a pulley to lift an identical crate up to a truck. How can both workers do the same amount of work?

13. **Observe** What type of mirror is shown here? How does it work?

14. What are the different forms of energy? Give an example of what each kind is used for and why it is important.

Performance Assessment

Wave Good-bye!

Your goal is to observe interference in waves.

What to Do

1. Fill a large, rectangular pan half full with water. Touch the water with the point of a pen. Now touch the water with the flat end of the pen.
2. Using the points of two pens, touch the water on opposite sides of the pan at the same time.
3. Repeat step 2, but touch the water at two different spots on the same side of the pan.

Analyze Your Results

- Draw the results of each step. Compare your drawings, and write down your results. At what points did interference occur? Explain.

Test Prep

1. Look at the photograph below.

What type of circuit is used here?

A an open circuit

B a parallel circuit

C a series circuit

D a short circuit

Heating-and-Air-Conditioning Technician

Air conditioning helps people endure the steamy days of summer. In northern climates, people also depend on heating systems to warm them up during bitter, cold winters. What happens when these systems break down? The problems are solved by heating-and-air-conditioning technicians. These workers install, maintain, and repair heating, air-conditioning, refrigeration, and ventilation systems. To work in this profession, you would need a high-school education, training, and apprenticeships, in which you would learn alongside experienced workers. In most areas, certification and licensing are required in order to work with refrigerant gases and heating and air-conditioning units.

▲ This technician makes sure that building temperatures remain comfortable.

▼ Physics teachers can explain universal scientific laws.

Physics Teacher

When you see a roller coaster complete a loop, do you ever think about the forces that keep the machine moving on the track? If you like physics, would you enjoy sharing your interest with the next generation? If so, a career as a physics teacher might be for you. Physics teachers apply their scientific knowledge by leading discussions, performing demonstrations, and even doing research with their students. Most states require a bachelor's degree in physics and science education as well as state teaching certification. Advanced degrees are needed to teach at the college or university level.

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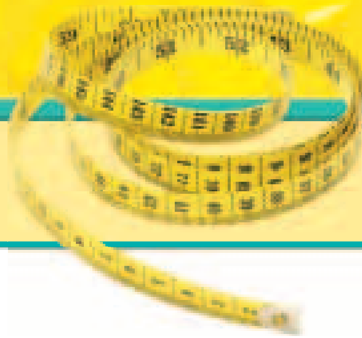
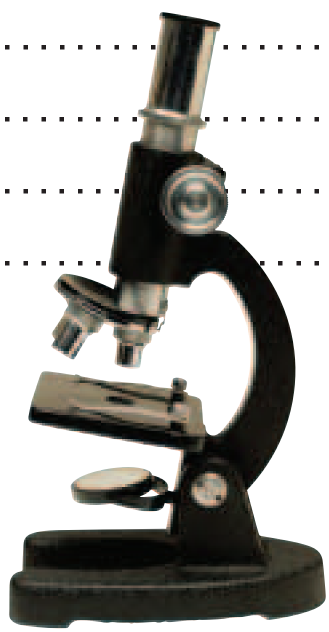
Reference

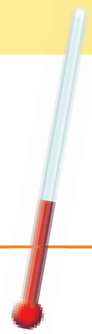
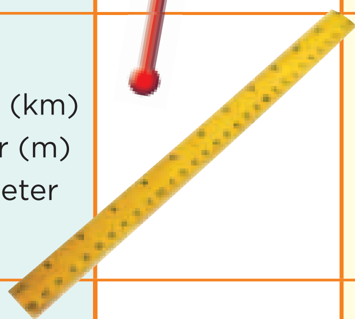


Science Handbook



Measurements

Units of Measurement

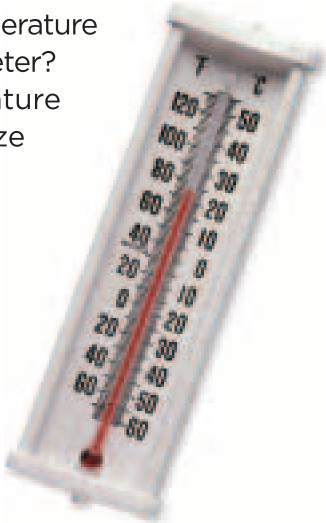
Table of Measurements		
International System of Units (SI)		**Customary Units**
Temperature Water freezes at 0°C (degrees Celsius) and boils at 100°C		**Temperature** Water freezes at 32°F (degrees Fahrenheit) and boils at 212°F
Length and Distance 1,000 meters (m) = 1 kilometer (km) 100 centimeters (cm) = 1 meter (m) 10 millimeters (mm) = 1 centimeter (cm)		**Length and Distance** 5,280 feet (ft) = 1 mile (mi) 3 feet (ft) = 1 yard (yd) 12 inches (in.) = 1 foot (ft)
Volume 1,000 milliliters (mL) = 1 liter (L) 1 cubic centimeter (cm^3) = 1 milliliter (mL)		**Volume** 4 quarts (qt) = 1 gallon (gal) 2 pints (pt) = 1 quart (qt) 2 cups (c) = 1 pint (pt) 8 fluid ounces (oz) = 1 cup (c)
Mass 1,000 grams (g) = 1 kilogram (kg)		**Mass (and Weight)** 2,000 pounds (lb) = 1 ton (T) 16 ounces (oz) = 1 pound (lb)
Weight 1 kilogram (kg) weighs 9.81 newtons (N)		

Making Measurements

Temperature

You use a thermometer to measure temperature. A thermometer is made of a thin tube with a liquid inside that is usually red in color. When the liquid inside the tube gets warmer, it expands and moves up the tube. When the liquid gets cooler, it contracts and moves down the tube.

1. Look at the thermometer shown here. It has two scales—a Fahrenheit scale and a Celsius scale.
2. What is the temperature on the thermometer? At what temperature does water freeze on each scale?



Time

You use timing devices to measure how long something takes to happen. Two timing devices are a clock with a second hand and a stopwatch. A clock with a second hand is accurate to one second. A stopwatch is accurate to parts of a second.

Length

1. Look at the ruler below. Each centimeter is divided into 10 millimeters. Estimate the length of the paper clip.
2. The length of the paper clip is about 3 centimeters plus 8 millimeters. You can write this length as 3.8 centimeters.

Try estimating the length of some objects found in your classroom. Then measure the length of the objects with a ruler. Compare your estimates with accurate measurements.

Measurements

Measuring Mass, Weight, and Volume

Mass

Mass is the amount of matter that makes up an object. You can use a balance to measure mass. To find the mass of an object, you balance or compare it with masses you know.

1. Place the balance on a level surface. Check that the two pans are empty, clean, and balanced with each other. The pointer should point to the middle mark. If it does not, move the slider to the right or left until the pans are balanced.
2. Gently place the object you want to measure in the left pan. The left pan will then move lower.
3. Now add masses to the right pan until both pans are balanced again. Add and get the total mass in the right pan. This total is the mass of the object in grams.

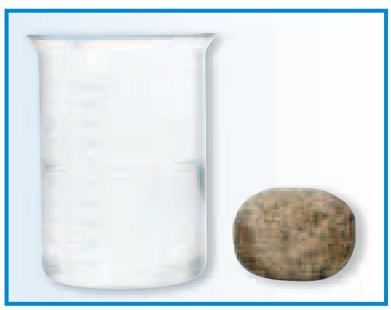
Weight

You use a spring scale to measure weight. Weight equals the amount of gravity pulling down on the mass of an object. Therefore weight is a force. Weight is measured in newtons (N).

1. To find the weight of your object, hold the spring scale by the top. Determine the weight of the empty plastic cup. Add the object to the cup.
2. Subtract the first measurement from the second, and the difference is the weight of the rock.

Volume

1. You can use a beaker or graduated cylinder to find the volume of a liquid.
2. You can also find the volume of a solid such as a rock. Add water to a beaker or graduated cylinder. Gently slide the object down into the beaker. To find the volume of the rock, subtract the starting volume of the liquid from the new volume. The difference is equal to the volume of the rock.



Collecting Data

Microscopes

1. Look at the photograph to learn the different parts of your microscope.
2. Always carry a microscope with both hands. Hold the arm of the microscope with one hand, and put your other hand beneath the base. Place the microscope on a flat surface.
3. Move the mirror so that it reflects light from the room up toward the stage. Never point the mirror directly at the Sun or a bright light. ⚠ **Be careful.** Bright light can cause permanent eye damage.
4. Place a small piece of newspaper on a slide. Put the slide under the stage clips. Be sure that the area you are going to examine is over the hole in the stage.
5. Look through the eyepiece. Turn the focusing knob slowly until the newspaper comes into focus.
6. Draw what you see through the microscope.
7. Look at other objects through the microscope. Try a piece of leaf, a human hair, or a pencil mark.

Other Lenses

You use a hand lens to magnify an object, or make the object look larger. With a hand lens, you can see more detail than you can without the lens. Look at a few grains of salt with a hand lens and draw what you see. Binoculars are a tool that makes distant objects appear closer. In nature, scientists use binoculars to look at animals without disturbing them. These animals may be dangerous to approach or frightened at the approach of people. Cameras can act like binoculars or they can be used to see things up close. Cameras have the advantage of making a record of your observations. Cameras can make a record on film or as data on a computer chip.

Use Calculators

Sometimes after you make measurements, you have to analyze your data to see what they mean. This might involve doing calculations with your data. A handheld calculator helps you do calculations quickly and accurately, and can also be used to verify your own calculations.

Hints

- Make sure the calculator is on and previous calculations have been cleared.
- To add a series of numbers, press the + sign after you enter each number. After you have entered the last number, press the = sign to find the sum.
- If you make a mistake while putting numbers in, press the clear entry key. You can then enter the correct number.
- To subtract, enter the first number, then the – sign. Then enter the number you want to subtract. Then press the = sign for the difference.
- To multiply, enter the first number, then the × sign and enter the second number you want to multiply by. Then press the = sign for the product.
- To divide, enter the number you want to divide, press the ÷ sign and enter the number you want to divide by. Then press the = sign for the quotient.
- You can also find averages and percents with a calculator, and verify your own work.

Use Computers

A computer has many uses. You can write a paper on a computer. You can use programs to organize data and show your data in a graph or table. The Internet connects your computer to many other computers and databases around the world. You can send the paper you wrote to a friend in another state or another country. You can collect all kinds of information from sources near and far. Best of all, you can use a computer to explore, discover, and learn. You can also get information from computer disks that can hold large amounts of information. You can fit the information found in an entire encyclopedia set on one disk.

One class used computers to work on a science project. They were able to collect data from students in another state who were working on a similar project, and share their data with them. They were also able to use the Internet to write to local scientists and request information. The students collected and stored their data, moved paragraphs around, changed words, and made graphs. Then they were able to print their report to share their discoveries with others.

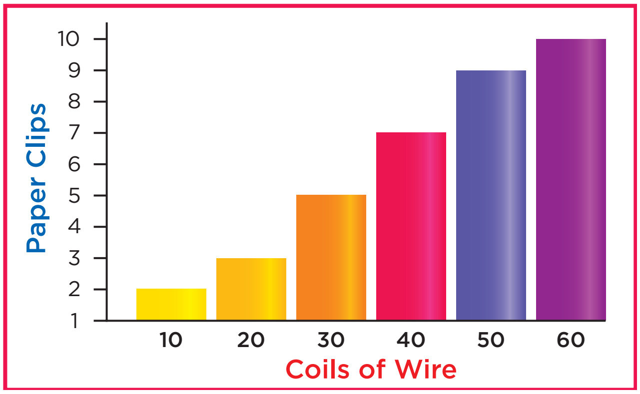
Organizing Data

Use Graphs

When you do an experiment in science, you collect information, or data. To find out what your data means, you can organize it into graphs. There are several different kinds of graphs. You can choose a type of graph that best organizes your data and makes it easier for you and for others to understand the data presented.

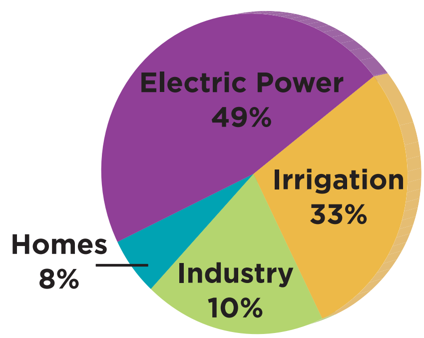
Bar Graphs

A bar graph uses bars to show information. For example, what if you performed an experiment to test the strength of a nail electromagnet and the number of coils of wire wrapped around it? This graph shows that increasing the number of coils increases the strength of the electromagnet.



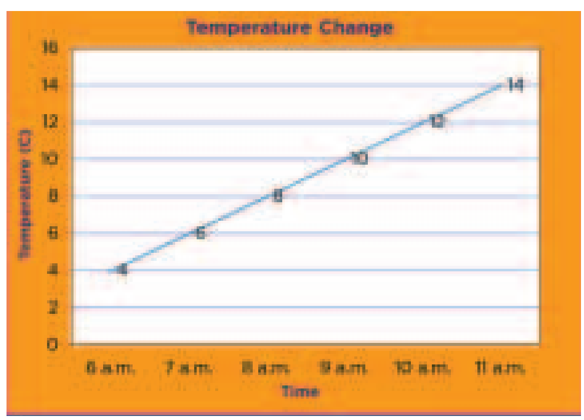
Circle Graphs

A circle graph is used to show how a complete set of data is divided into parts. This circle graph shows how water is used in the United States. In a circle graph, all the data must add up to 100.



Line Graphs

A line graph shows information by connecting dots plotted on a graph. A line graph is often used to show changes that occur over time. For example, this line graph shows the relationship between temperature and time for a particular morning.



Use Tables and Maps

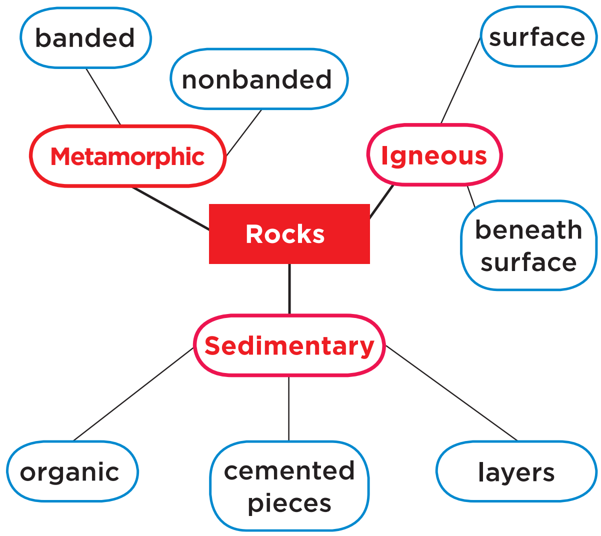
Tables

Tables help you organize data during experiments. Most tables have columns that run up and down, and rows that run horizontally. The columns and rows have headings that tell you what kind of data goes in each part of the table. The table here shows a record of the conductivity of several different kinds of substances.

Material	Thermal Conductivity
Aluminum	109.0
Copper	385.0
Wood	0.1
Packing foam	0.01

Idea Maps

This kind of map shows how ideas or concepts are connected to each other. Idea maps help you organize information about a topic. The idea map shown here connects different ideas about rocks.



