Section 1

Water on Earth

Reading Preview

Key Concepts

- How does Earth's water move through the water cycle?
- Where are fresh water and salt water found on Earth?

Key Terms

- water cycle
- precipitation
- groundwater

Target Reading Skill

Identifying Main Ideas As you read the Distribution of Earth's Water section, write the main idea in a graphic organizer like the one below. Then write four supporting details that further explain the main idea.

Main Idea

Earth's water is distributed among . . .

Detail | Detail | Detail | Detail

Lab zone Discover Activity

Where Does the Water Come From?

1. Fill a glass with ice cubes and water, taking care not to spill any water. Set the glass aside for 5 minutes.
2. Observe the outside of the glass. Pick up the glass and examine the surface it was sitting on.

Think It Over

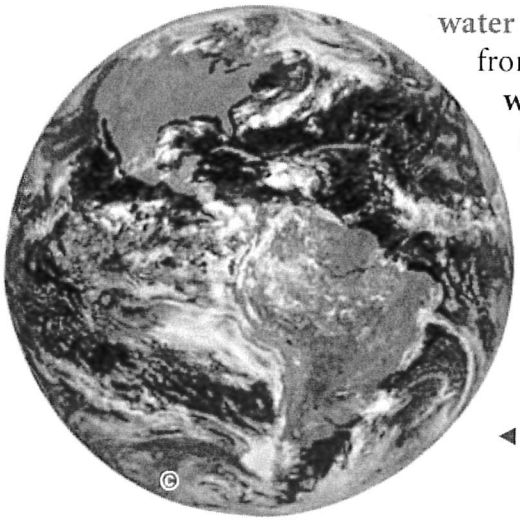
Inferring Where did the water on the outside of the glass come from? How do you think it got there?

In a galaxy called the Milky Way, nine planets orbit a star known simply as the sun. Some of the planets have spectacular rings. Others have volcanoes that are larger than continents, or storms that last for centuries. But only one of the planets, Earth, has a surface covered mainly by water. In fact, oceans cover about 70 percent of our planet's surface. That's why Earth is often called the "water planet."

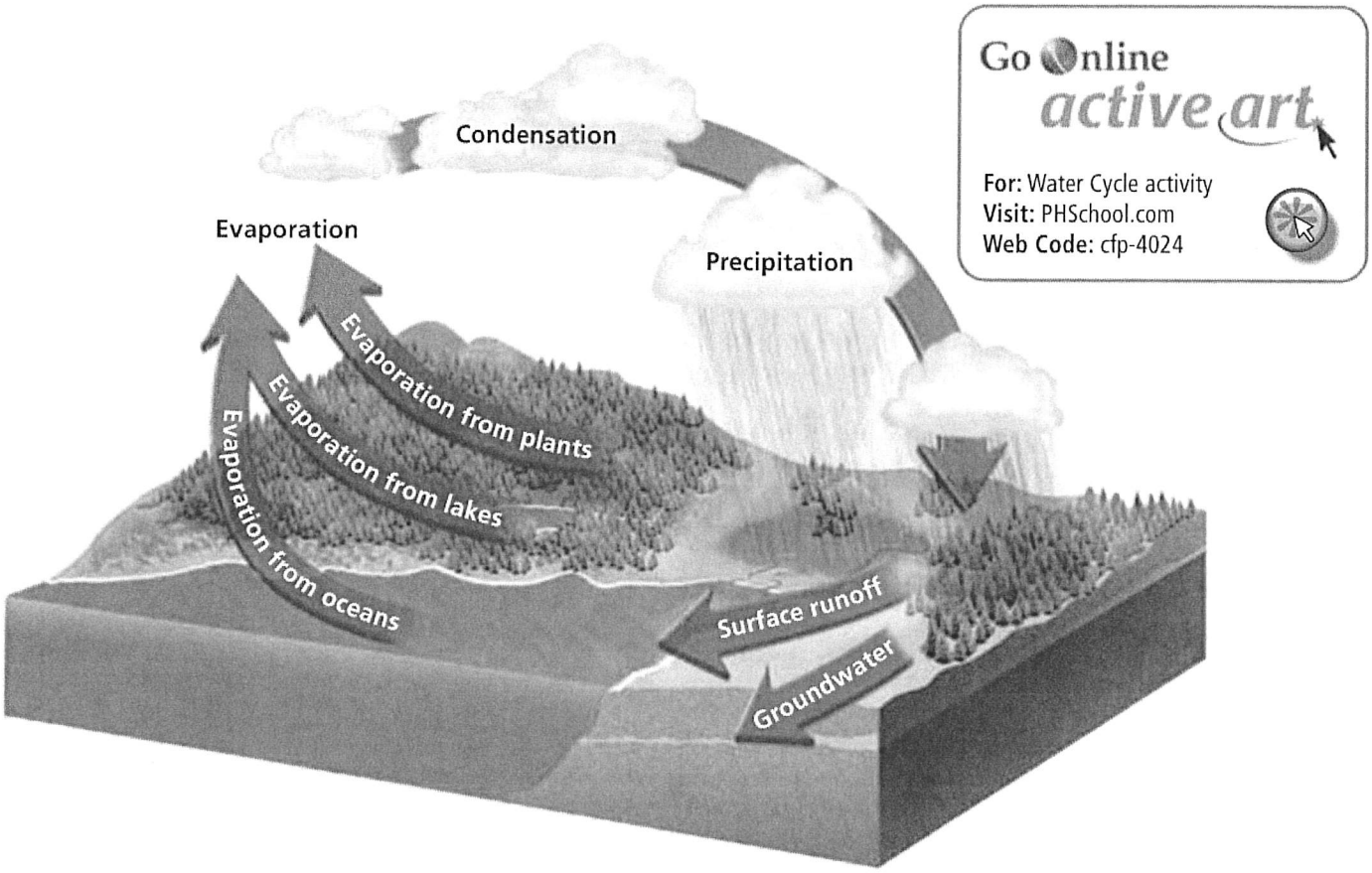
Earth differs from the other planets in another important way. It is the only place known thus far where you, your classmates, your pets, your plants, and every other living thing can survive. Life on Earth could not exist without water.

The Water Cycle

Earth's water is naturally recycled through the water cycle. The water cycle is the continuous process by which water moves from Earth's surface to the atmosphere and back. **In the water cycle, water moves from bodies of water, land, and living things on Earth's surface to the atmosphere and back to Earth's surface.** As shown in Figure 1, the water cycle has three major steps—evaporation, condensation, and precipitation. The cycle itself has no beginning or end. But it is driven by an energy source—the sun.



◀ Earth, the "water planet"



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Water Evaporates In the process of evaporation, liquid water changes to a gas called water vapor. Water is constantly evaporating from the surfaces of lakes and oceans and even from the soil. Plants play a role, too, in this step of the water cycle. Plants draw in water from the soil through their roots and release it through their leaves as water vapor.

Condensation Forms Clouds What happens after water evaporates? Warm air carries the water vapor upward. At higher altitudes, air tends to become much colder. Cold air cannot hold as much water vapor as warm air can. As a result, some of the water vapor cools and condenses into liquid water. Condensed droplets of water clump together around tiny dust particles in the air, forming clouds.

Precipitation As more water vapor condenses, the drops of water in the cloud grow larger. Eventually, the heavy drops fall back to Earth as **precipitation**—rain, snow, sleet, or hail. Most precipitation falls back into the ocean or lakes. The precipitation that falls on land may soak into the soil and become groundwater. Or the precipitation may run off the land, eventually flowing back into the ocean.

FIGURE 1
The Water Cycle
Water moves continuously through a cycle, from Earth's surface to the atmosphere and back. The sun's energy drives this process.
Interpreting Diagrams *In which step of the water cycle does water return to Earth's surface?*

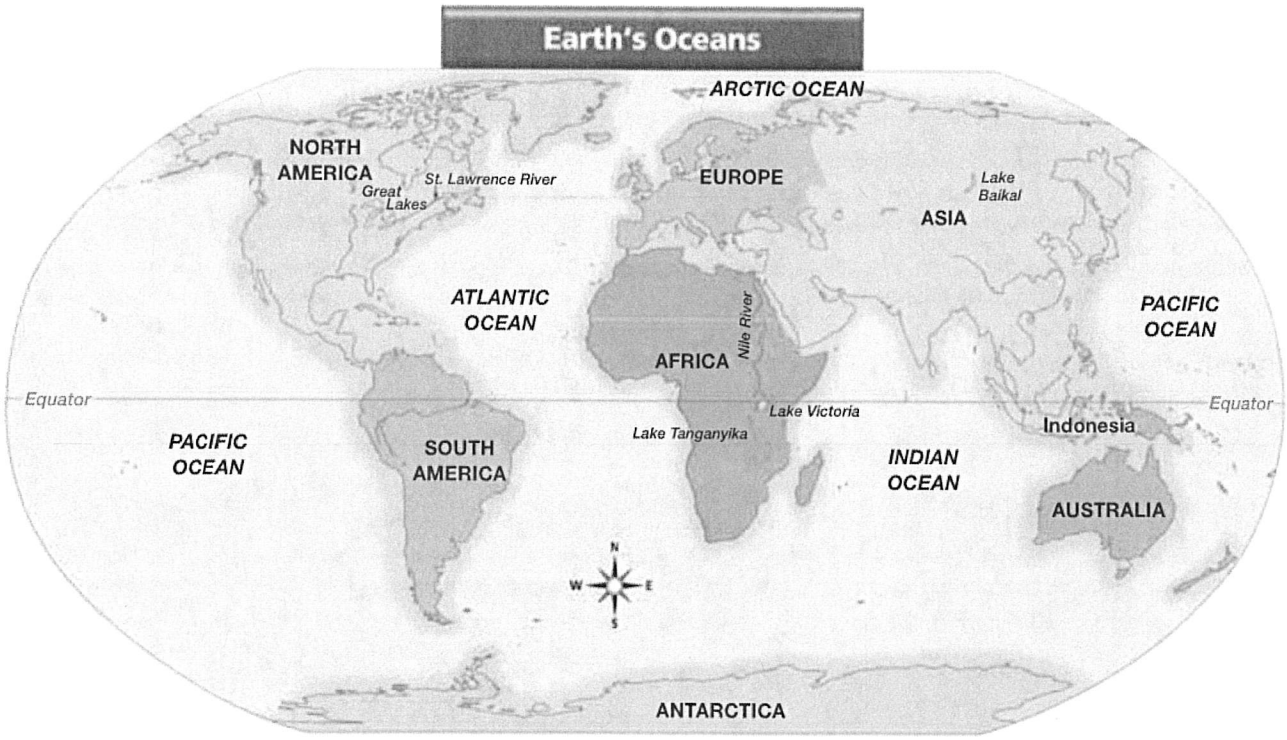


FIGURE 2
Earth's oceans are all connected, enabling a ship to sail all the way around the world. This map also shows some of the world's major rivers and lakes. **Interpreting Maps** *Which continents touch the Pacific Ocean? The Atlantic Ocean?*

Distribution of Earth's Water

Most of Earth's water—roughly 97 percent—is salt water found in oceans. Only 3 percent is fresh water. Of that 3 percent, about three quarters is frozen in huge masses of ice near the North and South poles. Almost a quarter of the fresh water is underground. A tiny fraction of Earth's fresh water occurs in lakes and rivers. An even tinier fraction is in the atmosphere, most of it in the form of water vapor.

Oceans A vast, salty ocean covers an area greater than all the land on Earth combined. Pacific, Atlantic, Indian, and Arctic are the names used for the different parts of the ocean. But the waters are really all interconnected, making up one big ocean.

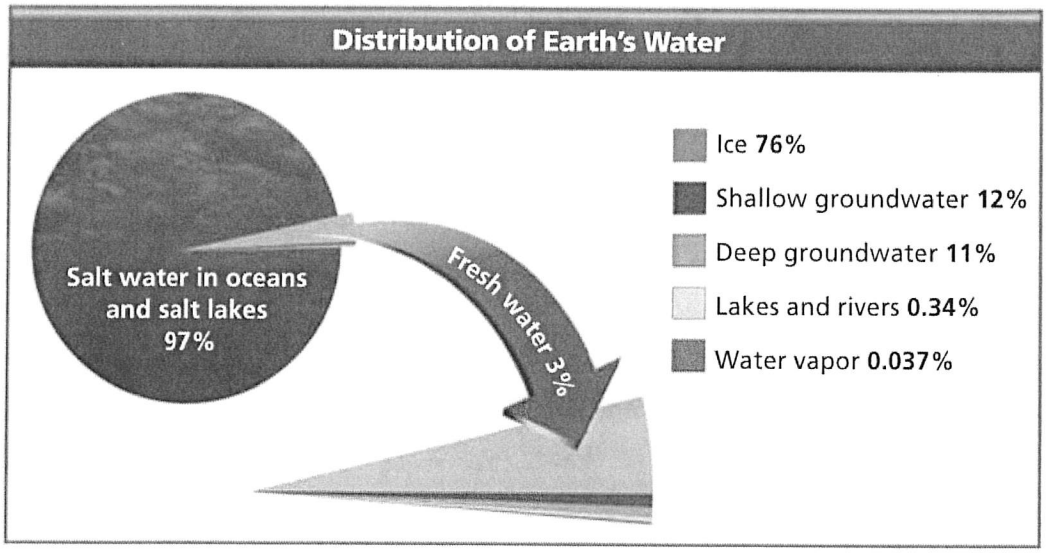
Ice Most of Earth's fresh water is locked in thick sheets of ice that cover Antarctica, near the South Pole, and Greenland, near the North Pole. Huge icebergs, floating chunks of ice made of fresh water, often break off the ice sheets. The icebergs slowly melt as they float toward warmer waters.