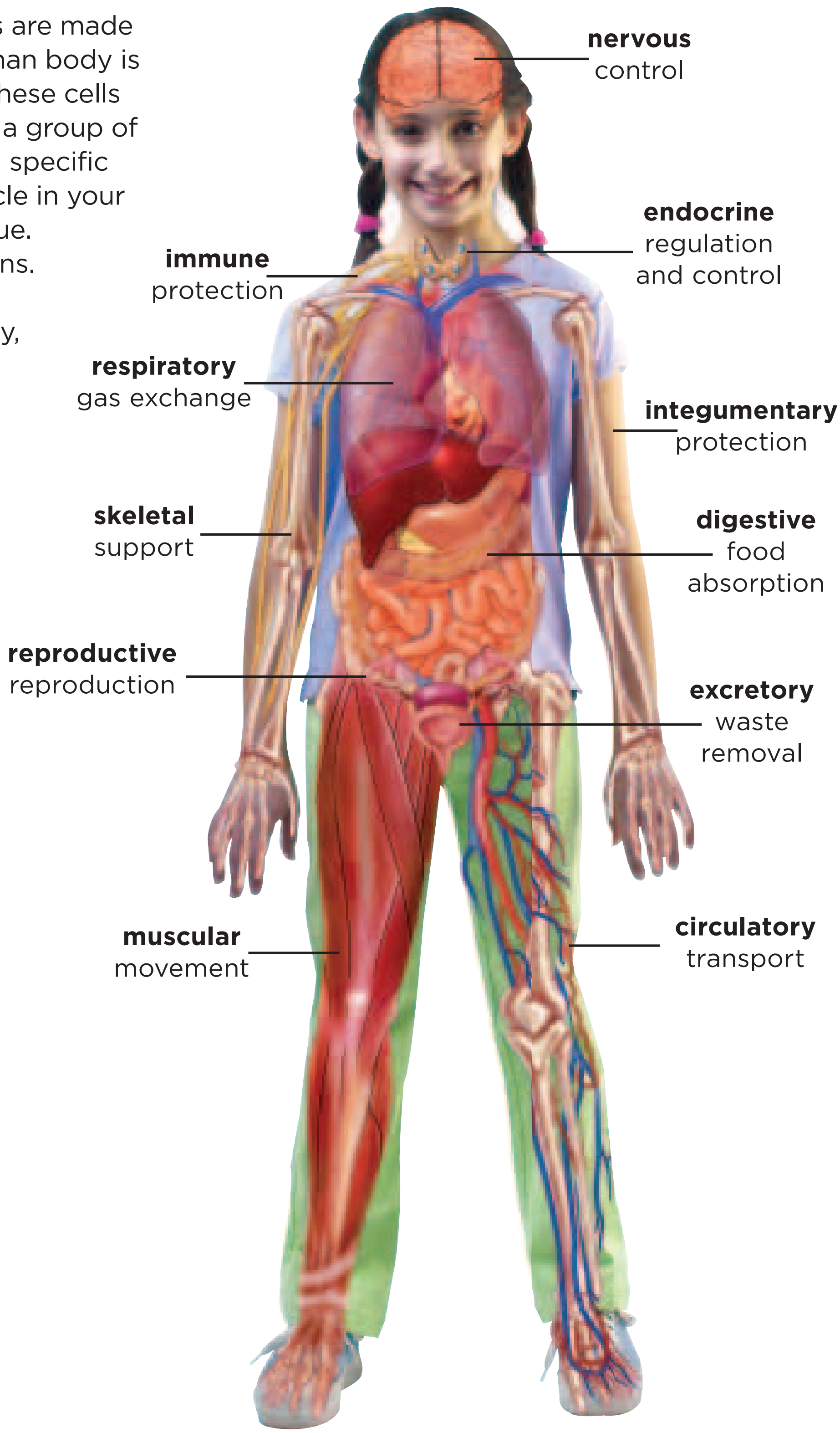
Maps

A map is a drawing that shows an area from above. Maps help you learn about a location. You are probably most familiar with road maps, which are often used to plan ways to travel from one place to another. Other kinds of maps show terrain. Hills and valleys, for example, can be shown on some types of maps. A good map also has a legend that shows the scale it was made to, and also a compass point that shows the direction of north and sometimes other directions as well.

Human Body Systems

Organization of the Human Body

Like all organisms, humans are made up of cells. In fact, the human body is made of trillions of cells. These cells are organized into tissues, a group of similar cells that perform a specific function. The cardiac muscle in your heart is an example of tissue. Tissues, in turn, form organs. Your heart and lungs are examples of organs. Finally, organs work together as part of organ systems. For example, your heart and blood vessels are part of the circulatory system. The organ systems in the human body all function together to keep the body healthy.



The Skeletal and Muscular Systems

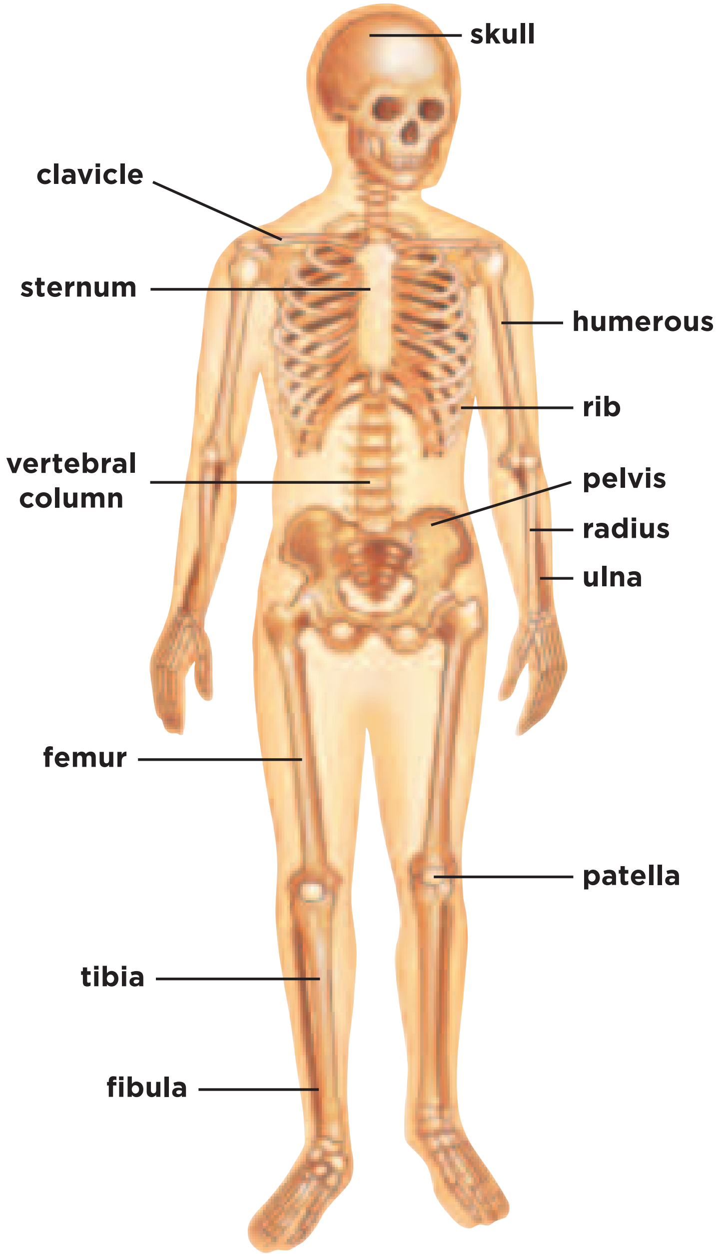
The body has a supporting frame called a skeleton, which is made up of bones. The skeleton gives the body its shape, protects organs in the body, and works with muscles to move the body.

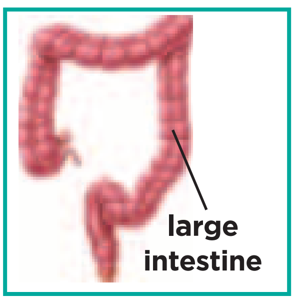
Each of the 206 bones of the skeleton is the size and shape best fitted to do its job. For example, long and strong leg bones support the body's weight.

Three types of muscles make up the body—skeletal muscle, cardiac muscle, and smooth muscle. Cardiac muscles are found only in the heart. These muscles contract to pump blood throughout the body.

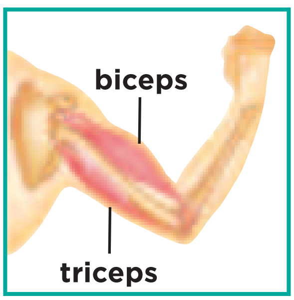
Smooth muscles make up internal organs such as the intestines, as well as blood vessels.

The muscles that are attached to and move bones are called skeletal muscles. Skeletal muscles pull bones to move them. Most muscles work in pairs to move bones.

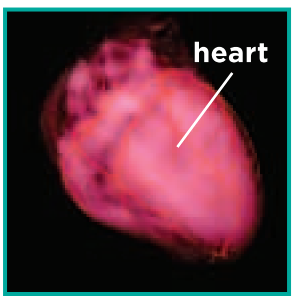




smooth muscle



skeletal muscles



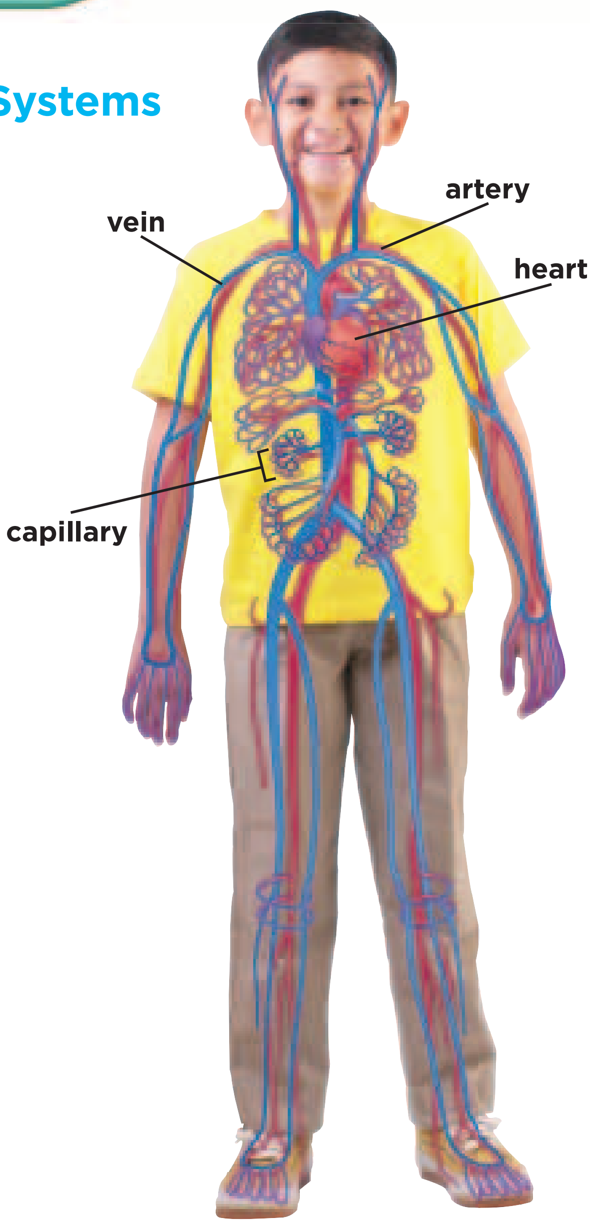
cardiac muscle

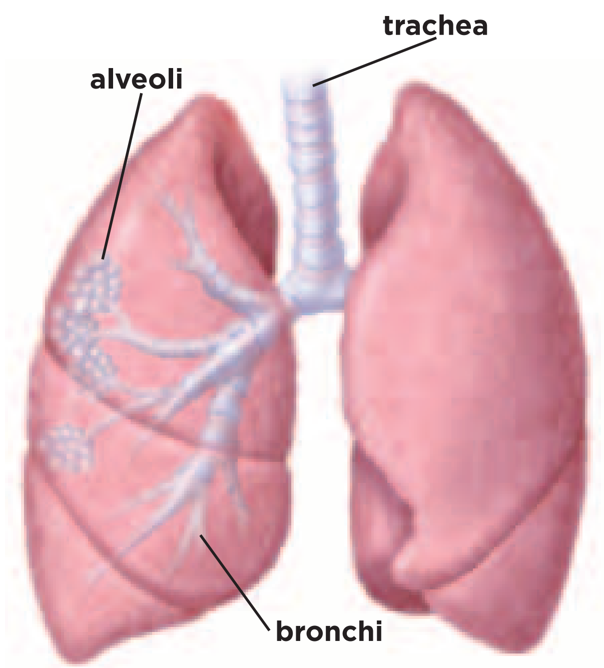
Human Body Systems

The Circulatory and Respiratory Systems

The circulatory system consists of the heart, blood vessels, and blood. Circulation is the flow of blood through the body. Blood is a liquid that contains red blood cells, white blood cells, and platelets. Red blood cells carry oxygen and nutrients to cells. They also carry CO_2 and cellular wastes away from the cells. White blood cells work to fight germs that enter the body. Platelets are cell fragments that help make the blood clot.

The heart is a muscular organ about the size of a fist. Arteries carry blood away from the heart. Some arteries carry blood to the lungs, where red blood cells pick up oxygen. Other arteries carry oxygen-rich blood from the lungs to all other parts of the body. Veins carry blood from other parts of the body back to the heart. Blood in most veins carries the wastes released by cells and has little oxygen. Blood flows from arteries to veins through narrow vessels called capillaries.



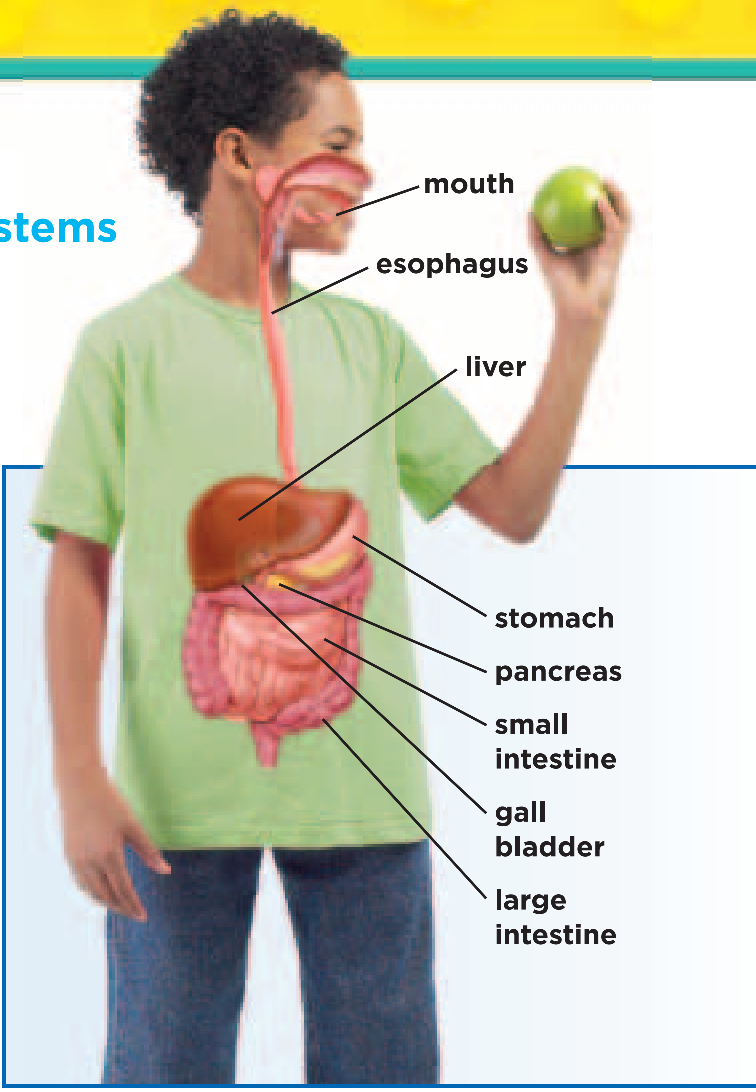


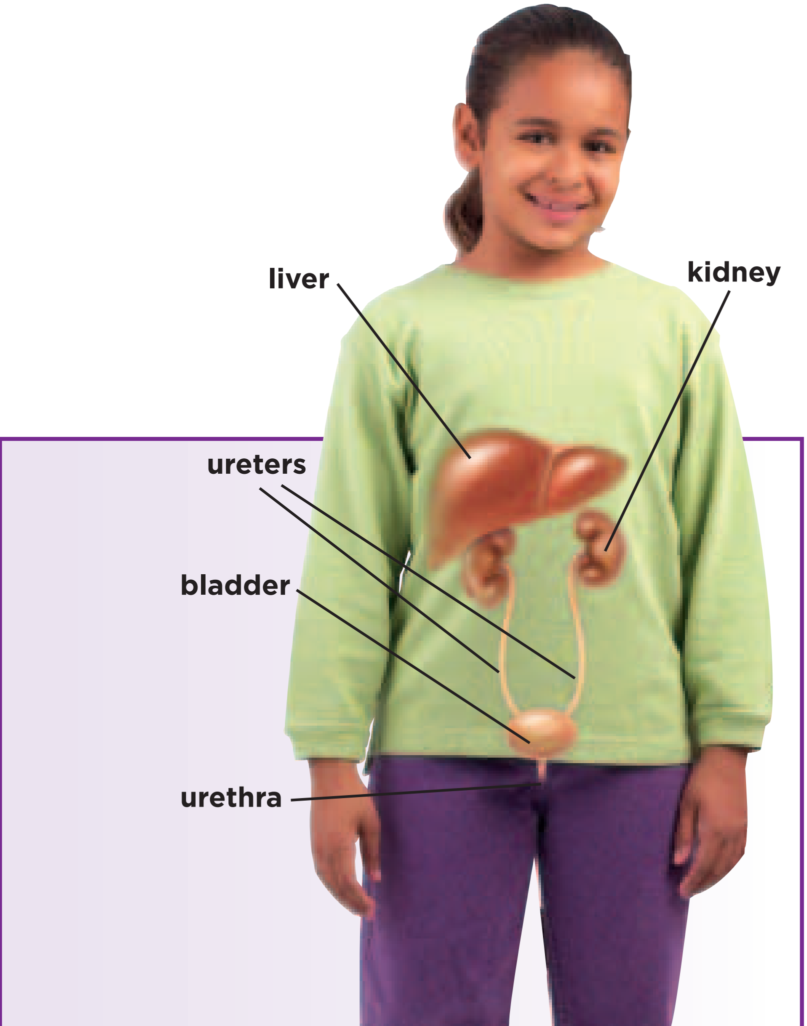
The process of getting and using oxygen in the body is called respiration. When a person inhales, air is pulled into the nose or mouth. The air travels down into the trachea. In the chest the trachea divides into two bronchial tubes. One bronchial tube branches into smaller tubes called bronchioles. At the end of each bronchiole are tiny air sacs called alveoli. The alveoli exchange carbon dioxide for oxygen.

The Digestive and Excretory Systems

Digestion is the process of breaking down food into simple substances the body can use. Digestion begins when a person chews food. Chewing breaks the food down into smaller pieces and moistens it with saliva. Food passes through the esophagus and into the stomach. The stomach mixes digestive juices with food before passing it on to the small intestine.

Digested food is absorbed in the small intestine. The walls of the small intestine are lined with villi, which are fingerlike projections. Digested food is absorbed through the surface of the villi. From the villi the blood transports nutrients to every part of the body. Water is absorbed from undigested food in the large intestine.





Excretion is the process of removing waste products from the body. The liver filters nitrogen wastes from the blood and converts them into urea. Urea is then carried by the blood to the kidneys for excretion. Each kidney contains more than a million nephrons. Nephrons are structures in the kidneys that filter blood.

The skin takes part in excretion when a person sweats. Glands in the inner layer of skin produce sweat. Sweat is mostly water. There is also a tiny amount of urea and mineral salts in sweat.

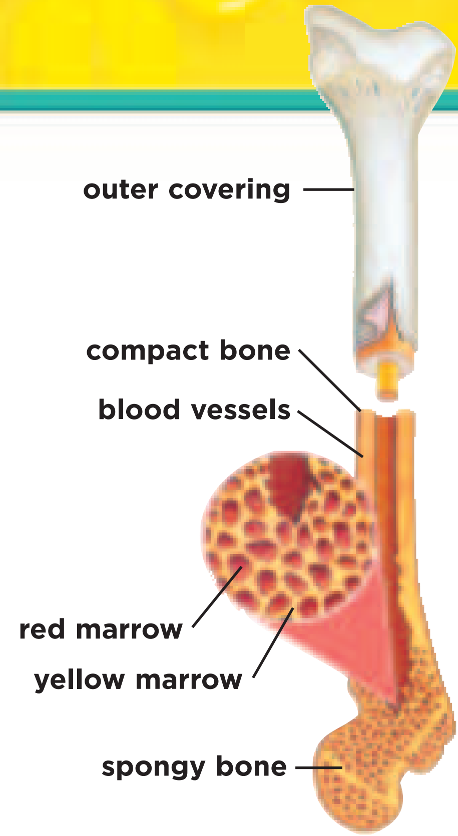
Human Body Systems

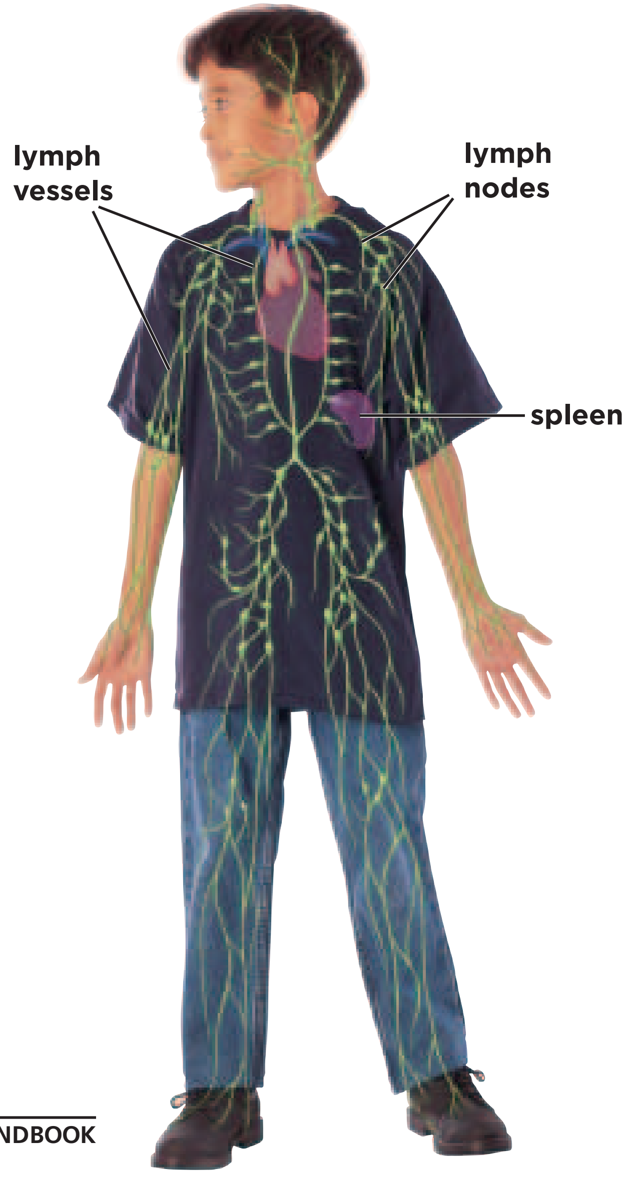
The Immune System

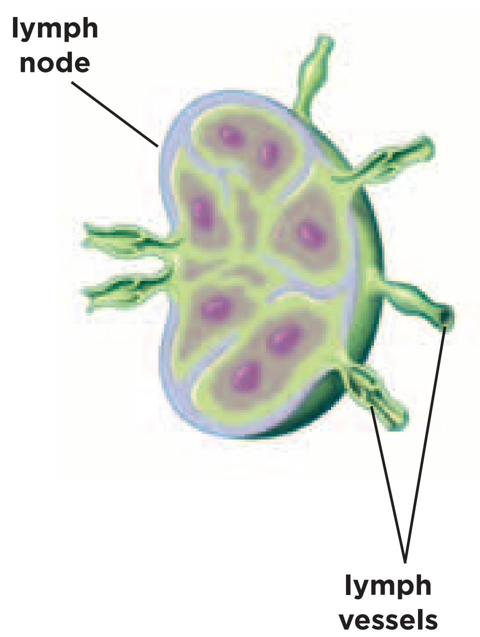
The immune system helps the body fight disease. A soft tissue known as red marrow fills the spaces in some bones. Red marrow makes new red blood cells, platelets that stop a cut from bleeding, and germ-fighting white blood cells.

There are white blood cells in the blood vessels and in the lymph vessels. Lymph vessels are similar to blood vessels. Instead of blood, they carry lymph. Lymph is a straw-colored fluid that surrounds body cells.

Lymph nodes filter out harmful materials in lymph. Like red marrow, they also produce white blood cells to fight infections. Swollen lymph nodes in the neck are a clue that the body is fighting germs.



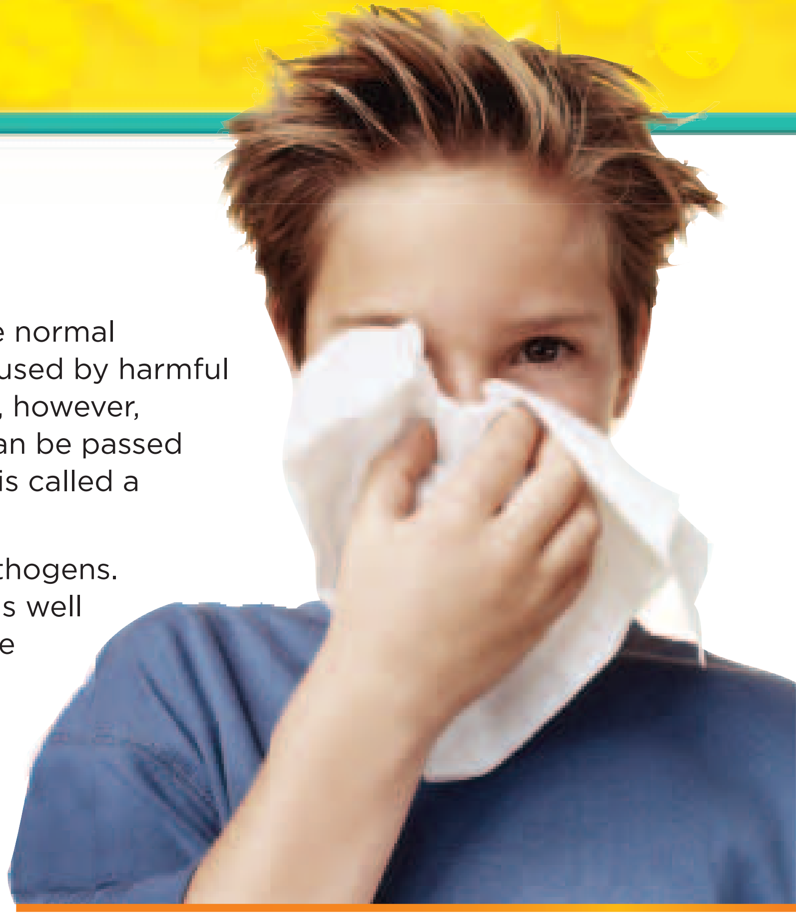




Communicable Diseases

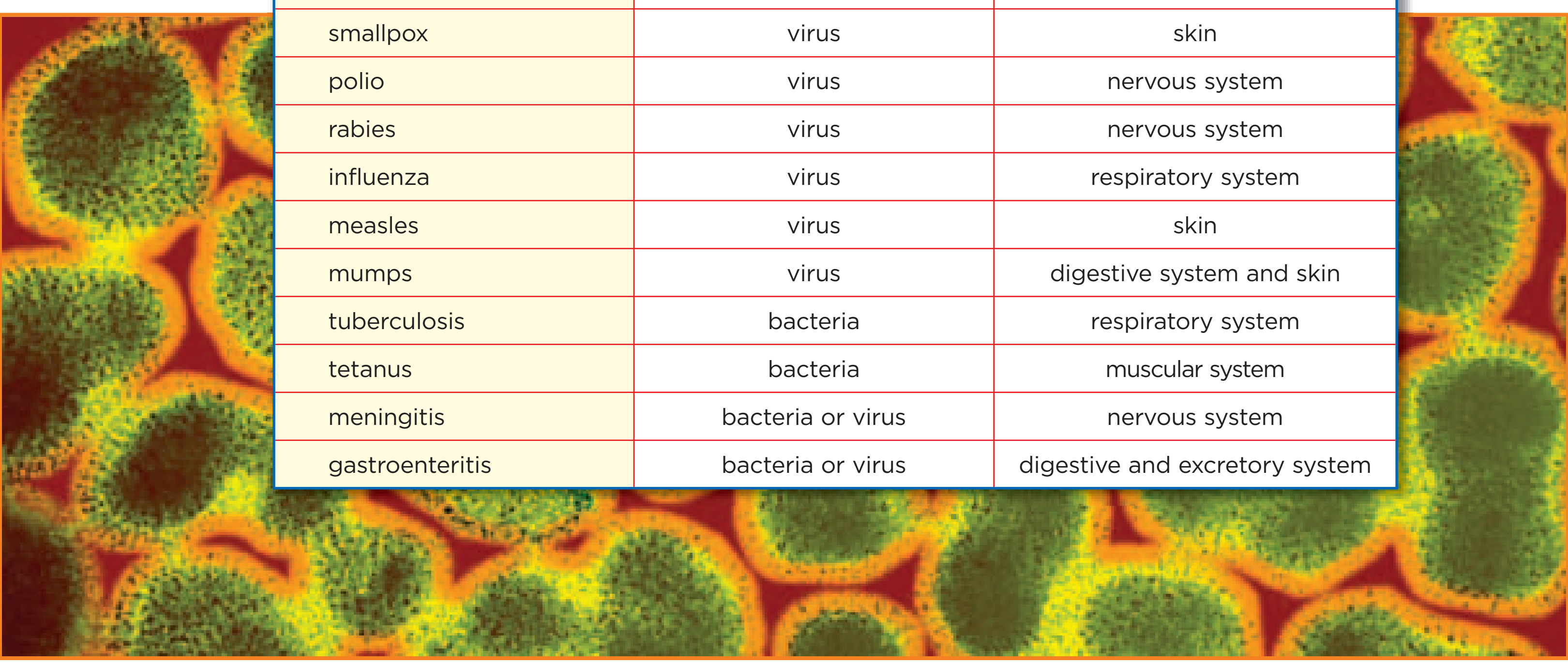
A disease is anything that interferes with the normal functions of the body. Some diseases are caused by harmful materials in the environment. Many diseases, however, are caused by microscopic organisms and can be passed from person to person. This type of disease is called a communicable or infectious disease.

Disease-causing organisms are called pathogens. Pathogens include many types of bacteria, as well as viruses. Diseases caused by pathogens are also called communicable diseases, because they can be passed from one person to another. Pathogens must enter the body before they can cause an illness. Once these invaders enter the body, the immune system works very hard to fight them off.



Human Infectious Diseases

Disease	Caused by	Organ System Affected
common cold	virus	respiratory system
chicken pox	virus	skin
smallpox	virus	skin
polio	virus	nervous system
rabies	virus	nervous system
influenza	virus	respiratory system
measles	virus	skin
mumps	virus	digestive system and skin
tuberculosis	bacteria	respiratory system
tetanus	bacteria	muscular system
meningitis	bacteria or virus	nervous system
gastroenteritis	bacteria or virus	digestive and excretory system



Human Body Systems

The Nervous System

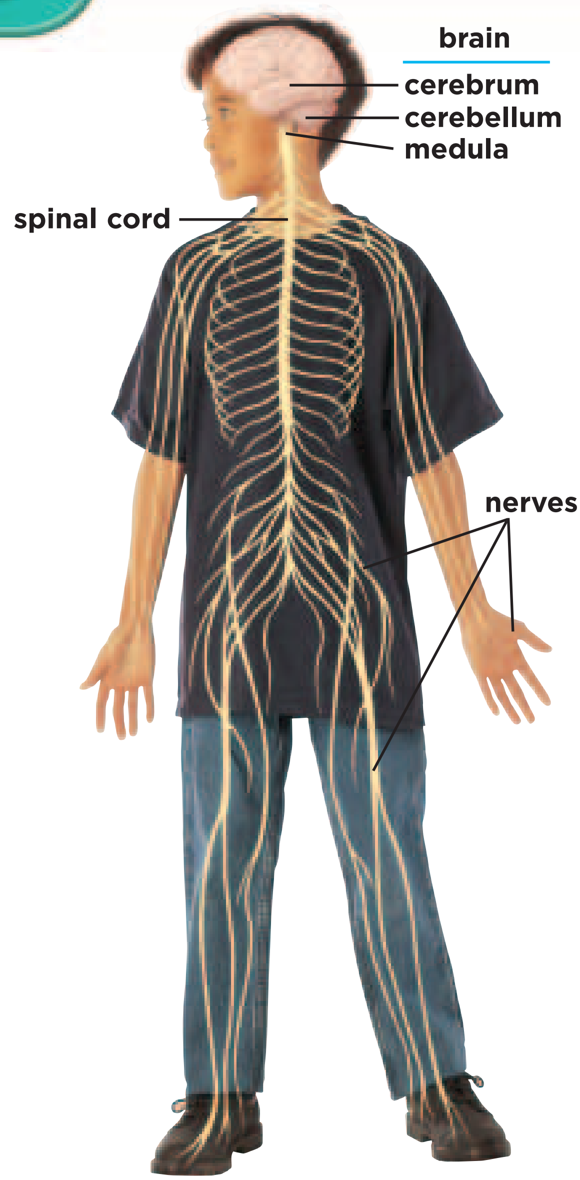
The nervous system has two parts. The brain and the spinal cord make up the central nervous system. All other nerves make up the outer, or peripheral, part of the nervous system.