Reading Checkpoint **What are icebergs?**

Lab zone Skills Activity

Calculating

Your teacher has set up an aquarium filled with 20 liters of water to model all the water on Earth. How much water would you need to remove from the aquarium to model Earth's fresh water? (*Hint*: Refer to the graph in Figure 3.)



Rivers and Lakes Relatively little of Earth's fresh water is found in rivers and lakes. But rivers and lakes are important sources of fresh water for the people who live near them. North America's five Great Lakes contain nearly 20 percent of all the water in the world's freshwater lakes.

Groundwater Water that fills the cracks and spaces in underground soil and rock layers is called **groundwater.** When it rains or snows, some water soaks into the ground. This water trickles down through spaces between particles of soil and rock. Eventually the water reaches a layer of rock that it cannot move through. Far more fresh water is located underground than in all of Earth's rivers and lakes.

FIGURE 3
Most of Earth's water is salt water. Only 3 percent is fresh water. Of that fresh water, only a tiny fraction is available for human use. (Percentages have been rounded off.)

Section 1 Assessment

Target Reading Skill Identifying Main Ideas Use your graphic organizer to help you answer Question 2 below.

Reviewing Key Concepts

HINT
1. a. Identifying What three major steps make up the water cycle?

HINT
b. Explaining How does water enter Earth's atmosphere? Explain your answer.

HINT
c. Relating Cause and Effect Would cutting down trees affect the amount of evaporation in an area? Explain.

HINT
2. a. Listing What are Earth's four main sources of water?

HINT
b. Classifying Which of the four main water sources contain salt water? Which contain fresh water?

HINT
c. Making Judgments Which freshwater source is most important to people? Use facts to defend your answer.

Writing in Science

Moving Through the Water Cycle Starting with a puddle on a sunny day, write a paragraph describing how water might move through the water cycle and eventually fall back as rain.

Section 2

Surface Water

Reading Preview

Key Concepts

- What is a river system?
- What are the characteristics of ponds and lakes?
- What are three types of wetlands and why are they important?

Key Terms

- tributary • watershed
- divide • habitat • reservoir
- wetland

Target Reading Skill

Outlining As you read, make an outline of this section. Use the red headings for the main ideas and the blue headings for the supporting ideas.

Surface Water

I. River systems
  A. Tributaries
  B.
  C.
II. Ponds
  A.

Lab zone Discover Activity

What's in Pond Water?

1. Using a hand lens, observe a sample of pond water.
2. Make a list of what you see in the water. If you don't know the name of something, write a description or draw a picture.
3. Your teacher has set up a microscope with a slide of pond water. Observe the slide under the microscope and add any new items to your list. Wash your hands when you are done.

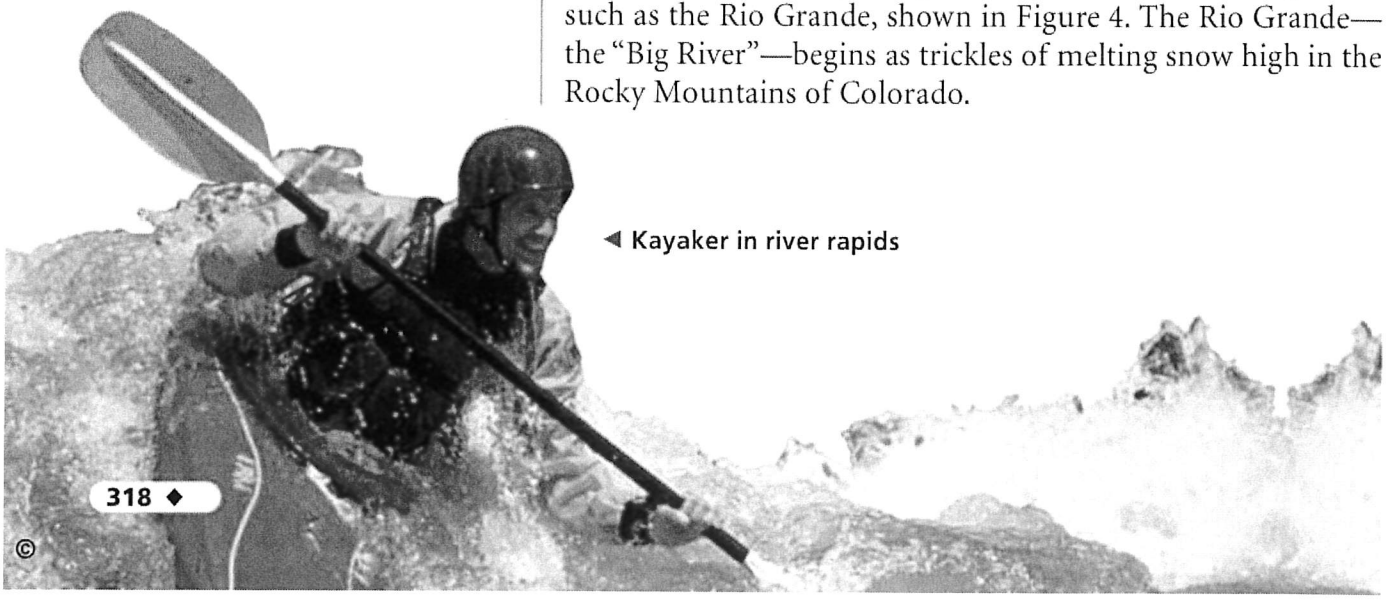
Think It Over

Classifying Use one of these systems to divide the items on your list into two groups: moving/still, living/nonliving, or microscopic/visible without a microscope. What does your classification system tell you about pond water?

Imagine that you are a raindrop falling from the clouds to Earth's surface. Down, down, you go and then, splash! You land in the tumbling waters of a fast-moving stream. You are in one of Earth's freshwater sources. Fresh water on Earth may be moving, as in streams and rivers, or still, as in ponds and lakes.

River Systems

Rivers often begin in the mountains, where the runoff from melting snow forms small streams. As you followed one small stream downhill, you would notice that the stream reached another stream and joined it. These streams would flow into a small river. Eventually this path would lead you to a large river such as the Rio Grande, shown in Figure 4. The Rio Grande—the "Big River"—begins as trickles of melting snow high in the Rocky Mountains of Colorado.



◄ Kayaker in river rapids

FIGURE 4
Major Watersheds
This map shows watersheds of several large rivers in the continental United States. Each river's watershed consists of the region drained by the river and all its tributaries. Interpreting Maps *What large rivers are tributaries of the Mississippi River?*

Tributaries The streams and smaller rivers that feed into a main river are called **tributaries.** Tributaries flow downward toward the main river, pulled by the force of gravity. **A river and all its tributaries together make up a river system.**

Watersheds Just as all the water in a bathtub flows toward the drain, all the water in a river system drains into a main river. The land area that supplies water to a river system is called a **watershed.** Watersheds are sometimes known as drainage basins.

As you can see in Figure 4, the Missouri and Ohio rivers are quite large. Yet they flow into the Mississippi River. So large rivers may be tributaries of still larger rivers. When rivers join another river system, the areas they drain become part of the largest river's watershed. You can identify a river's watershed on a map by drawing an imaginary line around the region drained by all its tributaries.

Divides What keeps watersheds separate? One watershed is separated from another by a ridge of land called a **divide.** Streams on each side of the divide flow in different directions. The Continental Divide, the longest divide in North America, follows the line of the Rocky Mountains.

Reading Checkpoint What is a divide?

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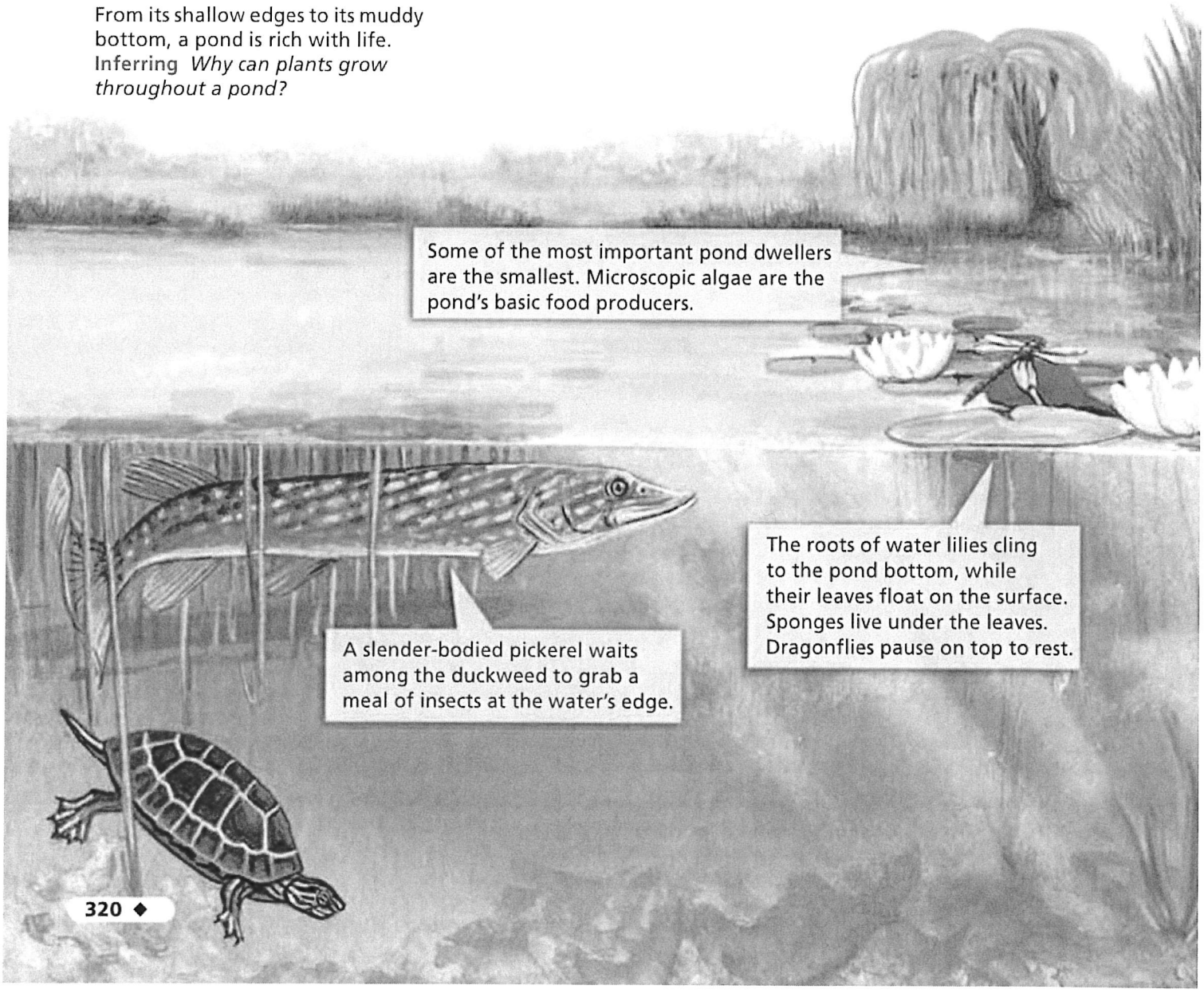
Ponds

Ponds are bodies of fresh water. Unlike the moving water in streams and rivers, ponds contain still, or standing, water. How can you tell the difference between ponds and lakes? There is no definite rule. **In general, however, ponds are smaller and shallower than lakes. Sunlight usually reaches to the bottom of all parts of a pond.**

How Ponds Form Ponds form when water collects in hollows and low-lying areas of land. Where does the water come from? Some ponds are supplied by rainfall, melting snow and ice, and runoff. Others are fed by rivers or groundwater. As a pond gains water from these sources, it also loses water to natural processes. For example, water may eventually flow out of a pond and into a river. Water also evaporates from the surface of a pond.

FIGURE 5
Life in a Pond
From its shallow edges to its muddy bottom, a pond is rich with life.
Inferring *Why can plants grow throughout a pond?*



Exploring a Pond If you've ever waded in a pond, you know that the muddy bottom is often covered with weeds. Because the water is shallow enough for sunlight to reach the bottom, plants grow throughout a pond. A quiet pond is actually a thriving habitat, supporting a wide diversity of living things, as shown in Figure 5. An organism's **habitat** is the place where it lives and obtains all the things it needs to survive.

Not all ponds exist year-round. Some ponds appear only in spring, when runoff from rain and melting snow collects in low areas. The ponds dry up by midsummer as the shallow water evaporates.

Reading Checkpoint **What is a habitat?**

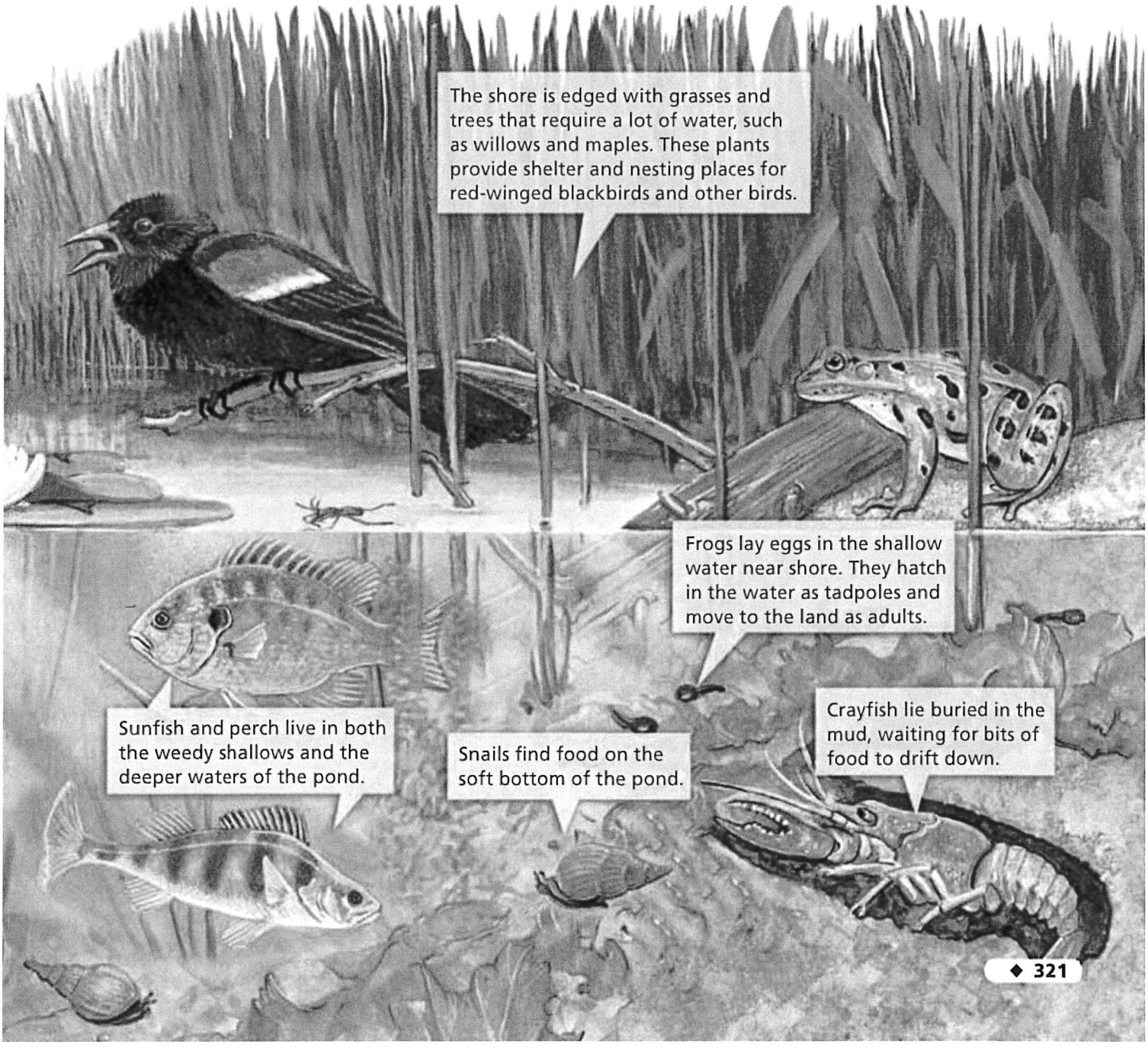


FIGURE 6
Lake Michigan
Lake Michigan is a freshwater lake that looks large enough to be mistaken for the ocean.

Lakes

Suppose you are shown a picture of waves breaking against large sand dunes. The water stretches as far as the eye can see. You might guess that this huge body of water is the ocean. But it could actually be a lake! You could be viewing a photo of dunes in Indiana, on the shore of Lake Michigan.

Characteristics of Lakes Most lakes are not as large as Lake Michigan. **But lakes are generally deeper and bigger than ponds. In addition, sunlight does not reach the bottom in a deep lake, as it does in a pond.** As a result, no plants and relatively few other organisms can live in a lake's chilly, dark depths. A lake bottom may consist of sand, pebble, or rock, whereas the bottom of a pond is usually covered with mud and algae.

How Lakes Form Lakes can form in several ways. Some lakes may form through the same processes that form ponds. Other lakes, especially larger ones, are the result of powerful forces that shape Earth's surface.

Some natural lakes, such as the Great Lakes, formed in depressions created by ice sheets that melted at the end of the Ice Age. Other lakes were created by movements of Earth's crust. Such movements formed the deep valleys in central Africa that lie below Lake Tanganyika and Lake Victoria. Still other lakes are the result of volcanoes. An erupting volcano can cause a flow of lava or mud that blocks a river and forms a lake. Some lakes form in the empty craters of volcanoes.

People can also create a lake by building a dam across a river. The lake may be used for supplying drinking water, for irrigating fields, and for recreation. A lake that stores water for human use is called a **reservoir.**

Wetlands

A **wetland** is a land area that is covered with water during part or all of the year. Wetlands help control floods and provide habitats for many species. They form where water is trapped in low areas or where groundwater seeps to the surface. Some wetlands fill up during spring rains, but dry up during summer.

Types of Wetlands **The three common types of freshwater wetlands are marshes, swamps, and bogs.** Marshes are usually grassy areas covered by shallow water or a stream. They teem with cattails and other tall, grasslike plants. Swamps look more like flooded forests, with trees and shrubs sprouting from the water. Many swamps are located in warm, humid climates, where trees grow quickly. Bogs are more common in cooler northern areas. They often form in depressions left by melting ice sheets thousands of years ago. The water in bogs tends to be acidic, and mosses thrive in these conditions.

Wetlands along coasts usually contain both fresh and salt water. Coastal wetlands include salt marshes and mangrove forests. Salt marshes are found along both coasts of the United States. Tall, strong grasses grow in the rich, muddy bottoms of salt marshes. Mangrove forests are found along the southeastern coast of the United States. In these forests, the mangrove trees are short and have thick, tangled roots.

Reading Checkpoint **What is a salt marsh?**

Lab zone **Try This Activity**

A Natural Filter

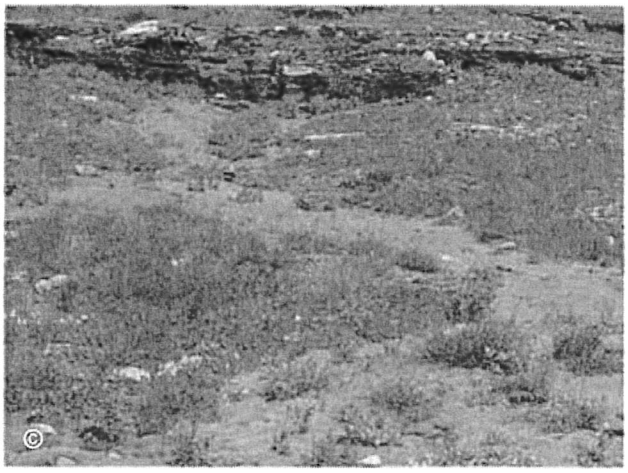
1. In one end of a loaf pan, build a sloping hill of damp soil.
2. Add water to the other end of the pan to form a lake.
3. Use a watering can to sprinkle rain onto the hill. Observe what happens to the hill and the lake.

4. Empty the water out of the pan and rebuild the hill.
5. Now push a sponge into the soil across the bottom of the hill to model a wetland.
6. Repeat Steps 2 and 3.

Observing Based on your observations, describe how wetlands filter water.

FIGURE 7
Freshwater Wetlands
Swamps and bogs are two kinds of wetlands.

Swamp Curtains of Spanish moss hang from cypress trees in this Louisiana swamp.



Bog Mosses thrive in the acidic water in this bog in Montana.

FIGURE 8
Florida Everglades
A rich variety of living things, including this great egret, make their homes in Everglades National Park. **Interpreting Maps** *Describe the flow of fresh water through the Everglades. Where does it begin? Where does it reach salt water?*

The Everglades: A Wetland If you were to walk down a path in Everglades National Park, you would feel the ground squish under your feet. Water is the key to the Everglades, a vast marsh in south Florida. A shallow stream of water moves slowly over the gently sloping land from Lake Okeechobee south to Florida Bay. Tall, sharp-edged blades of sawgrass grow in the water. The thick growth of sawgrass gave this region its Native American name, *Pa-hay-okee*, which means "river of grass."

The Everglades are home to many kinds of wildlife—alligators, fishes, snakes, and wading birds. The Everglades also provide habitats for many rare or endangered species, such as the Florida panther and the manatee.

Human activities near the Everglades threaten the region's water and wildlife. For example, farming has introduced harmful chemicals into the water. Water that once flowed into the Everglades from Lake Okeechobee has been diverted for farming and household use. New organisms brought into the area accidentally or for pest control compete with organisms that occur naturally in the Everglades.

Scientists have been trying for many years to develop a plan to preserve the Everglades and save its endangered wildlife. One plan involves building a system of pipes and canals to refill some drained areas with fresh water.

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Importance of Wetlands If you've ever enjoyed cranberry sauce or wild rice, you've eaten plants that grow in wetlands. Water in a wetland is shallow, and plant and animal materials add natural fertilizers to the water and soil. **Because of their sheltered waters and rich supply of nutrients, wetlands provide habitats for many living things.**

Wetlands are also important to people. Scientific studies show that wetlands help with pollution control and flood control. For example, as water moves slowly through a wetland, some waste materials settle out. Other wastes may be absorbed by plants. **In these ways, wetlands act as natural water filters. They also help control floods by absorbing extra runoff from heavy rains.** Wetlands are like giant sponges, storing rainwater until it gradually drains or evaporates. When wetlands are destroyed, the floodwaters are not absorbed. Instead, the water runs off the land quickly, worsening flood problems. Because of these important functions of wetlands, governments have passed laws to protect them.

Reading Checkpoint **What prompted wetlands protection laws?**

FIGURE 9
Natural Filters
Some wetland plants, such as the pickerel weed shown here, filter pollutants from water.

Section 2 Assessment

Target Reading Skill Outlining Use the information in your outline to help you answer the questions below.

Reviewing Key Concepts

HINT
1. a. Identifying What bodies of water make up a river system?

HINT
b. Summarizing How is a watershed related to a river system?

HINT
c. Applying Concepts How could you determine the boundaries of a river system by studying a map of the United States?

HINT
2. a. Reviewing How are lakes different from ponds?

HINT
b. Explaining Explain how ponds and lakes form.

HINT
c. Comparing and Contrasting What is the major difference between a reservoir and most other types of lakes?

HINT
3. a. Defining What is a wetland?

HINT
b. Classifying What are the three major types of freshwater wetlands?

HINT
c. Comparing and Contrasting How are the three major types of freshwater wetlands similar? How are they different?

Lab zone **At-Home Activity**

Runoff Show a family member how water runs off different materials. Pour some water in the grass and watch what happens. Then pour some water on the sidewalk or driveway. What happened to the water in each case? How does this relate to the role of wetlands in controlling floods?

Section 3

Water Underground

Reading Preview

Key Concepts

- How does water move through underground layers of soil and rock?
- How do people obtain water from an aquifer?

Key Terms

- permeable • impermeable
- saturated zone • water table
- unsaturated zone • spring
- aquifer • artesian well
- geyser

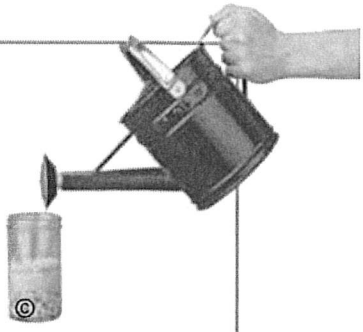
Target Reading Skill

Previewing Visuals Before you read, preview Figure 12. Then write one question that you have about the diagram in a graphic organizer like the one below. As you read, answer your question.

Springs and Wells

Q. What is an artesian well?
A.
Q.

Lab zone Discover Activity



Where Does the Water Go?