The largest part of the human brain is the cerebrum. A deep groove separates the right half, or hemisphere, of the cerebrum from the left half. Both the right and left hemispheres of the cerebrum contain control centers for the senses. The cerebrum is the part of the brain where thought occurs.

The cerebellum lies below the cerebrum. It coordinates the skeletal muscles so they work smoothly together. It also helps in keeping balance.

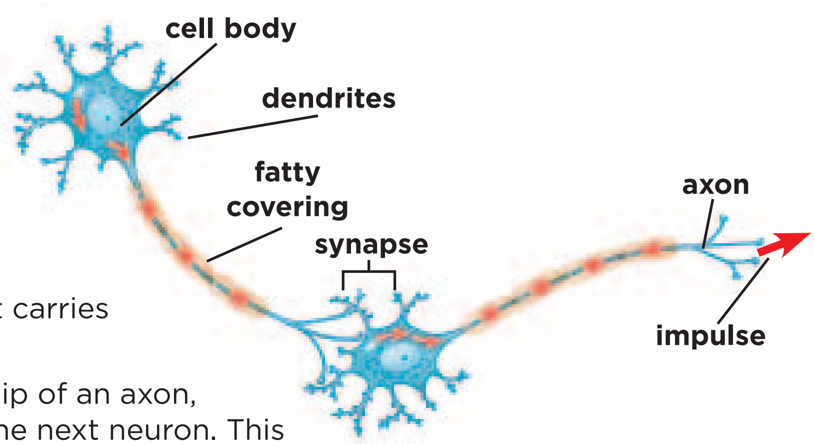
The brain stem connects to the spinal cord. The lowest part of the brain stem is the medulla. It controls heartbeat, breathing, blood pressure, and the muscles in the digestive system.

The spinal cord is a thick band of nerves that carries messages to and from the brain. Nerves branch off from your spinal cord to all parts of your body. The spinal cord also controls reflexes. A reflex is a quick reaction that occurs without waiting for a message to and from the brain. For example, if you touch something hot, you pull your hand away without thinking about it.



Parts of a Neuron

The nerves in the nervous system are made up of nerve cells called neurons. Each neuron has three main parts—a cell body, dendrites, and an axon. Dendrites are branching nerve fibers that carry impulses, or electrical signals, toward the cell body. An axon is a nerve fiber that carries impulses away from the cell body.



When an impulse reaches the tip of an axon, it must cross a tiny gap to reach the next neuron. This gap between neurons is called a synapse.

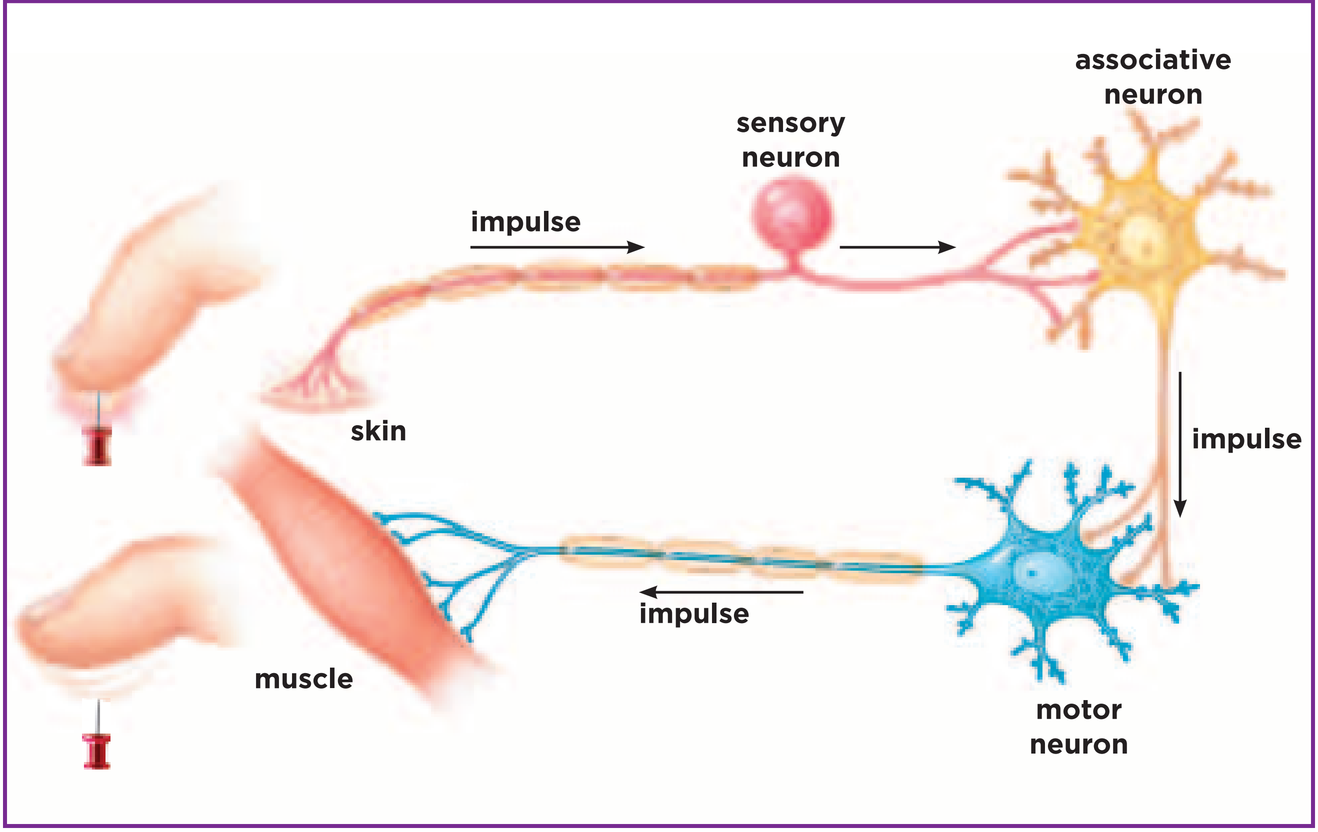
Stimulus and Response

The nervous system, the skeletal system, and the muscular system work together to help you adjust to your surroundings. Anything in the environment that requires your body to adjust is called a stimulus (plural: stimuli). A reaction to a stimulus is called a response.

As you learned, nerve cells are called neurons. There are three kinds of neurons: sensory, associative, and motor. Each kind does a different job to help your body respond to stimuli. Sensory neurons receive stimuli from your body and the environment. Associative neurons connect the sensory neurons to the motor neurons. Motor neurons carry signals from the central nervous system to the organs and glands.

In addition to responding to external stimuli, your body also responds to internal changes. Your body regulates its internal environment to maintain a stable condition for survival. This is called a steady-state condition.

Nerve Response



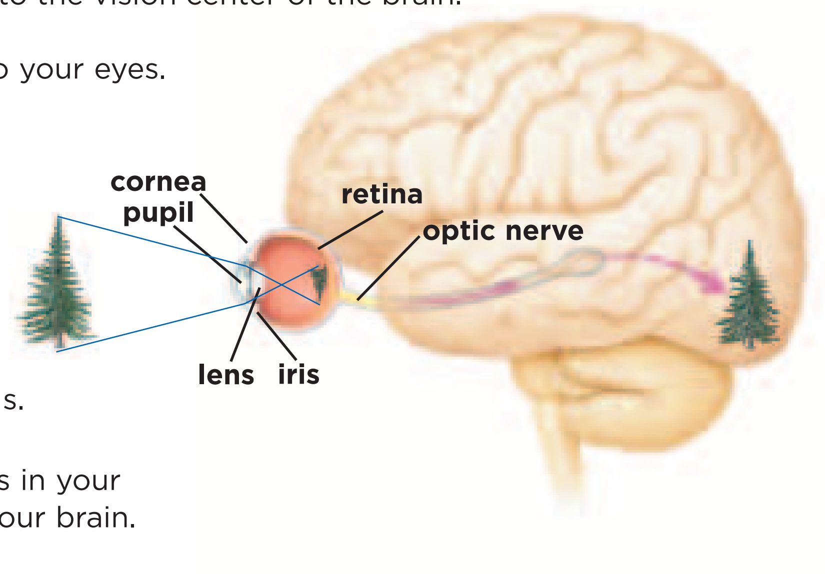
Human Body Systems

The Senses

Sense of Sight

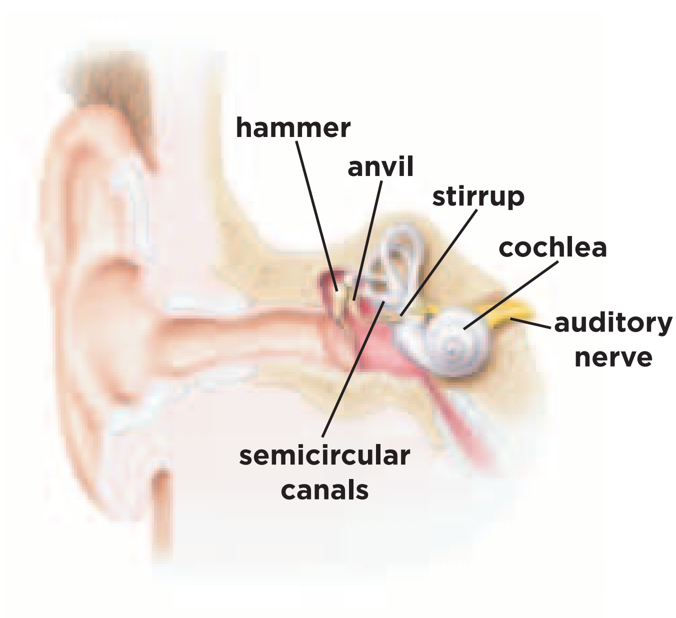
Light reflected from an object enters your eye and falls on the retina. Receptor cells change the light into electrical signals, or impulses. These impulses travel along the optic nerve to the vision center of the brain.

1. Light reflects off the tree and into your eyes.
2. The light passes through your cornea and the pupil in your iris.
3. The lens bends the light so that it hits your retina.
4. Receptor cells on your retina change the light into electrical signals.
5. The impulses travel along neurons in your optic nerve to the seeing center of your brain.



Sense of Hearing

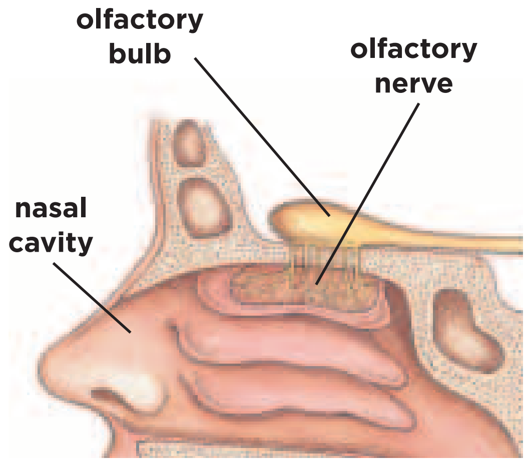
Sound waves enter your ear and cause the eardrum to vibrate. Receptor cells in your ear change the sound waves into impulses that travel along the auditory nerve to the hearing center of the brain.



1. Your outer ear collects sound waves.
2. They travel down your ear canal.
3. The eardrum vibrates.
4. Three tiny ear bones vibrate.
5. The cochlea vibrates.
6. Receptor cells inside your cochlea change.
7. The impulses travel along your auditory nerve to the brain's hearing center.

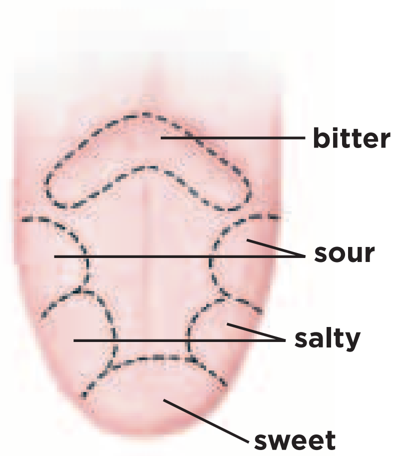
Sense of Smell

The sense of smell is really the ability to detect chemicals in the air. When you breathe, chemicals dissolve in mucus in the upper part of your nose or nasal cavity. When the chemicals come in contact with receptor cells, the cells send impulses along the olfactory nerve to the smelling center of the brain.



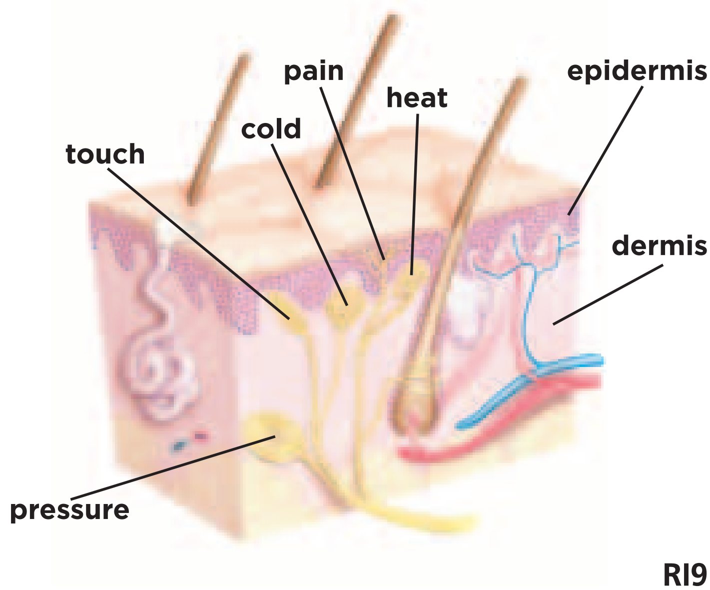
Sense of Taste

When you eat, chemicals in the food dissolve in saliva. Saliva carries the chemical to taste buds on the tongue. Inside each taste bud are receptors that can sense the four main tastes—sweet, sour, salty, and bitter. The receptors send impulses along a nerve to the taste center of the brain. The brain identifies the taste of the food, which is usually a combination of the four main taste categories.



Sense of Touch

Receptor cells in the skin help a person tell hot from cold, wet from dry. These can also tell the light touch of a feather or the pressure of stepping on a stone. Each receptor cell sends impulses along sensory nerves to the spinal cord. The spinal cord then sends the impulses to the touch center of the brain.