1. Add pebbles to a jar to form a layer about 5 centimeters deep. Cover the pebbles with a layer of dry sand about 3 centimeters thick. Pour the sand in slowly to avoid moving the pebbles. These materials represent underground soil layers.
2. Sprinkle water onto the sand to simulate rainfall.
3. Looking through the side of the jar, observe the path of the water as it soaks through the layers. Wash your hands when you are finished with this activity.

Think It Over

Observing Describe what happened when the water reached the bottom of the jar.

When you were a little child, did you ever dig a hole in the ground hoping to find a buried treasure? You probably never found a trunk full of gold. But there was a certain kind of treasure hidden underground. If you had dug past the tangled grass roots and small stones, the bottom of your hole would have filled with water. You would have "struck groundwater"! In the days before public water systems, water underground was truly a hidden treasure. Today, many people still rely on the water underground to meet their water needs.

How Water Moves Underground

Where does this underground water come from? Like the water in rivers, lakes, and glaciers, it comes from precipitation. Recall that precipitation can evaporate, run off the surface, or soak into the ground. If water soaks into the ground, it trickles downward, following the pull of gravity.

If you pour water into a glass full of pebbles, the water trickles down around the pebbles until it reaches the bottom of the glass. Then the water begins to fill up the spaces between the pebbles. **In the same way, water underground trickles down between particles of soil and through cracks and spaces in layers of rock.**

Effects of Different Materials Different types of rock and soil have different-sized spaces, or pores, between their particles, as shown in Figure 10. The size of the pores determines how easily water moves through rock and soil. If the pores are connected, this too affects water movement. Because they have large and connected pores, materials such as sand and gravel allow water to pass through, or permeate. They are thus known as **permeable** (PUR mee uh bul) materials.

As water soaks down through permeable rock and soil, it eventually reaches layers of material that it cannot pass through. These materials have few or no pores or cracks. Two examples are clay and granite. Clay and granite are **impermeable,** meaning that water cannot pass through easily.

Water Zones Once water reaches an impermeable layer, it is trapped. It can't soak any deeper. Instead, the water begins to fill up the spaces above the impermeable material. The area of permeable rock or soil that is totally filled, or saturated, with water is called the **saturated zone.** The top of the saturated zone is the **water table.** If you know the depth of the water table in your area, you can tell how deep you must dig to reach groundwater.

Soil and rock layers above the water table contain some moisture, too. But here the pores contain air as well as water. They are not saturated. Therefore, the layer of rocks and soil above the water table is called the **unsaturated zone.**

Reading Checkpoint **Give an example of a permeable material.**

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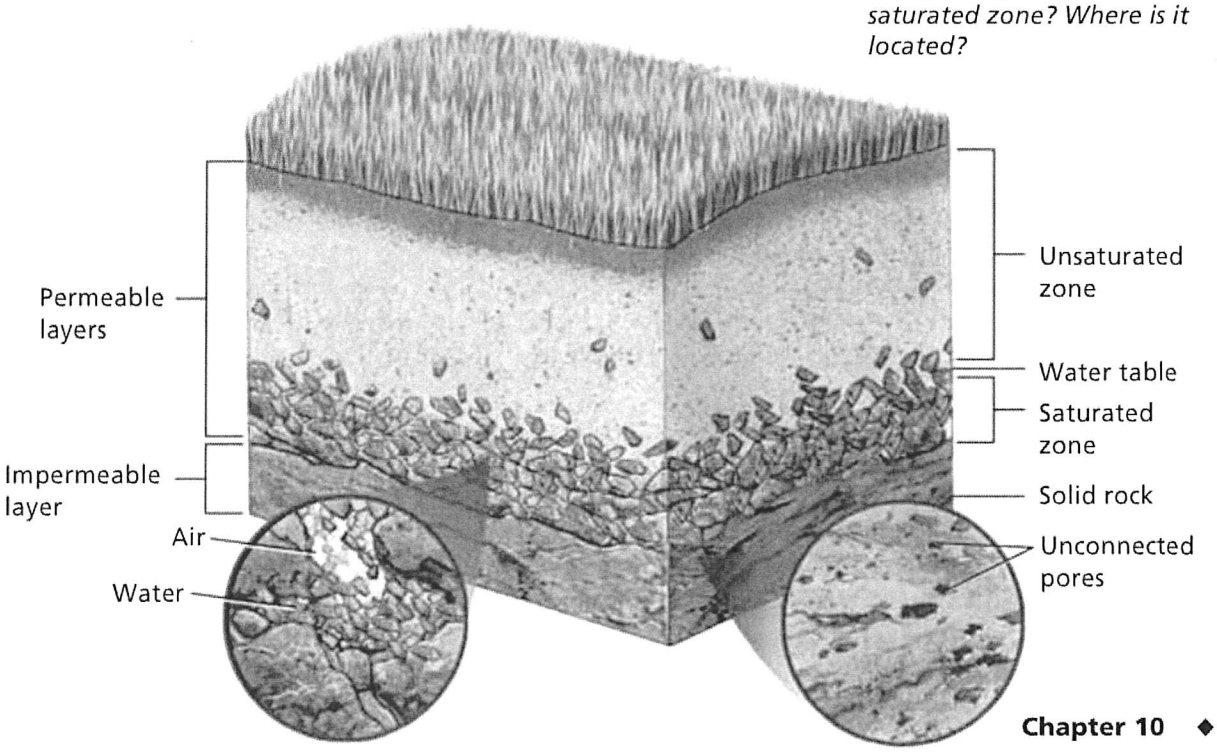


FIGURE 10
Groundwater Formation
Differences in the materials that form layers underground determine where groundwater forms. Water can move through certain layers but not others.
Interpreting Diagrams *What is the saturated zone? Where is it located?*

Bringing Up Groundwater

Suppose you live far from a city, town, or body of fresh water. How could you reach groundwater to use it for your daily needs? You may be in luck: the water table in your area might be only a few meters underground. In fact, in some places the water table actually meets the surface. **Springs** can form as groundwater bubbles or flows out of cracks in the rock. A short distance away, the water table may be deep underground.

Aquifers Any underground layer of rock or sediment that holds water is called an **aquifer.** Aquifers can range in size from a small underground patch of permeable material to an area the size of several states. The huge Ogallala aquifer lies beneath the plains of the Midwest, from South Dakota to Texas. Millions of people obtain drinking water from this aquifer. The aquifer also provides water for crops and livestock.

Do you picture groundwater as a large, still pool beneath Earth's surface? In fact, the water is moving, seeping through layers of rock. The rate of movement depends largely on the slope of the aquifer and the permeability of the rocks. Groundwater in some aquifers moves only a few centimeters a day. At that rate, the water moves about 10 meters a year. Groundwater may travel hundreds of kilometers and stay in an aquifer for thousands of years before coming to the surface again.

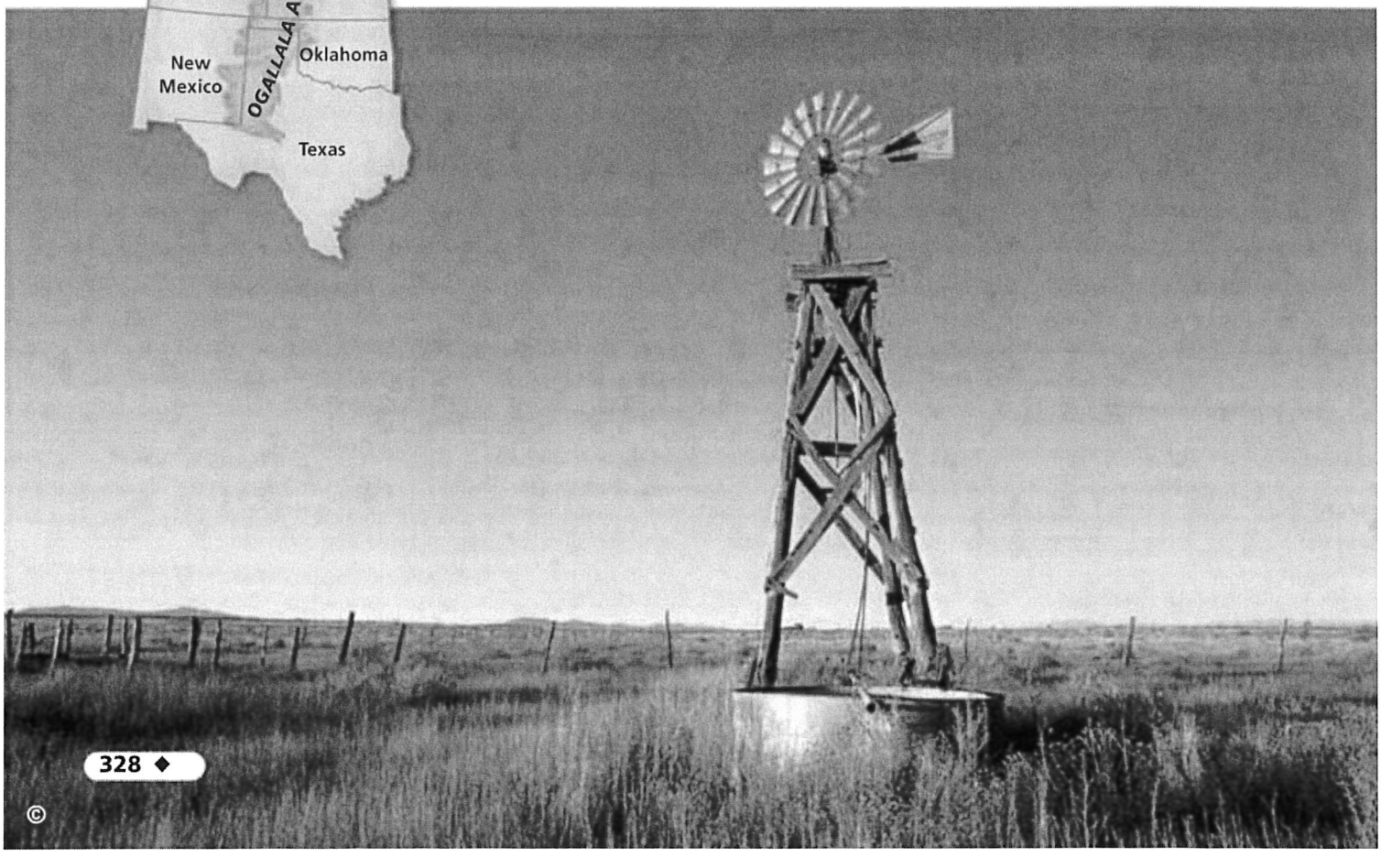


FIGURE 11
Ogallala Aquifer
The Ogallala aquifer is a main source of water for farming, ranching, and human consumption in eight states.

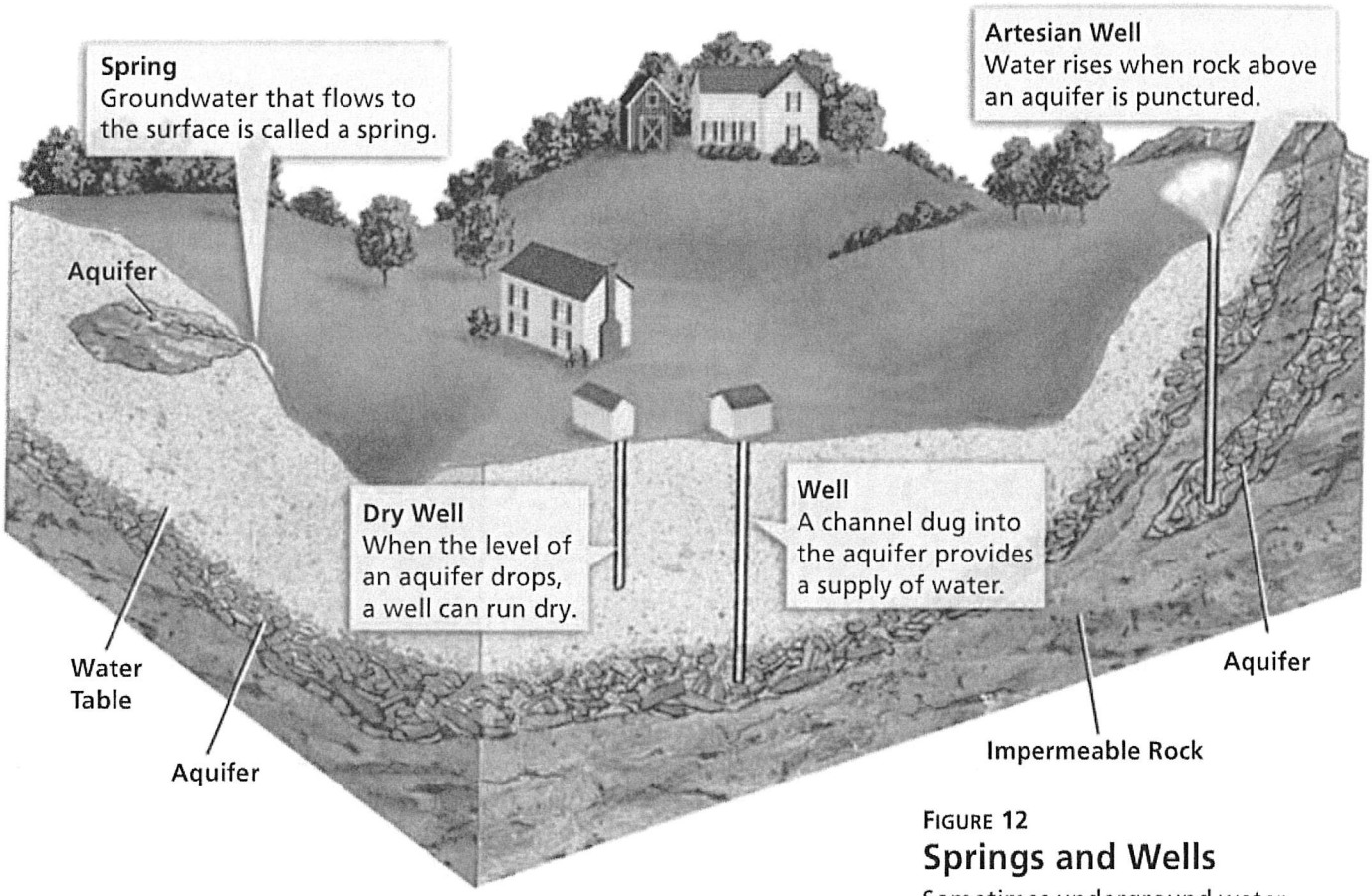


FIGURE 12
Springs and Wells
Sometimes underground water comes to the surface naturally. Other times, people use energy to obtain groundwater.
Comparing and Contrasting *How do the ordinary well and the dry well differ?*