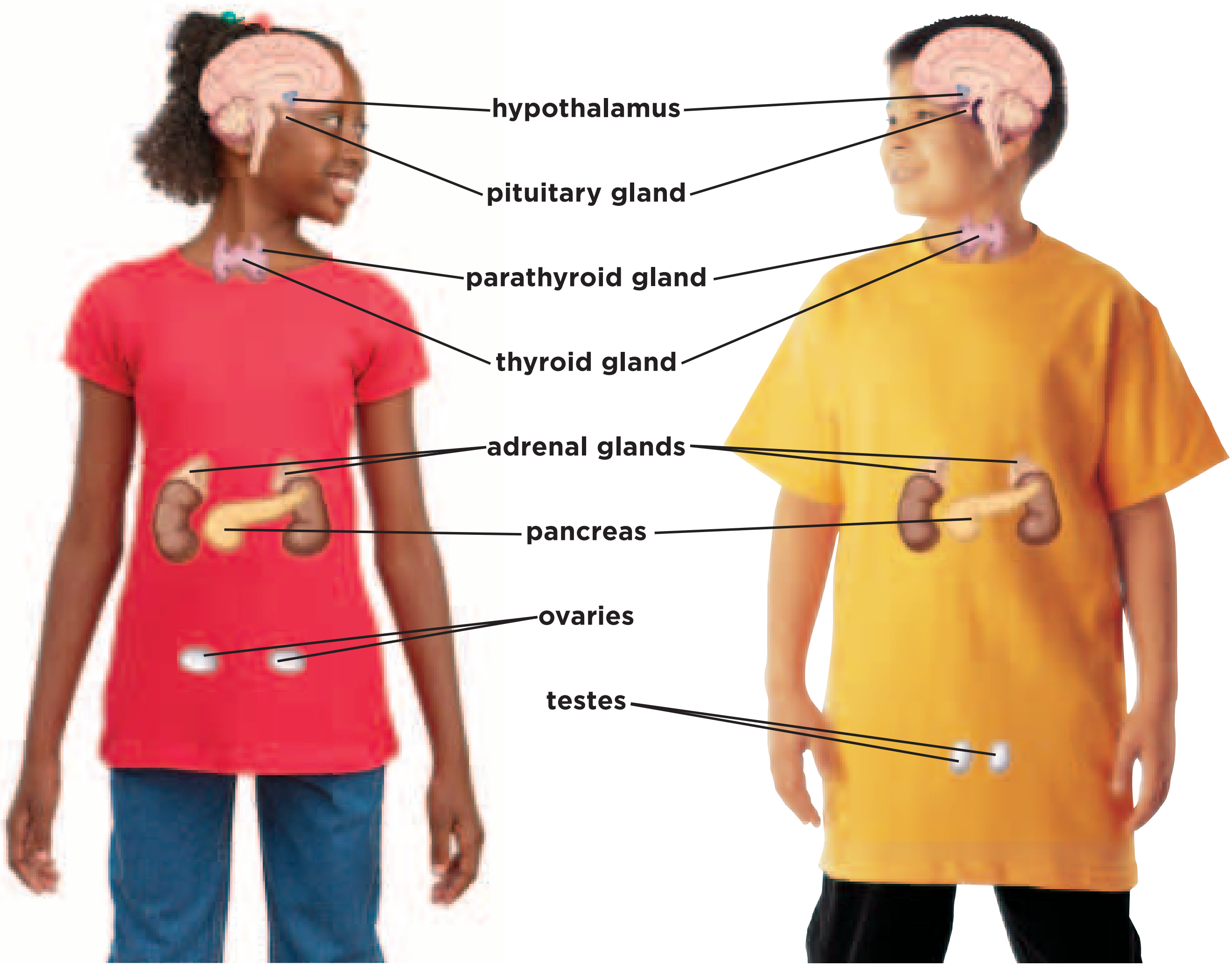


The Endocrine System

Hormones are chemicals that control body functions. An organ that produces hormones is called an endocrine gland.

The endocrine glands are scattered around the body. Each gland makes one or more hormones. Every hormone seeks out a target organ or organ system, the place in the body where the hormone acts. Changing levels of different hormones communicate important messages to target organs and organ systems.

The endocrine glands help to maintain a constant healthy condition in your body. These glands can turn the production of hormones on or off whenever your body produces too little or too much of a particular hormone.



FOLDABLES™

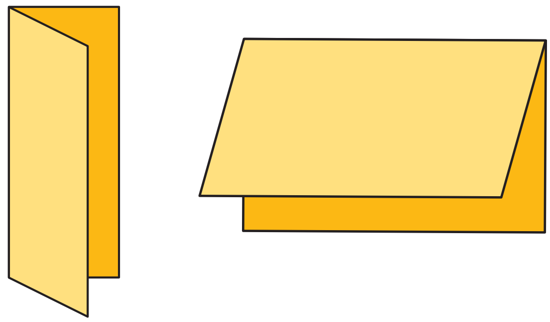
by Dinah Zike

Folding Instructions

The following pages offer step-by-step instructions to make the Foldables study guides.

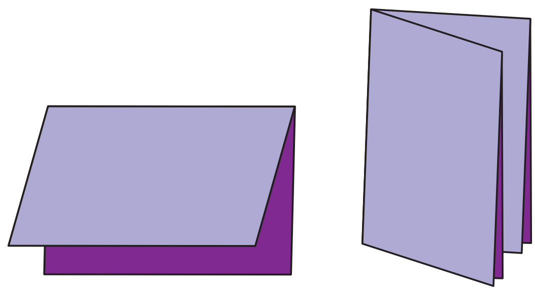
Half-Book

1. Fold a sheet of paper ($8\frac{1}{2}$" × 11") in half.
2. This book can be folded vertically like a hot dog, or . . .
3. . . . it can be folded horizontally like a hamburger



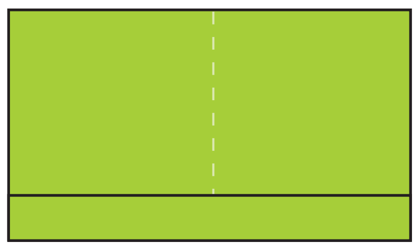
Folded Book

1. Make a Half-Book.
2. Fold in half again like a hamburger. This makes a ready-made cover and two small pages inside for recording information.



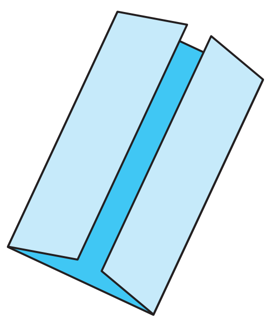
Pocket Book

1. Fold a sheet of paper ($8\frac{1}{2}$" × 11") in half like a hamburger.
2. Open the folded paper, and fold one of the long sides up 2 inches to form a pocket. Refold along the hamburger fold so that the newly formed pockets are on the inside.
3. Glue the outer edges of the 2-inch fold with a small amount of glue.



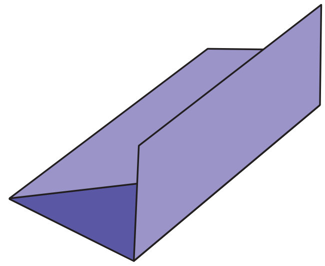
Shutter Fold

1. Begin as if you were going to make a hamburger, but instead of creasing the paper, pinch it to show the midpoint.
2. Fold the outer edges of the paper to meet at the pinch, or midpoint, forming a Shutter Fold.



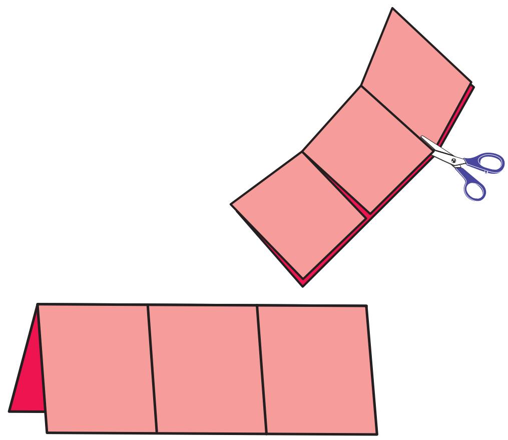
Trifold Book

1. Fold a sheet of paper ($8\frac{1}{2}$" × 11") into thirds.
2. Use this book as is, or cut into shapes.



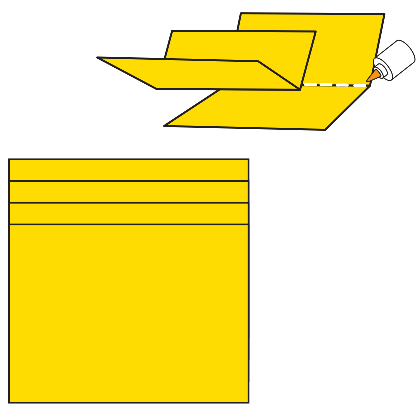
Three-Tab Book

1. Fold a sheet of paper like a hot dog.
2. With the paper horizontal and the fold of the hot dog up, fold the right side toward the center, trying to cover one half of the paper.
3. Fold the left side over the right side to make a book with three folds.
4. Open the folded book. Place one hand between the two thicknesses of paper, and cut up the two valleys on one side only. This will create three tabs.



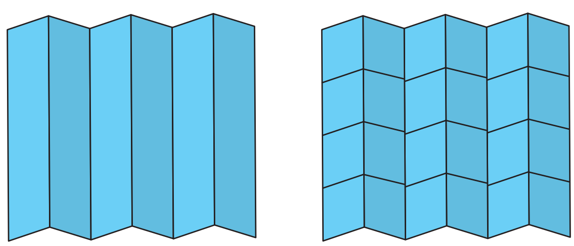
Layered-Look Book

1. Stack two sheets of paper ($8\frac{1}{2}$" × 11") so that the back sheet is 1 inch higher than the front sheet.
2. Bring the bottoms of both sheets upward, and align the edges so that all of the layers or tabs are the same distance apart.
3. When all the tabs are an equal distance apart, fold the papers and crease well.
4. Open the papers, and glue them together along the valley, or inner center fold, or staple them along the mountain.



Folded Table or Chart

1. Fold the number of vertical columns needed to make the table or chart.
2. Fold the horizontal rows needed to make the table or chart.
3. Label the rows and columns.



Glossary

Use this glossary to learn how to pronounce and understand the meanings of Science Words used in this book. The page number at the end of each definition tells you where to find the word in this book.

A

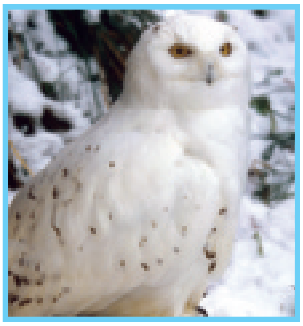
abiotic factor (ā′bī·ot′ik fak′tər) The effects on the ecosystem that are a result of the nonliving parts of that ecosystem. (p. 187)

acceleration (ak·sel′ə·rā′shən) A change in the velocity of an object over time. (p. 593)

acid (as′id) A substance that has a pH below 7, tastes sour, and turns blue litmus paper pink or red. (p. 554)

acid rain (as′id rān) Acid that is formed when the sulfur and nitrogen gases produced by burning fossil fuels combine with water vapor in the air and then fall to Earth as rain. (p. 345)

acquired trait (ə·kwīrd′ trāt) A trait influenced by experience or the environment. (p. 141)



active transport (ak′tiv trans′pôrt) The movement of materials through a cell membrane, which requires energy. (p. 102)

adaptation (a′dəp·tā′shən) A change in an organism that helps it survive or reproduce in its environment. (p. 70)

aftershock (af′tər·shok′) Smaller earthquakes that follow a major earthquake. (p. 270)

air mass (âr mas) A large region of the atmosphere in which the air has similar properties throughout. (p. 400)

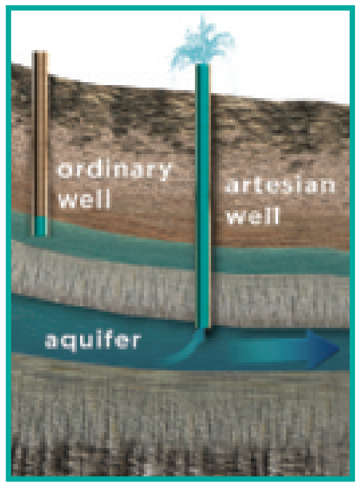
air pressure (âr presh′ər) The force exerted on a given area by the weight of the air above it. (p. 374)

alloy (al′oi) A mixture of one or more metals with other solids. (p. 528)

amplitude (am′pli·tüd′) The height of a wave from its trough or crest to its midpoint. (p. 648)

antibiotic (an′tē·bī·ot′ik) A medicine that kills disease–causing bacteria without harming the host. (p. 176)

aquifer (ak′wə·fər) An underground area of rock and soil filled with water that is squeezed between tightly packed layers of rock. (p. 333)



Pronunciation Key

The following symbols are used throughout the Macmillan/McGraw-Hill Science Glossaries.

a	**a**t	e	**e**nd	o	h**o**t	u	**u**p	hw	**wh**ite	ə	**a**bout
ā	**a**pe	ē	m**e**	ō	**o**ld	ū	**u**se	ng	so**ng**		tak**e**n
ä	f**a**r	i	**i**t	ôr	f**or**k	ü	r**u**le	th	**th**in		penc**i**l
âr	**c**are	ī	**i**ce	oi	**oi**l	u̇	p**u**ll	th	**th**is		lem**o**n
ô	l**a**w	îr	p**ier**ce	ou	**ou**t	ûr	t**ur**n	zh	mea**s**ure		circ**u**s

′ = primary accent; shows which syllable takes the main stress, such as **kil** in **kilogram** (kil′ ə gram′).

′ = secondary accent; shows which syllables take lighter stresses, such as **gram** in **kilogram**.

asteroid (as′tə·roid′) A rocky or metallic object that orbits the Sun. (p. 448)

astronomy (ə·stron′ə·mē) The study of the universe. (p. 422)

atmosphere (at′məs·fîr′) The layer of gases that surround Earth. (p. 370)

atom (at′əm) The smallest particle of an element that still has the same chemical properties of the element. (p. 500)

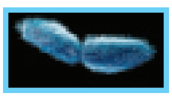
atomic number (ə·tom′ik num′bər) The number of protons in an atom of an element. (p. 501)

B

background radiation (bak′ground′ rā′dē·ā′shən) Radiation that is left over from the beginning moments of the universe and is coming from all directions in space. (p. 473)

base (bās) A substance that has a pH above 7, tastes bitter, and turns red litmus paper blue. (p. 554)

big bang (big bang) The beginning moment when the universe was very hot and dense, resulting in a tremendous "explosion." (p. 472)



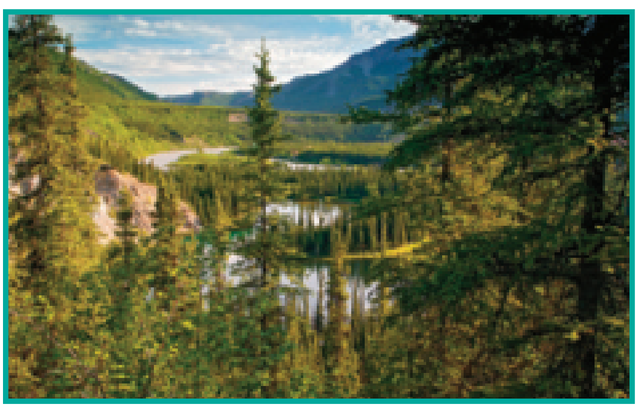
binary fission (bī′nə·rē fish′ən) Asexual reproduction in which an organism divides in two. (p. 124)

biodegradable (bī′ō·di·grā′də· bəl) The ability to break down naturally over time. (p. 346)

biodiversity (bī′ō·di·vûr′si·tē) The wide variety of life on Earth. (p. 225)

biomass (bī′ō·mas′) Plant and animal wastes that can be processed to make fuel. (p. 354)

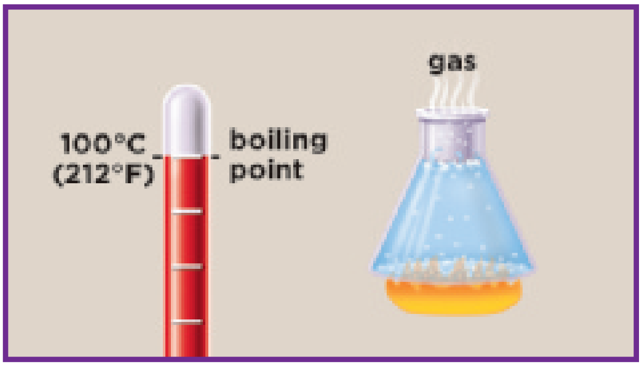
biome (bī′ōm) A region that has a particular climate and contains certain types of plants and animals. (p. 208)



biotic factor (bī·ot′ik fak′tər) The effects on an ecosystem that are a result of the living things in that ecosystem. (p. 187)

black hole (blak hōl) An object whose gravity is so strong that even light cannot escape from it. (p. 463)

boiling point (boil′ing point) The temperature at which a liquid becomes a gas. (p. 515)



budding (bud′ing) A form of asexual reproduction used by some fungi, such as yeasts. (p. 125)

C

calorie (kal′ə·rē) The amount of energy needed to raise the temperature of 1 gram of water by 1°C. One thousand calories equals one food Calorie.(p. 682)

camouflage (kam′ə·fläzh′) An appearance that makes something look like its surroundings. (p. 72)

carrier (kar′ē·ər) An organism that has inherited the gene for a specific trait but does not express that trait. (p. 155)

cartilage (kär′tə·lij) A soft, bone-like material that is part of the endoskeleton of an animal. (p. 49)

cell (sel) The basic unit of life and the smallest part of a living thing that is capable of life. (p. 86)

cell cycle (sel sī′kəl) The ongoing process of growth, division, and replacement within cells. (p. 108)

cellular respiration (sel′yə·lər res′pə·rā′shən) The process in which organisms convert the energy in molecules of glucose into usable energy. (p. 101)