Wells The depth of a water table can vary greatly over a small area. Its level may vary as well. Generally, the level of a water table follows the shape of underground rock layers, as shown in Figure 12. But it can rise during heavy rains or snow melts, and then fall in times of dry weather. So what do you do if the depth and level of the water table in your area is far underground? How can you bring the water to the surface?

Since ancient times, people have brought groundwater to the surface for drinking and other everyday uses. **People can obtain groundwater from an aquifer by drilling a well below the water table.** Locate the well near the center of Figure 12. Because the bottom of the well is in a saturated zone, the well contains water. Notice the level of the bottom of the dry well in the diagram. Because this well does not reach below the water table, water cannot be obtained from it.

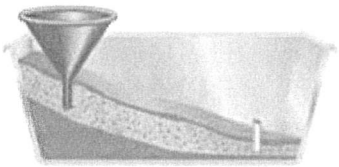
Reading Checkpoint **Why might a water table rise? Why might a water table fall?**

Lab zone **Try This Activity**

An Artesian Well

For this activity, cover your desk with newspaper.

1. Cover the bottom of a loaf pan with clay. Pile the clay higher at one end. Cover the clay with about 4 cm of moist sand.
2. Cover the sand with a thin sheet of clay. Seal the edges of the clay tightly against the pan.
3. Push a funnel into the high end so the bottom of the funnel is in the sand.



4. Insert a short piece of plastic straw through the clay and into the sand layer at the low end. Remove the straw, discard it, and then insert a new piece of straw into the same hole.
5. Slowly pour water into the funnel. Do not let the water overflow.
6. Observe the level of water in the straw.

Making Models How is your model like a real artesian well? How is it different?

Using Pumps Long ago, people dug wells by hand. They lined the sides of the well with brick and stone to keep the walls from collapsing. To bring up the water, they lowered and raised a bucket. People may also have used simple pumps, like the one shown in Figure 13. Today, however, most wells are dug with well-drilling equipment. Mechanical pumps bring up the groundwater.

Pumping water out of an aquifer lowers the water level near the well. If too much water is pumped out too fast, a well may run dry. The owners of the well will have to dig deeper to reach the lowered water table, or wait for rainfall to refill the aquifer. New water that enters the aquifer from the surface is called recharge.

Relying on Pressure Now you know how to bring groundwater to the surface. But what if that doesn't work? You might not be out of luck. You might be able to drill an artesian well. In an **artesian well** (ahr TEEZH un), water rises because of pressure within an aquifer.

Look back at Figure 13 and locate the artesian well. In some aquifers, groundwater becomes trapped between two layers of impermeable rock or sediment. This water is under great pressure from the weight of the rock above. If the top layer of rock is punctured, the pressure sends water spurting up through the hole. No pump is necessary—in an artesian well, pressure does the job.

FIGURE 13
Working for Water Here a resident of Bangladesh uses a hand pump to bring groundwater to the surface.
Interpreting Photographs *What is one disadvantage of a hand pump?*

Springs and Geysers Sometimes, groundwater comes to the surface through natural processes. Recall that places where groundwater bubbles or flows out of cracks in the rock are called springs. Most springs contain water at normal temperatures. Others, like those in Figure 14, contain water that is warmed by the hot rocks deep below the surface. The heated water bubbles to the surface in hot springs.

In some areas, you might see a fountain of boiling hot water and white steam burst into the air. This is a **geyser** (GY zur), a type of hot spring from which the water periodically erupts. The word *geyser* comes from an Icelandic word, *geysir*, which means "gusher."

A geyser forms when very hot water that has been circulating deep underground begins to rise through narrow passages in the rock. Heated gases and bubbles of steam are forced up these passages by the pressure of the hot water boiling below. Just as pressure builds up in a partly blocked water pipe, the pressure within these narrow openings in the rock increases. Finally, the gases, steam, and hot water erupt high into the air.

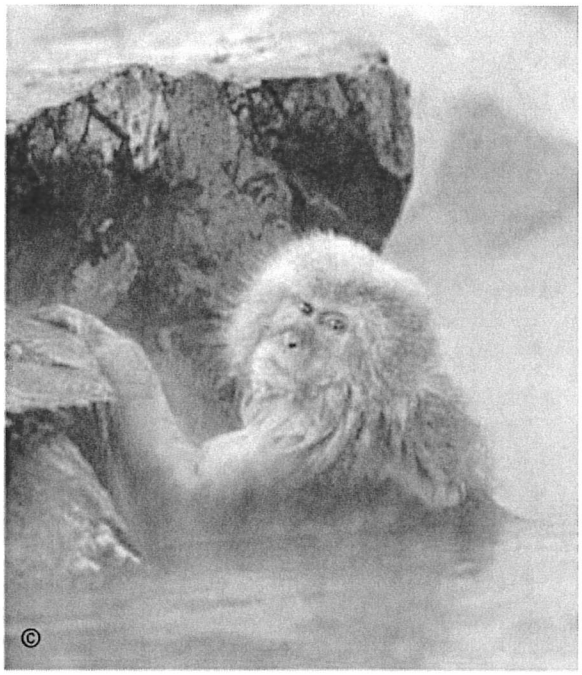


FIGURE 14
A Hot Spring
A Japanese macaque takes advantage of the warm water that rises to the surface of a hot spring in Nagano, Japan.

Reading Checkpoint **How do geysers form?**

Section 3 Assessment

Target Reading Skill Previewing Visuals
Refer to your questions and answers about Figure 12 to help you answer Question 2 below.

Reviewing Key Concepts

HINT
1. a. Reviewing How does water move underground?

HINT
b. Explaining Explain the two factors that determine how easily water can move through underground materials.

HINT
c. Comparing and Contrasting How are the saturated zone and the unsaturated zone similar? How are they different?

HINT
2. a. Describing How can people obtain water from an aquifer?

HINT
b. Interpreting Diagrams Using Figure 12 as a guide, explain why is it important to know the depth of an aquifer before drilling a well.

HINT
c. Problem Solving During the winter, you draw your water from a well on your property. Every summer, the well dries up. What might be the reason for the change?

Writing in Science

Formal Letter Water use in your town has risen in recent years due to population growth. Your town obtains its water from a nearby aquifer. You are concerned that the water level of the aquifer may be going down. Write a letter to local government officials explaining your concerns. Describe the effect of heavy water use on the aquifer and suggest measures that can be taken to avoid a water shortage.

Soil Testing

Problem

How fast does water move through sand, clay, and pebbles?

Skills Focus

observing, developing hypotheses, designing experiments

Suggested Materials

- hand lens
- 100 mL of sand
- stopwatch
- 3 rubber bands
- 3 100-mL beakers
- 300 mL of water
- 100 mL of pebbles
- 100 mL of powdered potter's clay
- 3 squares of cheesecloth
- 3 large funnels or cut-off plastic bottle tops

Procedure

PART 1 Observing the Flow of Water Through Sand

1. Copy the data table in your notebook.
2. Use a hand lens to observe the sand sample closely. Record your observations in your data table.
3. Place a piece of cheesecloth over the bottom of one funnel or bottle top and secure it with a rubber band.
4. Place the sand in the funnel. Be sure that there is about 5 cm of space above the sand in the funnel.
5. Place the funnel on top of a beaker.

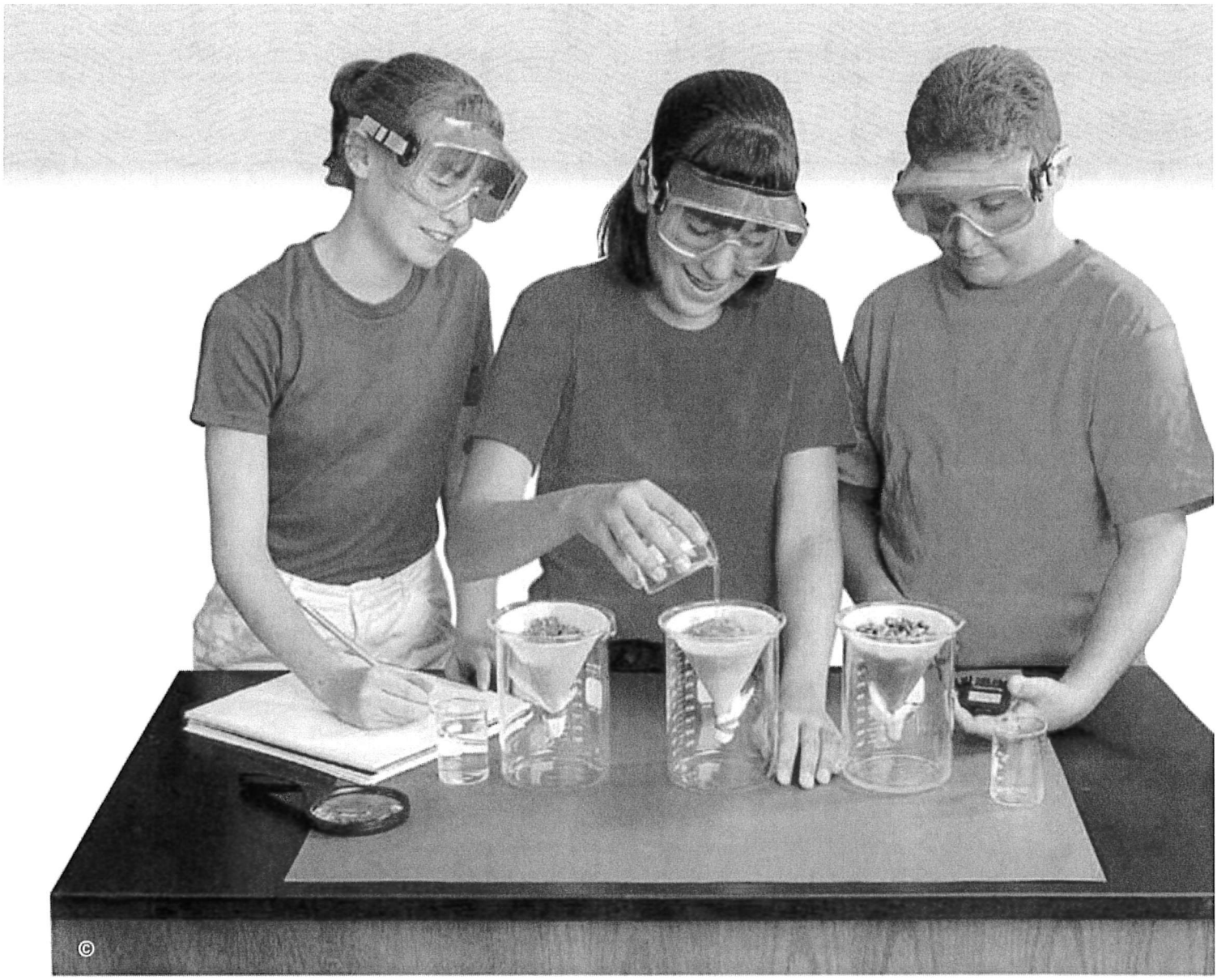
Data Table

Material	Observations	Time for Water to Stop Dripping
Sand		
Clay		
Pebbles		

6. Slowly pour 100 mL of water into the funnel. Do not let the water overflow the funnel.
7. Start the stopwatch when the water begins to flow or drip out of the funnel.
8. Stop the stopwatch when the water stops dripping out of the funnel or after 5 minutes. Record the time to the nearest second in your data table.

PART 2 Comparing the Flow of Water Through Different Soil Samples

9. Use a hand lens to observe each of the two other material samples closely. Record your observations in the data table.
10. Using the procedures you followed in Part 1, design an experiment to compare the flow of water through sand, clay, and pebbles. Be sure to write a hypothesis and to control all necessary variables.
11. Submit your experimental plan to your teacher. After making any necessary changes, carry out your experiment. Record your observations in your data table.
12. When you are finished with this activity, dispose of the materials according to your teacher's instructions. Wash your hands thoroughly with soap.



Analyze and Conclude

1. **Observing** In Part 1, how did the sand look under the hand lens? How long did it take the water to flow through the sand?
2. **Developing Hypotheses** What hypothesis did you test in Part 2? On what did you base your hypothesis?
3. **Designing Experiments** What was the manipulated variable in Part 2? What was the responding variable?
4. **Drawing Conclusions** Through which material did water move the fastest? The slowest? What can you conclude about the permeability of the three materials?
5. **Predicting** Based on the results of this lab, would you expect to get more water from a well dug in sand, pebbles, or clay? Explain.
6. **Communicating** You and your neighbor are discussing your gardens. You're explaining that it's important for a gardener to know the permeability of different soils. Write your conversation in dialogue form. Use quotation marks for each speaker.

More to Explore

Of the soil samples you tested, which do you think most resembles the soil on the grounds at your school? Explain your reasoning. How might you test your hypothesis?

Section 4

Using Freshwater Resources

Reading Preview

Key Concepts

- How do people use water?
- What are some ways to conserve available fresh water?
- How do scientists classify sources of water pollution?

Key Terms

- irrigation • conservation
- water pollution • pollutant
- point source • nonpoint source

Target Reading Skill

Using Prior Knowledge Before you read, write what you know about water conservation in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. I can conserve water by taking shorter showers.
2.

What You Learned
1.
2.

Lab zone Discover Activity

Can You Find a Balance?

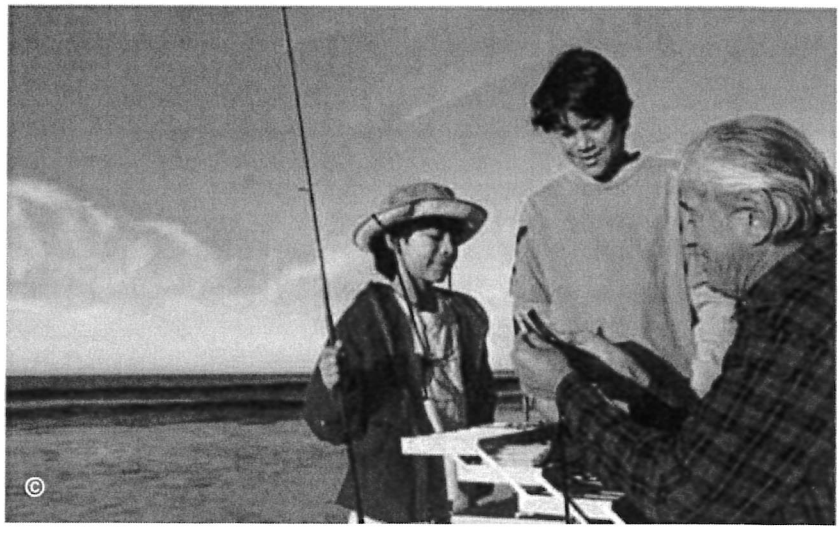
1. Fill a large measuring cup with water to represent a reservoir. Record the level of the water. One partner, the water supplier, should have a plastic dropper and a small bowl of water. The other partner, the water user, should have a spoon and an empty bowl.
2. Start a stopwatch. For two minutes, the water supplier should add water to the measuring cup one dropperful at a time. Each time the water supplier adds a dropperful of water, the water user should remove one spoonful of water from the reservoir.
3. At the end of two minutes, record the level of water in the cup.
4. Now increase the rate of water use by removing two spoonfuls of water for every dropperful added.
5. After two minutes, record the level of water in the cup.

Think It Over

Predicting What changes will you need to make so that the water level in the reservoir stays constant?

If you have ever gone fishing, you know that it can be exciting. You cast your fishing line out over the smooth, dark blue water. As you gently reel in the line, suddenly you feel a slight pull that quickly grows to a strong tug. You've caught a fish!

Good fishing depends on a supply of clean, fresh water in rivers and lakes. Yet there are many other uses of fresh water. Some of these uses can reduce the overall water supply or make the water unsuitable for fishing.



This family is enjoying a freshwater resource—fish. ▶

How People Use Water

Think about the ways that people use water in your community. As you walk around your neighborhood on a hot summer afternoon, you might see young children running through a sprinkler. Nearby, someone is watering plants or washing a car. Across the United States, thousands of different uses consume more than 1,280 billion liters of water every day.

People use water for household purposes, industry, transportation, agriculture, and recreation. As cities grow, so too does the water needed for household uses. Industries also need water to cool machinery and produce materials such as paper. Meanwhile, farmers need a large amount to water their fields. Cities, industries, and farms compete for water rights—the legal right to take water from a particular source.

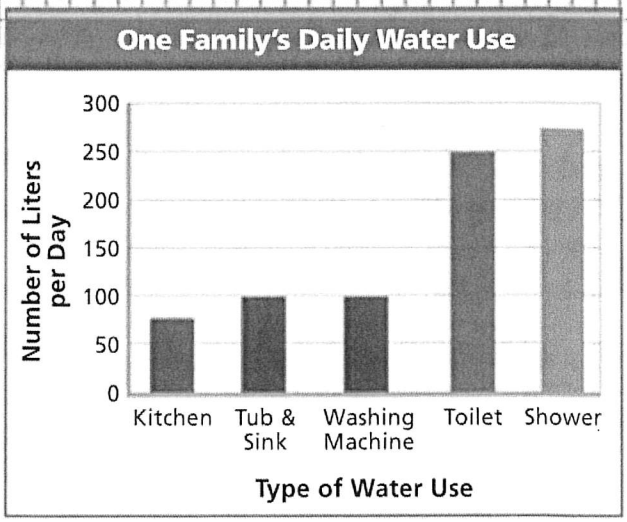
In some parts of the United States, such as the Southwest, water is scarce. As you know, water is constantly recycled in the water cycle. However, sometimes water is used faster than it can be replaced by precipitation. A water shortage occurs when there is too little water or too great a demand in an area—or both. A water shortage may occur because of natural processes or because of rapidly growing human water needs.

Math Analyzing Data

Household Water Use

A family conducted a survey of their current water use. Their average daily use is shown in the bar graph. Study the graph and answer the following questions.

1. **Reading Graphs** What variable is shown on the horizontal axis? What variable is shown on the vertical axis?
2. **Interpreting Data** Where does this family use the greatest amount of water?
3. **Calculating** The family uses an average of about 800 liters of water per day. What percentage of the water is used for laundry?
4. **Inferring** Do you think the family's water use would vary during the year? Explain.



5. **Predicting** Suggest three ways that this family might be able to save a significant amount of water each day.

In the Home Take a minute to list all of the ways you used water this morning. You probably washed your face, brushed your teeth, and flushed the toilet. Perhaps you drank a glass of water or used water to make oatmeal. These are some common uses of water in the home.

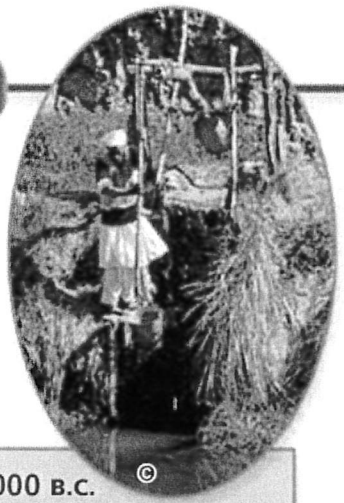
Industry and Transportation Think about the objects in your backpack—books, pens, folders. Even though water is not part of these things, it plays a role in making them. Industries use water in other ways, too. For example, power plants and steel mills both need huge volumes of water to cool hot machinery. Water that is used for cooling can often be recycled.

Since ancient times, water has been used to transport people and goods. If you look at a map of the United States, you will notice that many large cities are located on the coasts. Ocean travel led to the growth of these port cities. In early America, rivers also served as natural highways.

• Tech & Design in History •

Water and Agriculture

Plants require a steady supply of water to grow. How have farmers throughout history provided their crops with water? This timeline shows some methods developed in different parts of the world.



3000 B.C. Irrigation
One of the oldest known methods of irrigation was developed for growing rice. Farmers built paddies, or artificial ponds with raised edges. The farmers flooded the paddies with water from a nearby stream. This ancient technique is still widely used throughout Southeast Asia.

2000 B.C. Shadufs
Egyptian farmers invented a device to raise water from the Nile River. The shaduf acted as a lever to make lifting a bucket of water easier. The farmers then emptied the water into a network of canals to irrigate their fields. The shaduf is still in use in Egypt, India, and other countries.

700 B.C. Canals and Aqueducts
Sennacherib, king of the ancient nation Assyria, surrounded the capital city of Nineveh with fruit trees and exotic plants. To help irrigate the gardens, he built a canal and an aqueduct to transport water from the nearby hills.

3000 B.C. 2000 B.C. 1000 B.C.

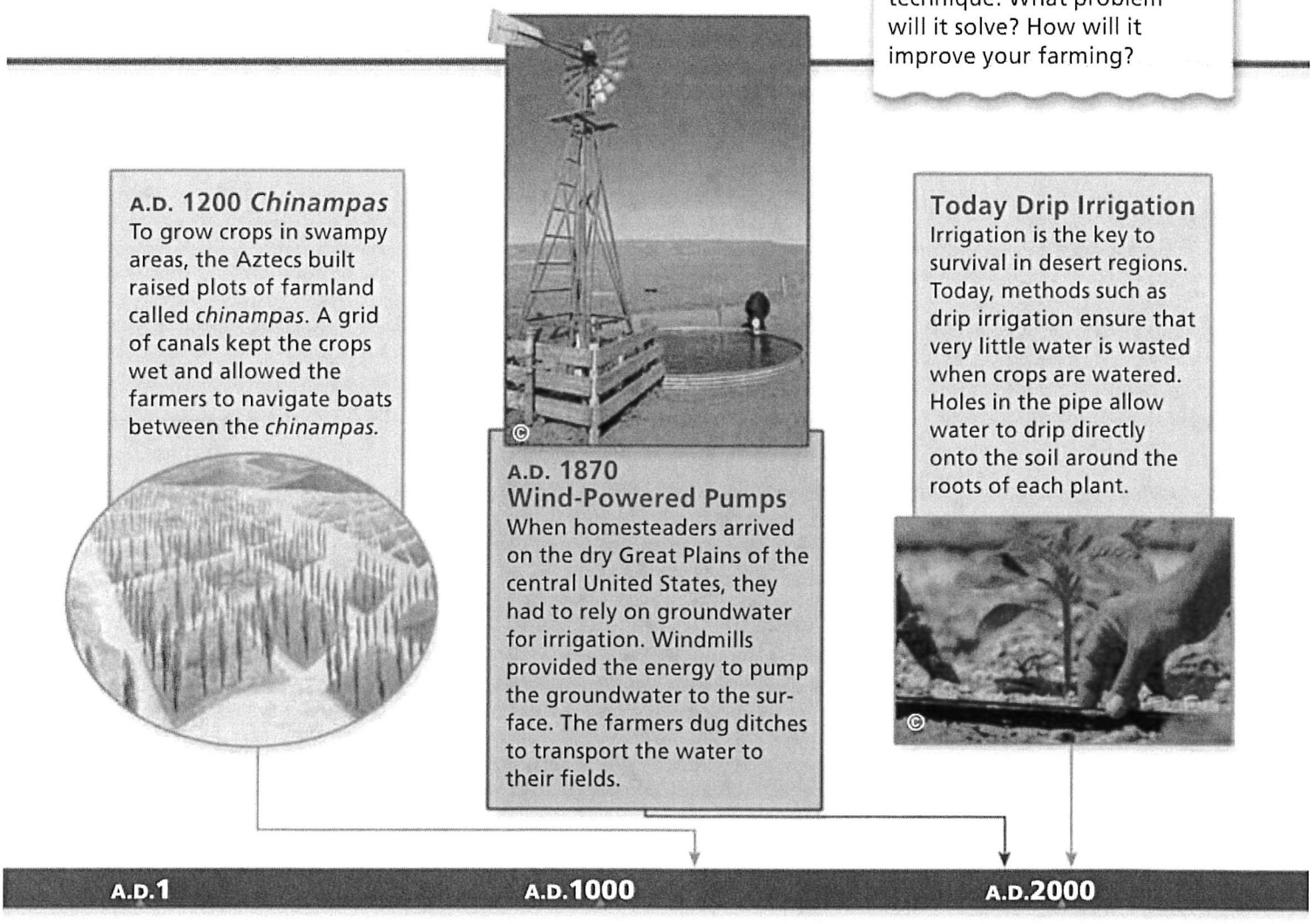
Agriculture Has your family ever had a garden? If so, you know that growing fruits and vegetables requires water. On a large farm, a constant supply of fresh water is essential. However, some areas don't receive enough regular rainfall for agriculture. In such places, farmland must be irrigated. **Irrigation** is the process of supplying water to areas of land to make them suitable for growing crops. In the United States, more water is used for irrigation than for any other single purpose.