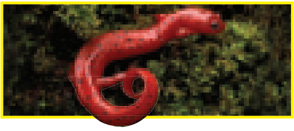
chain reaction (chān rē·ak′shən) A reaction in which the products keep the reaction going. (p. 574)

chemical bond (kəm′i·kəl bond) Forces that hold atoms together. (p. 542)

chemical change (kəm′i·kəl chānj) A change in matter that produces a new substance with different properties from the original. (p. 542)

chemical equation (kəm′i·kəl i·kwā′zhən) A way to represent a chemical reaction by using symbols for the amounts of reactants and products in the change. (p. 543)

chemical property (kəm′i·kəl prop′ər·tē) The way a substance reacts with other substances. (p. 552)



chordate (kôr′dāt) An animal with a nerve cord running down its back. (p. 19)

chromosome (krō′mə·sōm′) One of the threadlike structures in the nucleus of a cell that stores detailed directions for the cell's activities. (p. 152)

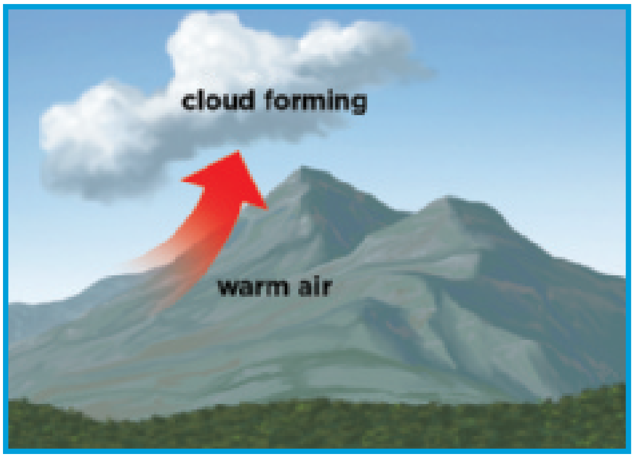
circulation (sûr′kyə·lā′shən) The movement of important materials such as oxygen, glucose, and wastes throughout the body. (p. 62)

climate (klī′mət) The average weather pattern of a region over time. (p. 208)

climax community (klī′maks kə·mū′ni·tē) The final stage of succession when a community is stabilized and succession is slow or at a stop. (p. 227)

clone (clōn) A living organism that receives all of its DNA from one parent and is genetically identical to that parent. (p. 165)

clouds (cloudz) Collections of water vapor in the atmosphere which are described as high, middle, or low, depending on the altitude at which they form. Examples include stratus clouds, cumulus clouds, and cirrus clouds. (p. 384)



cold-blooded (kōld′·blud′əd) A type of animal whose body temperature changes with the temperature of its surroundings. (p. 62)

colloid (kol′oid) A stable homogeneous mixture in which very small, fine particles of one material are scattered through another material, blocking the passage of light without settling out. (p. 527)

comet (kom′it) A sphere of ice and rock that orbits the Sun. (p. 452)

community (kə mū′ni tē) All the populations that live together in the same place. (p. 187)

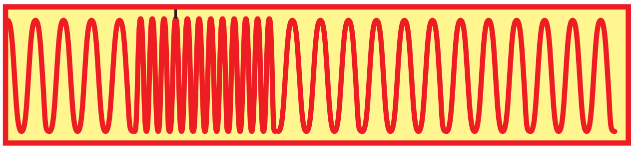
competition (kom′pə·tish′ən) The struggle among organisms for resources in an ecosystem. (p. 192)

compound (kom′pound) A new substance formed by the chemical combination of two or more elements. (p. 90)

compound machine (kom′pound mə·shēn′) A device that is a combination of two or more simple machines. (p. 636)

compression (kəm·presh′ən) An area where particles in a medium are pushed together by a wave's energy. (p. 647)

compressional wave (kəm·presh′ən·əl wāv) A wave that moves matter back and forth as it travels through a medium. (p. 646)



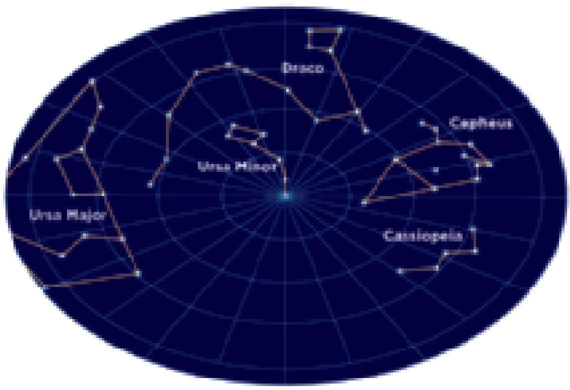
concave (kon′cāv′) A surface that curves inward. (p. 663)

condensation (kon′den·sā′shən) The changing of a gas into a liquid as heat is removed. (p. 382)

conduction (kən·duk′shən) The movement of energy such as heat or electricity through direct contact. (p. 684)

conjugation (kon′jə·gā′shən) A form of sexual reproduction in which organisms fuse, or attach themselves to each other, and exchange genetic information. (p. 124)

constellation (kon′stə·lā′shən) A group of stars that appears to form a pattern. (p. 458)



consumer (kən·sü′mər) An organism that does not make its own food. (p. 199)

continental drift (kon′tə·nen′təl drift) The slow movement of the continents over eons. (p. 256)

convection (kən·vek′shən) The transfer of energy by the flow of a liquid or a gas. (p. 685)

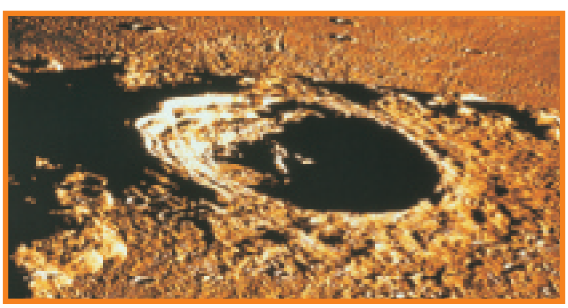
convection cell (kən·vek′shən sel) A circular pattern of rising air, sinking air, and winds. (p. 374)

convex (kon·veks′) A surface that curves outward. (p. 663)

core (kôr) The central part of Earth. (p. 250)

Coriolis effect (kôr′ē·ō′ləs i·fekt′) The shift in winds to the right or left caused by Earth's rotation. (p. 376)

crater (krā′tər) A depression in the Moon's surface formed by the impact of objects from space. (p. 435)



crust (krust) Earth's solid, rocky surface. (p. 250)

crystal (kris′təl) A solid that has a structure arranged in orderly, fixed patterns. (p. 315)

current (kûr′ənt) 1. The movement of the oceans' surface water that is caused by global winds. (p. 410) 2. In electricity, current is the flow of electrons moving through a circuit. (p. 698)

D

decomposer (dē′kəm·pō′zər) Any organism that breaks down dead plants and animals into simpler materials that enrich the soil. (p. 199)

density (den′si·tē) The measurement of how much mass fits within a certain volume. (p. 490)

deposition (dē′pə·zish′ən) The dropping off of eroded particles in different locations from where they were picked up. (p. 286)

diffraction grating (di·frak′shən grāt′ing) Glass or polished metal with many thin, parallel slits that refract light when it passes through. (p. 673)

diffusion (di·fyu′zhən) The movement of molecules from areas of higher concentration to areas of lower concentration. (p. 60)

digestion (di·jest′chən) The process in which digested food is broken down into molecules that are usable by cells. (p. 58)

distance (dis′təns) The length between two places. (p. 590)

distillation (dis′tə·lā′shən) The process by which the parts of a mixture are separated by vaporization and condensation. (p. 532)

DNA (dē en ā) Deoxyribonucleic acid, a long, complex molecule that controls heredity. (p 162)

dominant trait (dom′ə·nənt trāt) The form of an inherited trait that masks the other form of the same trait. (p. 143)

Doppler effect (dop′lər i·fekt′) The change in a sound's pitch if its source or recipient is in motion. (p. 652)

E

ecosystem (ē′kō·sis′təm) The living and nonliving things in an area interacting with each other. (p. 186)

efficiency (i·fish′ən·sē) The ratio between the work done by a machine and the work put into it. (p. 636)

egg (eg) The female sex cell. (p. 38)

electricity (i·lek·tris′i·tē) A flow of electrons, particles having negative electrical charges. (p. 694)

electromagnet (i·lek′trō·mag′nit) A device that is magnetized by current electricity. (p. 703)

electromagnetic spectrum (i·lek′trō·mag·net′ik spek′trəm) The full range of wavelengths, arranged from long waves with the lowest amount of energy to short waves with the highest amount of energy. (p. 674)

electron (i·lek′tron) A particle with a negative electrical charge. (p. 501)

element (el′ə·mənt) A pure substance that cannot be broken down into a simpler substance and is made of only one type of atom. (p. 90)

elevation (el′ə·vā′shən) The height of a place above sea level. (p. 249)

emulsion (i·mul′shən) A stable homogeneous mixture of very small droplets suspended, rather than dissolved, in a liquid. (p. 527)

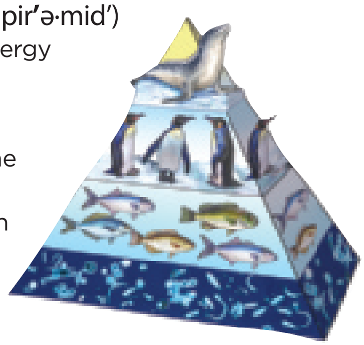
endangered (en·dān′jərd) A species whose numbers have been so reduced that the species is in danger of extinction. (p. 224)

endoskeleton (en′dō·skel′i·tən) An inner supporting structure of bone. (p. 49)

endothermic (en′dō·thûr′mik) A chemical reaction that absorbs heat energy. (p. 546)

energy (en′ər·jē) The ability to do work. (p. 618)

energy pyramid (en′ər·jē pir′ə·mid′) A model that shows how energy flows through a food chain. (p. 202)



epicenter (e′pi·sen′tər) The location on the surface of Earth above the focus of an earthquake. (p. 271)

era (îr′ə) Long stretches of time used to measure Earth's geological history. (p. 302)

erosion (i·rō′zhən) The picking up and removal of rock pieces and other particles. (p. 286)

estuary (es′chü·er′ē) Water ecosystems that are located where rivers flow into oceans. (p. 215)

evaporation (i·vap′ə·rā′shən) The slow changing of a liquid to a gas when particles vaporize at the water's surface. (p. 382)

excretion (ek·skrē′shən) The removal of wastes from the body. (p. 58)

exoskeleton (ek′sō·skel′i·tən) A hard covering that protects an invertebrate's body. (p. 52)

exothermic (ek′sō·thûr′mik) A chemical reaction that gives off heat energy. (p. 546)

expansion redshift (ek·span′shən red′shift′) The absorption lines that result in longer (redder) wavelengths from galaxies moving away from each other as space expands. (p. 472)

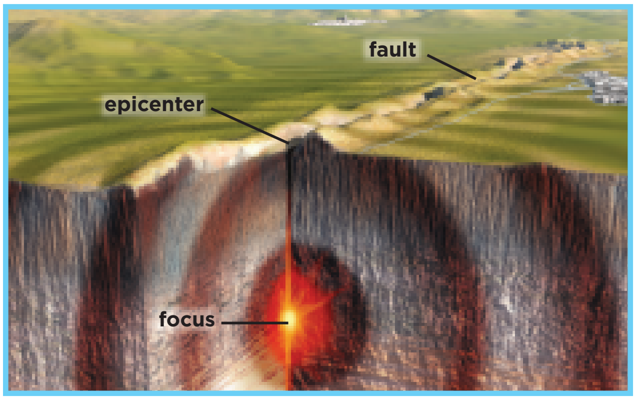
experiment (ek·sper′ə·ment′) To perform a test to support or disprove a hypothesis. (p. 656)

extinct (ek·stingkt′) Said of a species that no longer exists in the wild or in captivity. (p. 224)

F

fault (fôlt) A break, or crack, in the rocks of the lithosphere along which movements can take place. (p. 268)

fertilization (fûr′ti·lə·zā′shən) The joining of a sperm cell with an egg cell to make one new cell, a fertilized egg. (p. 115)



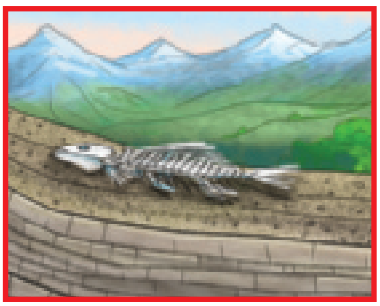
focus (fō′kəs) The point below the surface of Earth where an earthquake begins. (p. 270)

food chain (füd chān) A model of how the energy in food is passed from organism to organism in an ecosystem. (p. 198)

food web (füd web) A model of overlapping food chains in an ecosystem. (p. 200)

force (fôrs) A push or pull exerted by one object on another, possibly causing a change in motion. (p. 594)

fossil (fos′əl) Any trace, imprint, or remains of a living thing preserved in Earth's crust. (p. 300)



freezing point (frēz′ing point) The temperature at which a liquid changes to a solid. (p. 514)

frequency (frē′kwən·sē) A measure of how many wave crests or troughs pass a given point in one unit of time. (p. 648)

friction (frik′shən) A force that opposes the motion of an object in contact with a surface. (p. 596)

front (frunt) The boundary between two air masses. Examples include cold fronts, warm fronts, and occluded fronts. (p. 400)

fulcrum (fu̇l′krəm) The pivot point in a lever. (p. 630)

G

galaxy (gal′ək·sē′) A mass of billions of stars clustered together in a group. (p. 470)

gas (gas) Matter that has no definite shape and does not take up a definite amount of space. (p. 489)

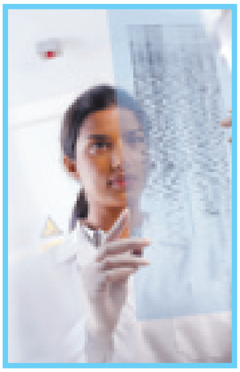
gene (jēn) The portion of a chromosome that controls a particular inherited trait. (p. 144)

generator (jen′ə·rā′tər) A device that converts mechanical energy—supplied by a hand crank, turbine, or motor—into electricity. (p. 704)

gene splicing (jēn splīs′ing) Adding the genes from one organism to the genes of another organism. (p. 165)

genetic disorder (jə·net′ik dis·ôr′dər) A condition caused by a mutation, or change, in a gene or set of genes. (p. 156)

genetic engineering (jə·net′ik en′jə·nîr′ing) A way of intentionally changing the DNA sequence of a gene so that the gene will produce a particular trait. (p. 164)



geneticist (je·net′ə·sist) A scientist who studies how heredity works. (p. 164)

genetics (jə·net′iks) The study of heredity. (p. 141)

genome (jē′nōm) All of the DNA that makes up an organism. (p. 163)

genotype (jen′ə·tīp′) The genes that are inherited by an organism for a particular trait. (p. 153)

geothermal energy (jē′ō·thûr′məl en′ər·jē) Heat from below Earth's surface. (p. 354)

gravity (grav′i·tē) The force of attraction among all objects. (p. 440)

H

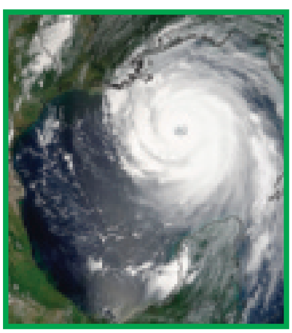
half-life (haf′·līf′) The time it takes for half the mass of a radioactive element to decay into other elements. (p. 302)

heat (hēt) The flow of thermal energy from warmer to cooler objects. (p. 682)

heredity (hə·red′i·tē) The passing of inherited traits from parents to offspring. (p. 140)

humidity (hū·mid′i·tē) A measurement of the amount of water vapor in the air. (p. 383)

humus (hū′məs) Decayed plants and animals in the soil. (p. 290)



hurricane (hûr′i·kān′) A large, swirling storm with low pressure at the center. (p. 390)

hybrid (hī′brid) An organism produced by the crossing of parents that have two different forms of the same trait. (p. 142)