Recreation Do you like to swim in a neighborhood pool? Catch fish from a rowboat in the middle of a lake? Walk along a beach collecting seashells? Or maybe just sit on the edge of a dock and dangle your feet in the water? Then you know some ways that water is used for recreation. And if you brave the winter cold to ski or skate, you are enjoying water in its frozen form.

Reading Checkpoint **List a household use, an industrial use, and an agricultural use of water.**

Writing in Science

Research and Write Find out more about one of these agricultural techniques. Imagine that you are a farmer seeing the method in action for the first time. Write a letter to a friend describing the new technique. What problem will it solve? How will it improve your farming?



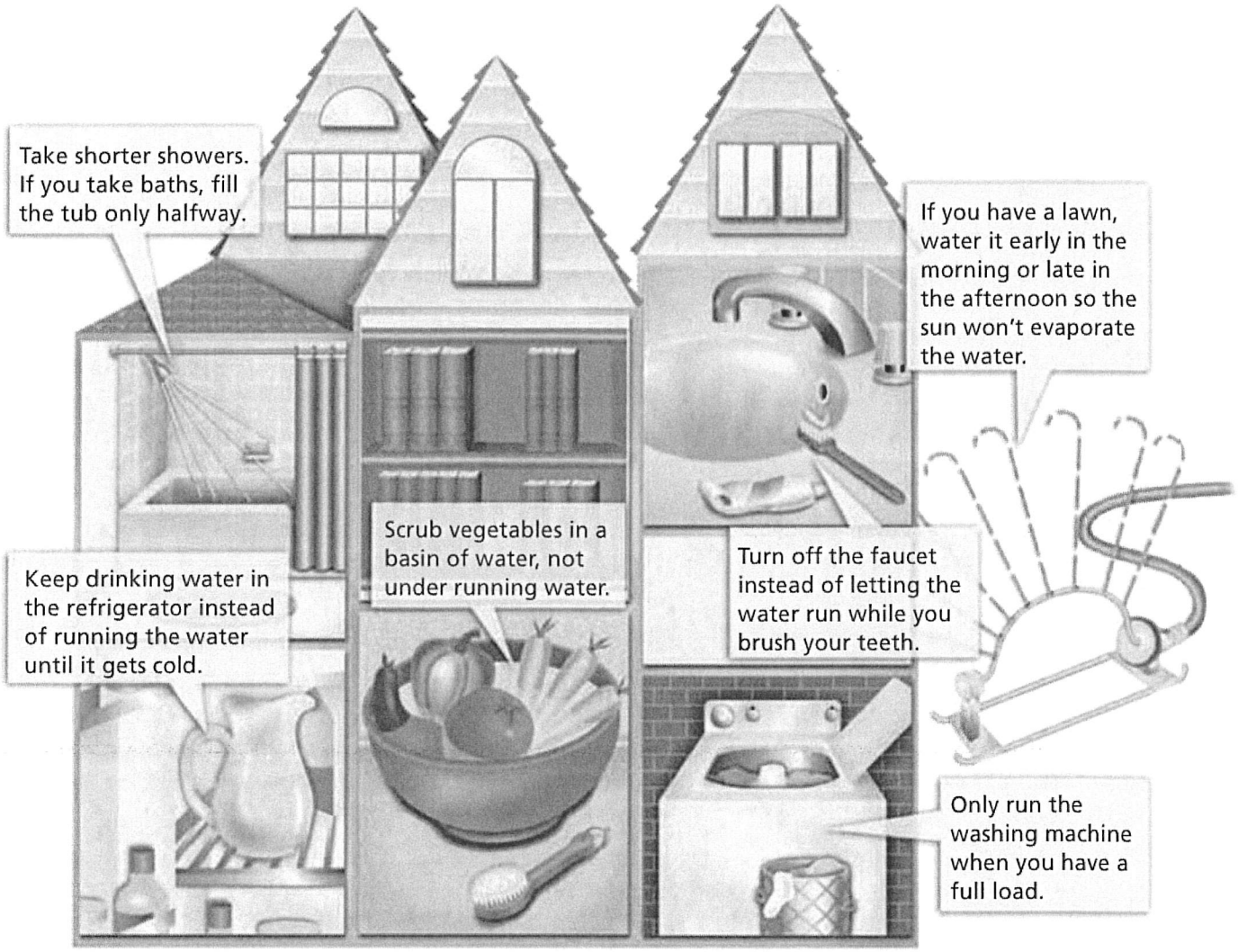


FIGURE 15

Conserving Water at Home

There are many simple ways to conserve water at home.
Developing Hypotheses *Which of these ideas do you think would save the most water per day in your home? How could you test your hypothesis?*

Conserving Water

During a water shortage, people often try to avoid wasting water. **Conservation** is the practice of using less of a resource so that it will not be used up. **Reducing water use, recycling water, and reusing water are three ways to conserve water.**

In the Home Most people in the United States have access to as much clean, safe water as they want. As a result, they often use more water than they need without thinking much about it. But as Figure 15 shows, there are some simple things you can do to help conserve water around your home.

Can these suggestions really help? Figure it out. For every minute you shower, you use about 18 liters of water. If you shower for 10 minutes, that's about 180 liters. But if you showered for 5 minutes, you would use only 90 liters. And if each student in a class of 25 showered for 5 minutes instead of 10, they would save a total of 2,250 liters of water!

In Industry Many industries have made changes in their manufacturing processes to use less water. For example, in the 1950s it took about 227,000 liters of water to make 1,000 kilograms of writing paper. By the 1980s, paper mills needed only half that much water to make the same amount of paper.

New water-saving techniques help industries save money in water costs and meet the requirements of environmental laws. These techniques conserve water while also reducing the amount of wastewater that plants release. For example, some factories that use water to cool machinery now build cooling pools on their property. The heated water cools off in the pools and then can be used again.

In Agriculture Agriculture accounts for the highest consumption of water in the United States. In the last few decades, farmers have found new ways to use less water. When water flows into fields in open ditches, much of it is lost through evaporation. Using pipes to carry water reduces the water loss.

Sprinkler irrigation and drip irrigation both use pipes to conserve water. Sprinkler irrigation sprays water onto crops from overhead pipes. Drip irrigation distributes water through pipes with tiny holes that lie close to the ground. Water drips onto the soil near the plants' roots so that very little is wasted.

Reading Checkpoint **How do sprinkler irrigation and drip irrigation differ?**

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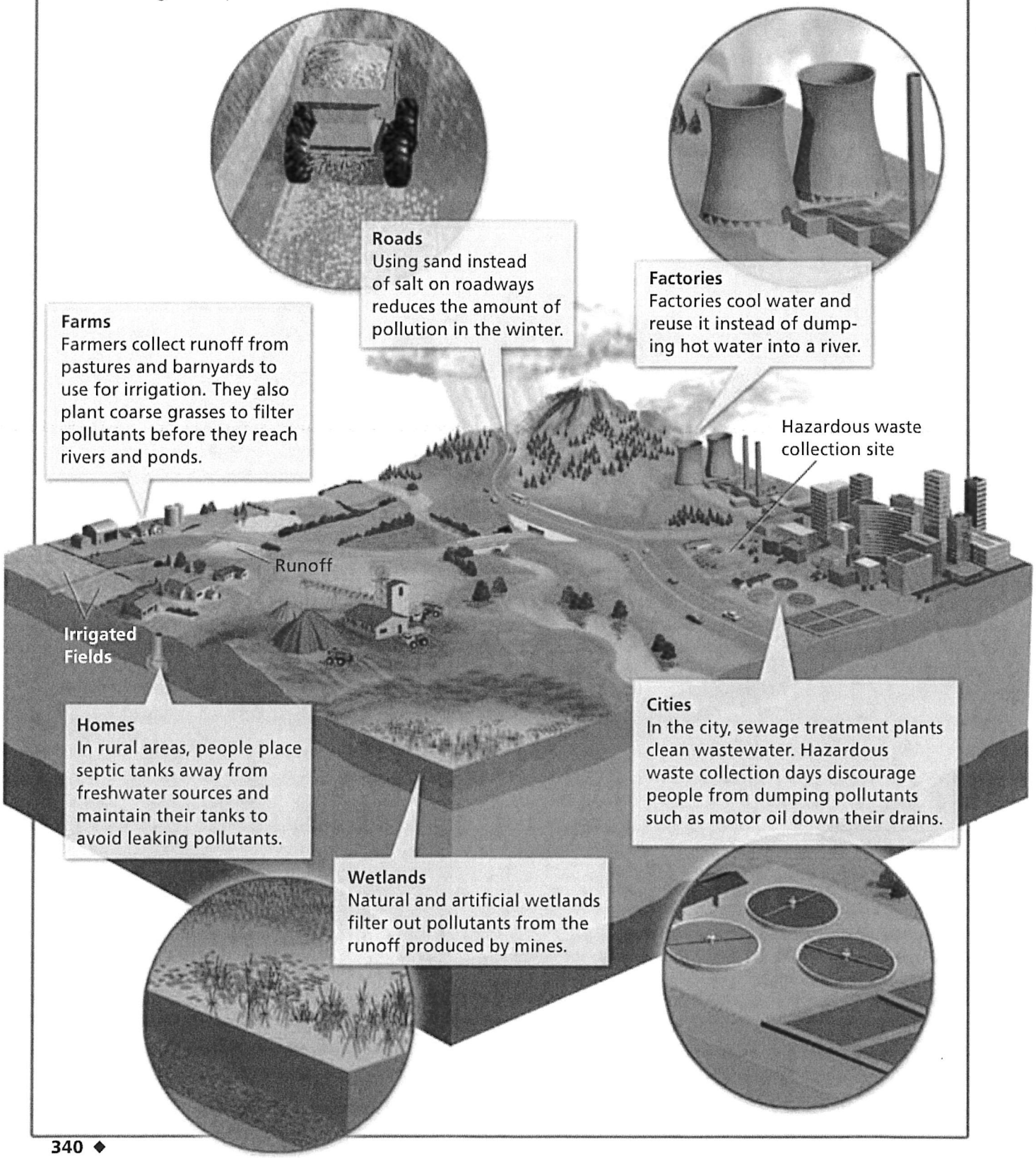
FIGURE 16
Conserving Water on Farms
One way that farmers can conserve water is to use sprinkler irrigation systems to water their crops.
Relating Cause and Effect *How does sprinkler irrigation conserve water?*

FIGURE 17

Pollution Solutions

People can prevent or clean up pollution in many ways. **Interpreting Diagrams** *What are two ways of reducing water pollution on farms?*



What Is Pollution?

Water pollution is the addition of any substance that has a negative effect on water or the living things that depend on the water. The substances that cause water pollution are called **pollutants.**

Scientists classify sources of pollution, in part, by how they enter a body of water. For example, suppose you notice a pipe gushing brightly colored water into a river. The pipe is a **point source,** a specific source of pollution that can be identified. In contrast, a widely spread source of pollution that can't be tied to a specific point of origin is called a **nonpoint source.** Examples of nonpoint sources include runoff from farm fields, streets, or construction sites.

There are many ways in which industries, farms, and homes can reduce water pollution. Figure 17 shows some of these techniques. At home, you can help to reduce water pollution. Dispose of toxic substances properly. For example, never pour paint or motor oil down the drain. Instead, take them to sites that collect hazardous waste.

Reading Checkpoint **What are pollutants?**

FIGURE 18
Preventing Water Pollution
One way you can help prevent water pollution is to educate others about its causes. This student has stenciled a storm drain to remind people of its connection to a nearby river.

Section 4 Assessment

Vocabulary Skill Identify Related Word Forms Choose one of the following words—*conserve, conservation, conserved*—to complete the following sentence: Farmers can use crop rotation to _____ valuable topsoil.

Reviewing Key Concepts

HINT
1. a. Listing Name five ways that people use water.

HINT
b. Describing How is water used in agriculture?

HINT
c. Predicting What might happen to the supply of water for agriculture in a region with a rapidly growing city?

HINT
2. a. Identifying What are three ways to conserve water?

HINT
b. Describing Describe the techniques that industries can use to conserve water.