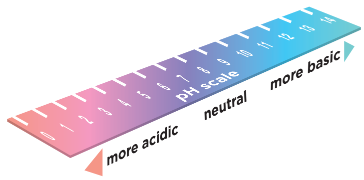
hydroelectricity (hī′drō·i·lek·tris′i·tē) The use of running water to generate electricity. (p. 355)

hydrosphere (hī′drə·sfîr′) The part of Earth that contains water. (p. 244)

I

igneous rock (ig′nē′əs rok) Rock that forms when melted rock in the form of lava or magma cools and turns into a solid. (p. 319)

inclined plane (in·klīnd′ plān) A straight, slanted surface that can multiply an effort force. (p. 634)



indicator (in′di·kā′tər) A material that changes color in the presence of acids or bases. (p. 554)

induced charge (in·düst′ chärj) A charge that forms on an area of a neutral object when a charged object is placed near it. (p. 696)

inertia (i·nûr′shə) The tendency of a moving object to stay in motion at the same speed and in the same direction. (p. 447)

infer (in·fûr′) To form an idea from facts or observations. (p. 122)

inherited trait (in·her′i·təd trāt) A characteristic that is passed from parent to offspring. (p. 140)

insolation (in′sə·lā′shən) The amount of the Sun's energy that reaches Earth at a given time and place. (p. 372)

instinct (in′stingkt′) An inherited behavior, one that is not learned but is done automatically. (p. 74)

insulation (in′sə·lā′shən) A material that does not conduct heat well. (p. 73) 2. Material that restricts the flow of electricity. (p. 492)

International Date Line (in′tər·nash′ə·nəl dāt līn) The 180° line of longitude. Going west across this line adds one day to the date; going east subtracts a day. (p. 425)

interpret data (in·tûr′prit dāt′ə) To use the information that has been gathered to answer questions or solve a problem. (p. 378)

invertebrate (in·vûr′tə·b rāt) An animal without a backbone. (p. 50)

isobar (ī′sə·bär′) A line on a weather map that connects places with equal air pressure. (p. 398)

K

kinetic energy (ki·net′ik en′ûr·jē) Energy of motion. (p. 618)

kingdom (king′dəm) The largest and most general classification of living things. (p. 24)

L

land breeze (land brēz) Wind that blows from land to sea. (p. 375)

landfill (land′fil′) A specially designed place where garbage is deposited into a lined pit. (p. 346)

latitude (lat′i·tüd′) The location north or south of the equator. (p. 248)

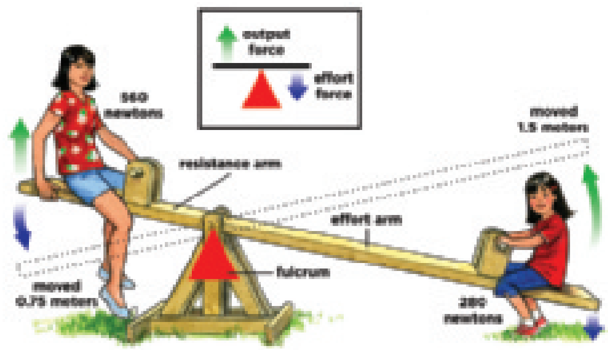
law of conservation of energy (lô uv kon′sər·vā′shən uv en′ûr·jē) Energy may change form but it cannot be created or destroyed. (p. 619)

law of conservation of mass (lô uv kon′sər·vā′shən uv mas) A physical law that states "matter is not created or destroyed during a chemical reaction." (p. 543)

law of reflection (lô uv ri·flek′shən) The angle between an incoming light ray and a surface is equal to the angle between the reflected light ray and the same surface. (p. 662)

lens (lenz) A piece of transparent material with at least one curved surface. (p. 661)

lever (lev′ər) A simple machine consisting of a rigid bar and a pivot point. (p. 630)



light-year (līt′·yîr′) The distance that light travels in one year. (p. 459)

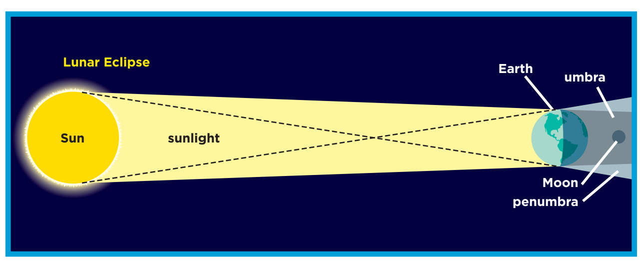
limiting factor (lim′i·ting fak′tər) Condition that controls the size or growth of a population. (p. 222)

liquid (lik′wid) Matter that takes up a definite amount of space but has no definite shape. (p. 489)

lithosphere (lith′ə·sfîr′) The crust and the rigid part of Earth's mantle. (p. 250)

longitude (lon′ji·tüd′) The location east or west of the prime meridian. (p. 248)

lunar eclipse (lü′nər i·klips′) A situation that occurs when the Sun, the Moon, and Earth are in a straight line and Earth's shadow falls across the Moon. (p. 438)

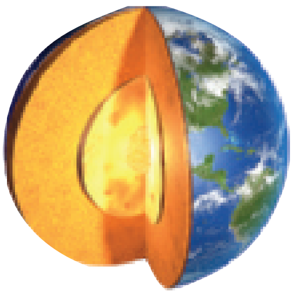


M

magma (mag′mə) Hot, fluid rock below Earth's surface. (p. 257)

magnetic field (mag·net′ik fēld) An invisible area where the forces of magnetic attraction or repulsion can be detected. (p. 702)

magnitude (mag′ni·tüd′) The measure of energy released by an earthquake. (p. 274)



mantle (man′təl) The layer of Earth beneath the crust. (p. 250)

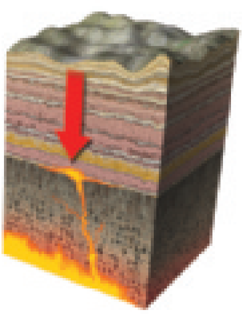
mass (mas) The amount of matter in an object. (p. 488)

mass wasting (mas wās′ting) Erosion caused by Earth's gravity pulling materials from high places to low places. (p. 287)

mechanical advantage (mi·kan′i·kəl ad·van′tij) The number of times a simple machine multiplies an effort force. (p. 629)

meiosis (mī·ō′sis) The special kind of cell division in which sex cells are produced with half as many chromosomes as in other cells. (p. 112)

melting point (melt′ing point) The temperature at which a solid melts to become a liquid. (p. 514)



metamorphic rock (met′ə·môr′fik rok) A rock that forms from other rocks which have changed from heat, pressure, or a chemical reaction. (p. 321)

meteor (mē′tē·ər) A meteoroid that enters Earth's atmosphere and burns with a streak of light. (p. 452)

meteorite (mē′tē·ə·rīt) Any part of a meteoroid that reaches Earth's surface. (p.452)

meteoroid (mē′tē·ə·roid) A small, rocky object that orbits the Sun in both the inner and outer regions of the solar system. (p. 452)

microbe (mī′krōb) An organism so small that it can be seen only with a microscope. (p. 122)

microorganism (mī′krō·ôr′gə·niz·əm) An organism that is not visible to the unaided eye. (p. 122)

migrate (mī′grat) To move from one place to another. (p. 76)

Milky Way (mil′kē wā) The medium-sized spiral galaxy that is our home galaxy. (p. 471)

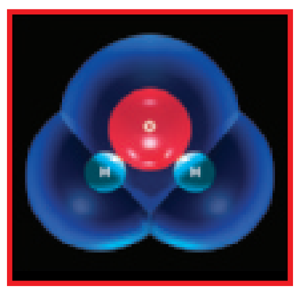
mimicry (mim′i·krē) An adaptation in which an animal is protected against predators by its resemblance to a different animal. (p. 72)

mineral (min′ə rəl) Any of the naturally occurring solid materials of Earth's crust. (p. 314)

mirror (mîr′ər) An object with a polished or smooth surface that forms images by reflection. (p. 662)

mitosis (mī′tō′sis) The division of the nucleus while a cell is dividing into two identical cells. (p. 110)

mixture (miks′chər) A physical combination of two or more substances that blend together without forming new substances. (p. 524)



molecule (mol′ə·kūl) The smallest particle of a compound that still has all the qualities of that compound. (p. 506)

momentum (mō·men′təm) The mass of an object multiplied by its velocity. (p. 607)

moon (mün) Any large object that orbits a planet. (p. 446)

moraine (mə·rān′) The sediment that forms in front of or along the sides of a glacier. (p. 289)

motion (mō′shən) A change in an object's position compared to fixed objects around it. (p. 590)

mutation (mū·tā′shən) A change in an organism's DNA. (p. 172)

N

natural selection (nach′ər·əl si·lek′shən) The survival and successful reproduction of the organisms that are best suited to their environment. (p. 174)

nebula (neb′ye·lə) A huge cloud of gas and dust in space that is the first stage of star formation. (p. 462)

neutralization (nü′trə·lī·zā′shən) The process in which an acid and a base of equal strength and ion concentration are mixed, producing water and salt. (p. 556)

neutron (nü′tron) A particle that is found in the nucleus of an atom and has no electrical charge. (p. 501)

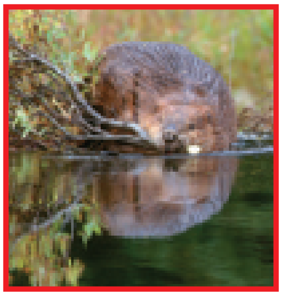
Newton's law of universal gravitation (nü′tənz lô uv ū′nə·vûr′səl grav′i·tā′shən) The planets, the stars, and the Sun all exert gravitational forces. (p. 609)

Newton's first law of motion (nü′tənz fûrst lô uv mō′shən) An object at rest tends to stay at rest and an object moving in a straight line at a constant speed tends to keep moving that way. (p. 600)

Newton's second law of motion (nü′tənz sek′ənd lô uv mō′shən) An object's acceleration depends on the object's mass and the amount of net force applied to it. (p. 606)

Newton's third law of motion (nü′tənz thûrd lô uv mō′shən) For every action there is an equal and opposite reaction. (p. 608)

niche (nich) The role a species plays in a food web. (p. 192)



nonvascular (non·vas′kyə·lər) A division of plants that lack vascular tissue, including roots, stems, and leaves with veins. (p. 26)

nuclear fission (nü′klē·ər fish′ən) The splitting of a nucleus into two or more pieces when struck with a slow-moving neutron. (p. 574)

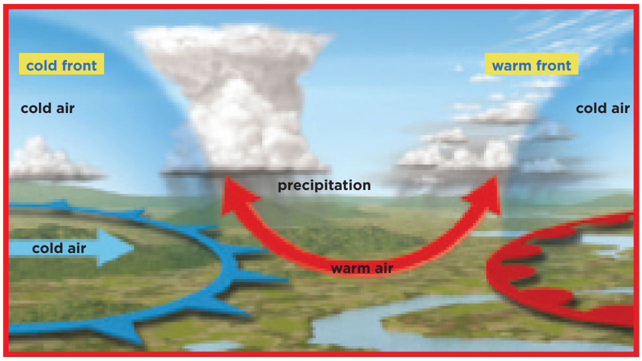
nuclear fusion (nü′klē·ər fūzh′ən) The merging of nuclei with small masses to form a nucleus with a larger mass. (p. 574)

nucleus (nü′klē·əs) 1. The largest, most visible part of a cell, which has its own membrane and is the control center of a cell's activities. (p. 92) 2. The center of an atom, which contains most of the atom's mass. (p. 501)

O

observe (əb·sûrv′) To use one or more of the senses to identify or learn about an object or event. (p. 92)

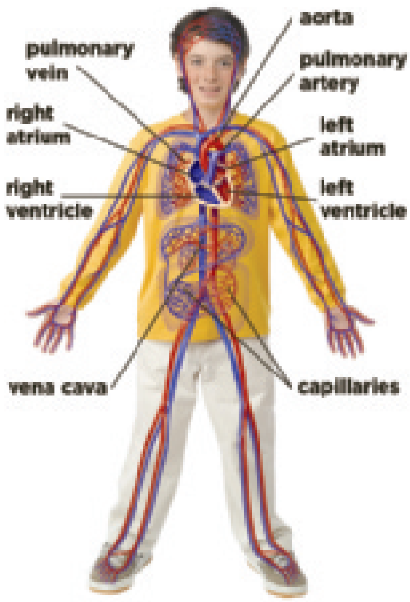
occluded front (ə·klüd′əd frunt) A weather front that occurs when cool air catches up with a warm front and then moves underneath the warm front, creating a wedge of warm air between two masses of cool air. (p. 400)



opaque (ō'pāk') Matter that does not allow light to pass through it. (p. 661)

organ (ôr'gən) A group of two or more types of tissue that work together to carry out one specific function. (p. 88)

organ system (ôr'gən sis'təm) A group of organs working together. (p. 89)



organic compound (ôr'gan·ik kom'pound) The chemical building blocks of all known living things. All organic compounds contain carbon. (p. 562)

organism (ôr'gən·iz'əm) A living thing. (p. 22)

osmosis (oz·mō'sis) The diffusion of water through a cell membrane. (p. 98)

ozone layer (ō'zōn lā'ər) A layer of ozone gas in Earth's atmosphere that screens out much of the Sun's ultraviolet rays. (p. 329)

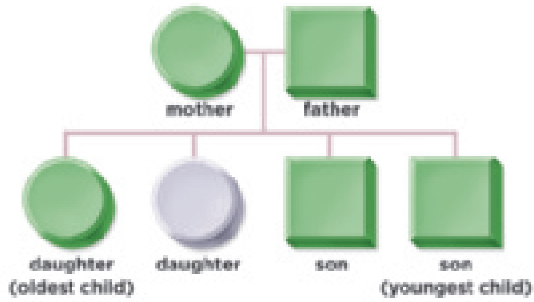
P

parallax (par'ə·lax') The apparent shift in an object's position when viewed from two locations. (p. 459)

parallel circuit (par'ə·lel' sûr'kit) A circuit with multiple paths along which current electricity can flow. (p. 701)

passive transport (pas'iv trans'pôrt') The movement of molecules through cell membranes without the use of energy by the cell. (p. 98)

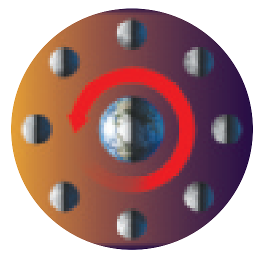
pedigree (ped'i·grē) A chart that traces the history of traits in a particular family. (p. 154)



period (pîr'ē·əd) 1. One of the primary divisions of a geologic era. (p. 302) 2. A cycle. (p. 647)

periodic table (pîr'ē·od'ik tā'bəl) A chart that shows the elements in order of increasing atomic number. (p. 502)

phase of the Moon (fāz uv thə mün) The shape of the Moon as seen in the night sky. (p. 437)



phenotype (fē'nə·tīp') The way in which a genotype is expressed, or shown, in an organism. (p. 153)

photosynthesis (fō'tə·sin'·thə·sis) The process in which plants and some other organisms use sunlight to make food in the form of glucose. (p. 37)

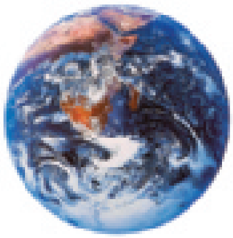
phylum (fī'ləm) n., phyla (-lə) pl. A main group within a kingdom, whose members share a main characteristic. (p. 24)

physical change (fiz'i· kəl chānj) A change in size, shape, or state, without forming a new substance. (p. 518)

physical property (fiz'i kəl prop'ər·tē) A property that can be observed without changing the identity of a substance. (p. 492)

pigments (pig′mənts) Tiny solid particles of primary colors, which can be mixed to produce all other colors. (p. 676)

pioneer community (pī′ə·nîr′ kə·mū′ni·tē) A new community established in a previously lifeless area. (p. 227)



planet (plan′it) A large body that orbits a star. (p. 446)

plastic (plas′tik) A molded material which contains carbon and can retain its shape. (p. 566)

plate tectonics (plāt tek·ton′iks) The theory that Earth's surface is broken into pieces, or plates, that slide over the magma in the mantle. (p. 257)

pollination (pol′ə·nā′shən) The transfer of pollen from an anther to the stigma. (p. 38)

pollution (pə·lü′shən) A harmful change in the natural environment. (p. 344)

population (pop′yə·lā′shən) All the organisms of the same kind that live in a particular area. (p. 187)

position (pə·zish′ən) The location of an object compared with things around it. (p. 590)

potential energy (pə·ten′shəl en′ûr·jē) The energy stored in an object or material. (p. 618)

power (pou′ər) The amount of work done per unit of time. (p. 622)

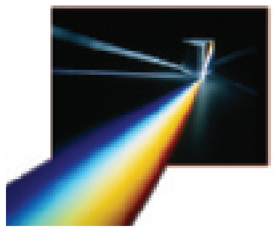
precipitation (pri sip′i tā′shən) Water that falls from clouds to the ground in the form of rain, sleet, hail, or snow. (p. 330)

predator (pred′ə tər) A living thing that hunts and kills other living things for food. (p. 201)

predict (pri·dikt′) To state possible results of an event or experiment. (p. 602)

pressure (presh′ər) The force exerted by a gas. (p. 516)

primary color (prī′mer·ē kul′ər) One of three colors of light—red, green, or blue—from which all other colors of light can be produced. (p. 676)



prism (priz′əm) A triangular piece of glass or plastic that bends light. (p. 672)

producer (prə·dü′sər) An organism that is able to make its own food. (p. 198)

product (prod′əkt) The new substance produced in a chemical reaction. (p. 543)

protein (prō′tēn) The most abundant organic compound in the human body, needed for cell growth and repair and made mainly of carbon, hydrogen, oxygen, and nitrogen. (p. 90)

proton (prō′ton) A positively charged particle inside an atom's nucleus. (p. 501)

pulley (pủl′ē) A grooved wheel that turns by the action of a rope in the groove. (p. 632)

Q

quasar (kwā′zär) An extremely bright, extremely distant high-energy source, shining with the light of a trillion suns. (p. 476)

R

radiation (rā′dē·ā′shən) The energy given off by a radioactive element. (p. 573)

radioactive (rā′dē·ō·ak·tiv′) A type of element that gives off energy in the form of rays or particles. (p. 573)

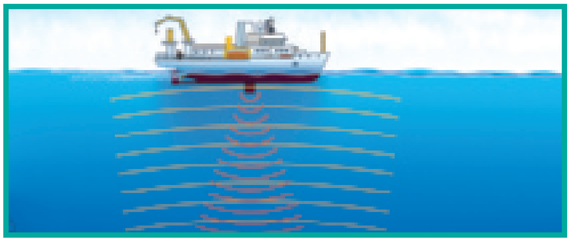
rain shadow (rān shad′ō) A region on the side of a mountain where air becomes dry and descends. (p. 411)

rarefaction (râr·ə·fak′shən) An area where particles in a medium are spread apart by a wave's energy. (p. 647)

reactant (rē·ak′tənt) An original substance at the beginning of a chemical reaction. (p. 543)

recessive trait (ri·ses′iv trāt) The hidden form of an inherited trait which will only show in the phenotype if it is paired with another recessive gene. (p. 143)

reflection (ri·flek′shən) How a wave bounces off an object and changes its direction of travel. (p. 650)



refraction (ri·frak′shən) The change in direction of a wave because of a change in the medium it is traveling through. (p. 651)

renewable resources (ri·nü′ə·bəl rē′sôrs′əs) Materials from the environment that people use. Resources are either renewable, meaning they can be replaced relatively quickly, or nonrenewable, meaning that there is a limited quantity available. (p. 340)

reproduction (rē·prə·duk′shən′) The process that a living thing uses to produce more of its own kind. May be asexual or sexual. (p. 38)

reservoir (rez′ər·vwär′) A natural or artificial lake that stores supplies of fresh water. (p. 333)

resistor (ri·zis′tər) A material through which electricity has difficulty flowing. (p. 699)

respiration (res′pə·rā′shən) The process of releasing energy from food molecules such as glucose, which takes place in the mitochondria of a cell. (p. 60)

revolution (rev′ə·lü′shən) One complete trip orbiting around an object, such as Earth orbiting the Sun. (p. 426)

rock cycle (rok sī′kəl) The process in which rocks continuously change from one kind into another over long periods of time. (p. 322)

root (rüt) A plant part that anchors a plant in the ground, stores food, and draws moisture and nutrients from the soil. (p. 35)

rotation (rō·tā′shən) One complete spin of an object such as Earth on its axis. (p. 424)

S

salt (sôlt) A compound formed by reactions between an acid and a base. (p. 556)

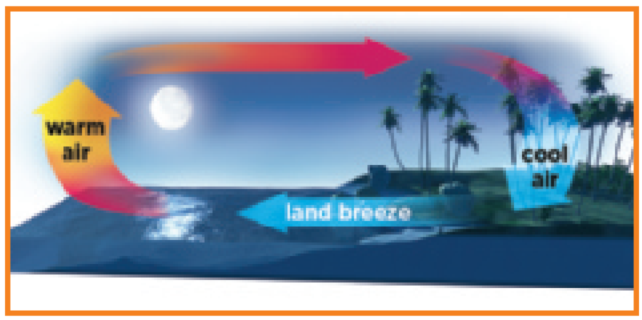
scavenger (skav′ən·jər) A meat-eating animal that feeds on the remains of dead animals that it did not hunt or kill. (p. 201)

scientific name (sī′ən·tif′ik nām) The name for every living thing that combines the genus and species. (p. 25)

screw (skrü) A simple machine made of an inclined plane wrapped around a central bar that can multiply an effort force. (p. 634)

sea breeze (sē brēz) Wind that blows from the sea toward the land. (p. 375)

seafloor spreading (sē′flôr′ spred′ing) The moving apart of plates on the ocean floor that is caused by magma flowing up between the plates and then hardening. (p. 258)



secondary color (sek′ən·der·ē kul′ər) A color that is produced when two primary colors blend together. (p. 676)

sediment (sed′ə·mənt) Small, loose pieces of minerals, rock, and organic material, some of which are deposited when a river slows. (p. 286)

sedimentary rock (sed′ə·men′tə·rē rok) A rock that forms when small pieces of rocks, minerals, and shells are deposited, buried, and are squeezed and cemented together. (p. 320)

seed (sēd) A structure that contains a young, developing plant and stored food. (p. 38)

seismic wave (sīz′mik wāv) A vibration that travels through Earth and is produced by earthquakes and volcanic eruptions. (p. 271)

seismograph (sīz′mə·graf′) An instrument that detects, measures, and records the energy of earthquake vibrations at a given location. (p. 272)

series circuit (sîr′ēz sûr′kət) A circuit with only one path along which current electricity can flow. (p. 700)

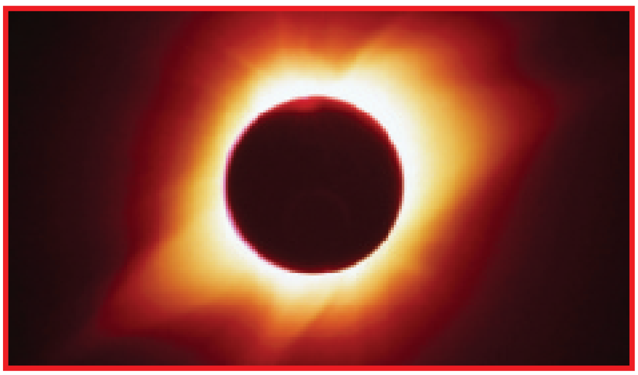
simple machine (sim′pəl mə·shēn′) A device with few, if any, moving parts that makes it easier to do work. (p. 628)

smog (smog) A mixture of smoke and fog, formed when smoke and fumes collect in moist, calm air. (p. 345)

soil (soil) A mixture of weathered rock, air, water, living things, and humus that can support the growth of rooted plants. (p. 290)

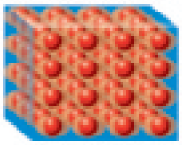
solar cell (sol′ər sel) A device that uses sunlight to produce electricity. (p. 355)

solar eclipse (sol′ər ē·klips′) A blocking of the Sun's light that happens when Earth passes through the Moon's shadow. (p. 438)



solar system (sol′ər sis′təm) A star such as the Sun, as well as the planets and other bodies that travel around it. (p. 446)

solid (sol′id) Matter that has a definite shape and occupies a definite amount of space. (p. 489)



solubility (sol′yə·bil′i·tē) The maximum amount of a substance that can be dissolved by another substance. (p. 529)

solution (sə·lü′shən) A mixture of one substance dissolved in another. (p. 528)

species (spē′shēz) A group of similar organisms that reproduce more of their own kind. (p. 24)

specific heat (spi′sif·ik hēt) The amount of heat energy, usually measured in joules, needed to raise the temperature of 1 gram of a substance by 1°C. (p. 688)

spectrum (spek′trəm) A band of colors made when white light is broken up. (p. 472)

speed (spēd) How fast an object's position changes with time at any given moment. (p. 592)

sperm (spûrm) A male sex cell. (p. 38)

standard time zone (stan′dərd tīm zōn) A vertical belt, about 15 degrees wide in longitude, in which all places have the same time. (p. 425)

star (stär) A large, hot ball of gases, which is held together by gravity and gives off its own light. (p. 458)

static electricity (stat′ik i·lek·tris′i·tē) The buildup of an electric charge, either positive or negative, on a material's surface. (p. 695)

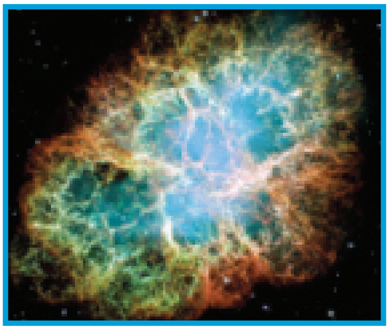
stem (stem) A structure that holds a plant up and supports its leaves. (p. 34)

sublimation (sub·lə·mā′shən) The process of changing directly from a solid to a gas, or from a gas to a solid, without first becoming a liquid. (p. 513)

succession (sək·sesh′ən) The gradual replacement of one species by another. (p. 226)

sunspot (sun′spot′) A dark area that appears temporarily on the Sun's surface. (p. 412)

supernova (süp′ər·nōv′ə) An exploded star. (p. 463)



suspension (sə·spen′shən) A mixture of small particles that separate upon standing. (p. 527)

symbiosis (sim′bī·ō′sis) A relationship between two kinds of organisms that lasts over time. (p. 190)

synthetic (sin·thet′ik) A material made by people. (p. 566)

T

telescope (tel′ə·skōp′) A device that collects light and magnifies images to make distant objects appear closer and larger. (p. 422)

temperature (tem′pər·ə·chər) A measurement of how hot or cold something is. (p. 512)

tetrapod (tet′rə·pod′) An animal with four legs or limbs, such as a turtle, salamander, or horse. (p. 49)

thermal energy (thûr′məl en′ûr·jē) The temperature of a substance or the movement of kinetic heat energy from one substance to another. (p. 618)

thermal expansion (thûr′məl ek·span′shən) An increase in volume that is caused by an increase in temperature. (p. 683)

threatened (thret′ənd) Said of a species whose numbers have declined to the point of becoming endangered if steps are not taken to protect it. (p. 224)

tide (tīd) The twice-daily rise and fall of the water level along a shore, caused by the gravity of the Moon and Sun. (p. 440)

till (til) A jumble of many sizes of sediment deposited by a glacier. (p. 289)

tissue (tish′ü) A group of similar cells that work together to perform the same function. (p. 88)

tornado (tôr·nā′dō) A violent, whirling wind that moves across the ground in a narrow path. (p. 389)

toxic waste (tok′sik wāst) A collection of poisonous materials. (p. 346)

translucent (trans·lü′sənt) Matter through which some light can travel and some is blocked or bounces in new directions. (p. 661)

transparent (trans·pâr′ənt) Allowing light to pass through with almost no distortion. (p. 661)

transverse wave (trans·vûrs′ wāv) A wave that moves matter up and down as it travels through a medium. (p. 646)

tropism (trōp′iz′əm) The response of an organism toward or away from a stimulus. (p. 70)

troposphere (trōp′ə·sfîr′) The layer of the atmosphere closest to the Earth's surface. (p. 370)

U

unicellular (ūn′ə·sel′yə·lər) A single-celled organism. (p. 122)

universe (ū′nə·vûrs′) Everything that exists, including Earth, the planets, the stars, and all of space. (p. 422)

use numbers (ūz num′bərz) To order, count, add, subtract, multiply, and divide to explain data. (p. 148)

use variables (ūz vâr′ē·ə·bəlz) To identify and separate things in an experiment that can be changed or controlled. (p. 324)

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V

vaporization (vā′pər·ə·zā′shən) The changing of a liquid to a gas as heat is applied to it. (p. 515)

variation (vâr′ē·ā′shən) A genetic difference among members of the same species that may enable individuals to better survive and reproduce. (p. 172)

vascular (vas′kyə·lər) Containing plant tissue through which water moves up and food moves down. (p. 26)

vent (vent) A central opening through which magma and gases erupt once reaching Earth's surface. (p. 276)

velocity (və·los′i·tē) A description of a moving object's speed and direction. (p. 593)

vertebrate (vûr′tə·brāt′) An animal with a segmented backbone. (p. 48)

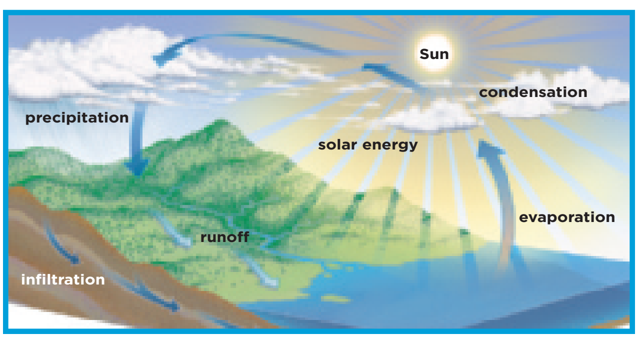
visible light (viz′ə·bəl līt) A mixture of wavelengths that the human eye can detect. (p. 672)

volume (vol′ūm) 1. The amount of space that matter takes up. (p. 488) 2. The loudness of a sound. (p. 653)

W

warm-blooded (wôrm′·blud′əd) The type of animal whose body temperature stays the same when the temperature of its surroundings changes. (p. 62)

water cycle (wô′tər sī′kəl) The continuous movement of water between Earth's surface and the air. (p. 330)



water table (wô′tər tā′bəl) The upper surface of the groundwater that lies between topsoil and tightly packed rocks. (p. 333)

watershed (wô′tər·shed′) The region that contributes water to a river or a river system. (p. 331)

wavelength (wāv′lengkth) The distance between a crest and the following trough of a wave. (p. 648)

weathering (weth′ər·ing) The breaking down of rocks into smaller pieces by natural processes. (p. 284)

wedge (wej) An inclined plane that changes the direction of an applied force. (p. 635)

weight (wāt) The measurement of the pull of gravity on an object. (p. 488)

weightlessness (wāt′lis·nis) The state of being without weight. (p. 610)

wheel and axle (hwēl and ak′səl) A simple machine that consists of a wheel that applies an effort force and a smaller axle that produces an output force. (p. 632)

work (wûrk) Force applied to an object times the distance the object moves in the direction of the force. (p 616)

X

X and Y chromosomes (eks and wī khrō′mə·sōmz) Chromosoms that combine to determine a person's gender. (p. 153)

Z

zygote (zī′gōt) The cell formed when a sperm cell and an egg cell join together. (p. 112)

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Note: Pages followed by an asterisk indicate activities.

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R31: VVG/Science Photo Library. R32: (bl) European Southern Observatory/Science Photo Library; (tr) Charles Mauzy/Corbis. R33: G Brad Lewis/Science Faction/Getty Images. R34: (tl) Royalty-Free/Corbis; (bl) StockTrek/Getty Images; (tr) Eastcott and Momatiuk/National Geographic Image Collection; (br) Klaus Nigge/National Geographic Image Collection. R35: (cl) Cathlyn Melloan/Stone/Getty Images. R36: (bl) Gusto/Science Photo Library; (r) Roger Ressmeyer/Corbis. R37: (tl) Russell Kightley/Science Photo Library; (r) Tony Freeman/Photo Edit. R38: (tl) Digital Vision/Fotosearch; (cl) Kimimasa Mayama/Pool/Reuters/Corbis.