HINT
c. Making Judgments To conserve water, should communities limit how often people can water their lawns or wash their cars? Why or why not?

HINT
3. a. Defining What is a point source of pollution? What is a nonpoint source?

HINT
b. Classifying In winter, some communities spread salt on the roads to melt ice. Runoff containing salt can flow into nearby streams or lakes. Is this an example of point

Lab zone **At-Home Activity**

Monitoring Water Use To show family members one way of conserving water, brush your teeth twice. The first time, allow the water to run into the sink with a stopper in the drain. When you're finished brushing, mark the water level with a piece of tape. Drain the sink, then replace the stopper and brush again. This time, use the water only when you need to. Point out the difference in the amount of water used.

Lab zone **Consumer Lab**

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Testing Water

Problem

How do distilled water, spring water, and mineral water differ from tap water?

Skills Focus

observing, inferring, drawing conclusions

Materials

- hot plate
- liquid soap
- ruler
- wax pencil
- tap water, 200 mL
- distilled water, 200 mL
- spring water, 200 mL
- mineral water, 200 mL
- 4 250-mL beakers
- 4 test tubes and stoppers
- 4 pieces of pH paper
- test tube rack
- 25-mL graduated cylinder
- pH indicator chart
- 4 paper cups per person

Procedure

1. Copy the data table into your notebook.
2. Label the beakers A, B, C, and D. Pour 100 mL of tap water into beaker A. Pour 100 mL of the other water samples into the correct beaker (refer to the data table).
3. Heat each water sample on a hot plate until about 20 mL remains. Do not allow the water to boil completely away. **CAUTION:** *Do not touch the hot plate or beakers with your bare hands.*
4. After the water samples have cooled, look for solids that make the water cloudy. Rank the samples from 1 to 4, where 1 has the fewest visible solids and 4 has the most visible solids. Record your rankings in the data table.
5. Label the test tubes A, B, C, and D. Pour 10 mL of each water sample from the source bottle into the correct test tube.
6. Dip a piece of pH paper into test tube A to measure its acidity. Match the color of the pH paper to a number on the pH indicator chart. Record the pH (0–14) in your data table.
7. Repeat Step 6 for the other samples.
8. Add two drops of liquid soap to test tube A. Put a stopper in the test tube and shake it 30 times. With the ruler, measure the height of the soapsuds in the test tube. Record the measurement in your data table.
9. Repeat Step 8 for the other samples.
10. Label the four cups A, B, C, and D. Write your name on each cup.
11. Pour a little tap water into cup A directly from the original source bottle. Taste the tap water. In your data table, describe the taste using one or more of these words: *salty, flat, bitter, metallic, refreshing, tasteless.* **CAUTION:** *Do not conduct the taste test in a lab room. Use a clean cup for each sample and discard it after use.*
12. Repeat Step 11 with the other samples.

Data Table

Water Sample	Visible Solids (1–4)	pH (0–14)	Soapsud Height (cm)	Taste
A – Tap Water				
B – Distilled Water				
C – Spring Water				
D – Mineral Water				

Analyze and Conclude

1. Observing Review your data table. Compare each of the bottled water samples to the tap water sample. What similarities and differences did you detect?
2. Inferring Rank the samples from the one with the fewest soapsuds to the one with the most. Compare this ranking to the one for visible solids. What pattern do you see? What do both of these tests have to do with the hardness of water?
3. Posing Questions What other information about the water samples might you need before deciding which one to drink regularly? Explain.
4. Drawing Conclusions Based on your results, which sample would you most want to use for (a) drinking, (b) boiling in a teakettle, and (c) washing laundry? Which sample would you least want to use for each purpose? Explain.
5. Communicating Create a brochure to educate consumers about water quality. Include information about acidity, hardness, and other factors that can affect the appearance, taste, and safety of drinking water.

More to Explore

Conduct a survey to find out what percentage of people buy bottled mineral water, distilled water, and spring water. Why do they buy each type of water, and how do they use it in their homes?

Chapter 10 Study Guide

The BIG Idea

Earth's waters In the water cycle, water moves continuously from oceans, rivers, and other sources to the atmosphere and back by the processes of evaporation, condensation, and precipitation.

1 Water on Earth

Key Concepts

In the water cycle, water moves from bodies of water, land, and living things on Earth's surface to the atmosphere and back to Earth's surface.

Most of Earth's water—roughly 97 percent—is salt water found in oceans. Only 3 percent is fresh water.

Key Terms

water cycle
precipitation
groundwater

2 Surface Water

Key Concepts

A river and all its tributaries together make up a river system.

In general, ponds are smaller and shallower than lakes. Sunlight usually reaches to the bottom of all parts of a pond.

Lakes are generally bigger and deeper than ponds. Sunlight does not reach the bottom in a deep lake, as it does in a pond.

The three common types of freshwater wetlands are marshes, swamps, and bogs.

Wetlands provide habitats for many living things. Wetlands help people by acting as natural water filters and by helping to control floods.

Key Terms

tributary
watershed
divide
habitat
reservoir
wetland

3 Water Underground

Key Concepts

Water underground trickles down between particles of soil and through cracks and spaces in layers of rock.

People can obtain groundwater from an aquifer by drilling a well below the water table.

Key Terms

permeable
impermeable
saturated zone
water table
unsaturated zone
spring
aquifer
artesian well
geyser

4 Using Freshwater Resources

Key Concepts

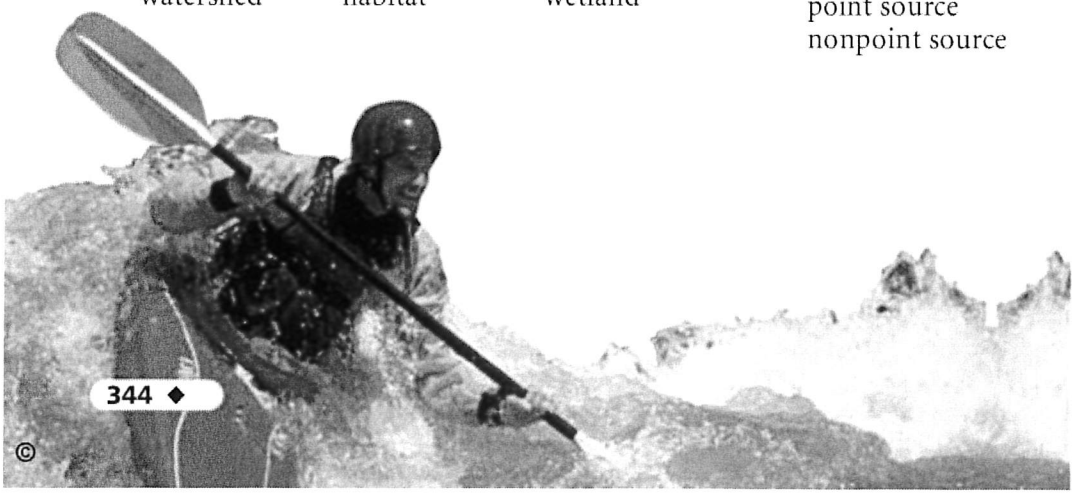
People use water for household purposes, industry, transportation, agriculture, and recreation.

Reducing water use, recycling water, and reusing water are three ways to conserve water.

Scientists classify sources of water pollution by how they enter a body of water.

Key Terms

irrigation
conservation
water pollution
pollutant
point source
nonpoint source



Review and Assessment

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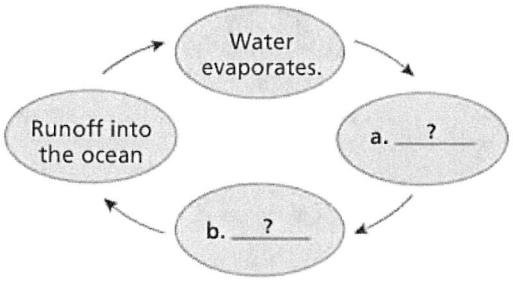
Organizing Information

Sequencing Copy and complete the cycle diagram to show how water moves throughout the water cycle. (For more on Sequencing, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

HINT
1. More than 97 percent of Earth's total water supply is found in
   a. ice sheets.
   b. the atmosphere.
   c. the oceans.
   d. groundwater.

HINT
2. The land area that supplies water to a river system is called a
   a. divide.
   b. watershed.
   c. wetland.
   d. tributary.

HINT
3. Wetlands help control floods by absorbing
   a. silt and mud.
   b. extra runoff.
   c. nutrients.
   d. waste materials.

HINT
4. The water table is the top of the
   a. saturated zone.
   b. unsaturated zone.
   c. aquifer.
   d. artesian well.

HINT
5. An underground layer of rock or sediment that holds water is called a(n)
   a. spring.
   b. aquifer.
   c. reservoir.
   d. water table.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

HINT
6. One watershed is separated from another by a divide.

HINT
7. An aquifer is an area of land covered with a shallow layer of water during some or all of the year.

HINT
8. Water moves easily through permeable materials.

HINT
9. Conservation is the practice of using less of a resource so that it will not be used up.

HINT
10. A specific source of pollution that can be identified is called a nonpoint source.

Writing in Science

Brochure Write a brochure describing the Florida Everglades. Be sure to include information about why so many organisms live here and why people need to protect the Everglades.

Discovery CHANNEL SCHOOL

Earth: The Water Planet
Video Preview
Video Field Trip
▶ Video Assessment

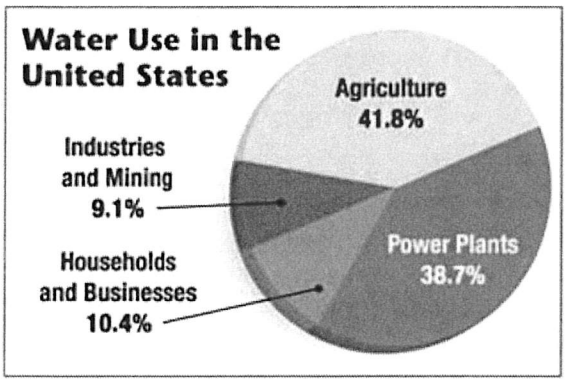
Review and Assessment

Checking Concepts

11. Why is so little of Earth's water available for human use?
12. Can a large river be a tributary? Explain.
13. Describe four ways in which lakes can form naturally.
14. Why doesn't an artesian well require a pump?
15. Describe one way that farmers can reduce the amount of water lost during irrigation.

Thinking Critically

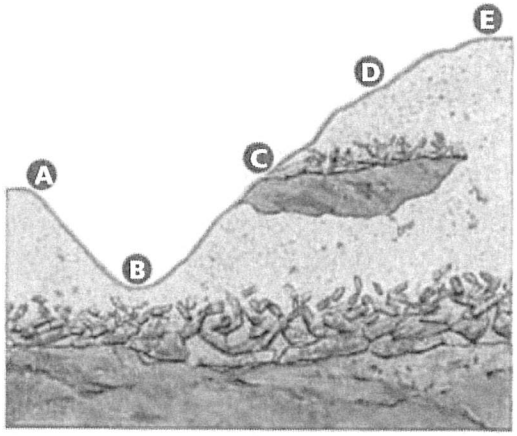
16. **Relating Cause and Effect** The water cycle begins as water evaporates from the surface of bodies of water. What is the energy source for this process? Explain.
17. **Applying Concepts** An engineer drilling a well finds water when the drill reaches 25 meters below the surface. What zone has the drill reached, what zone lies above it, and what do scientists call the level where the two zones meet? Explain.
18. **Inferring** Why are cities and towns often located along coasts or rivers?



19. **Interpreting Data** Which of the four categories of water users shown in the graph represents the largest use of water in the United States? Which is the smallest?
20. **Comparing and Contrasting** How would the variety of organisms in the center of a pond be different from those you would find in deep water at the center of a lake?
21. **Classifying** On a walk in a northern state, you come upon an area of spongy soil. It is carpeted with mosses along with some low-growing, flowering plants. What type of wetland is this likely to be? Explain.

Applying Skills

Use the diagram of underground layers to answer Questions 22–25.



22. **Drawing Conclusions** Would point D or point E be a better location to dig a well? Explain your reasoning.
23. **Inferring** At which location could you obtain groundwater without having to use a pump? What is this location called?
24. **Interpreting Data** At which point is the water table closest to the surface?
25. **Predicting** Draw a simple diagram showing how this area might look during a very rainy season.

Lab zone Chapter Project

Performance Assessment It's time to put your treatment system to the test! Use your system to clean up the dirty water sample. Measure the volume of water recovered by your system. Share your results with your classmates. How do your results compare with theirs?

GA Preparing for the CRCT

Test-Taking Tip

Reading All the Answer Choices

Always read *every* answer choice in a multiple-choice question before selecting the answer you think is correct. If you stop reading as soon as you find an answer that seems correct, you may not notice that "all of the above" is given as one of the answer choices.

Sample Question

Where on Earth is fresh water found?

- **A** icebergs
- **B** rivers and lakes
- **C** groundwater
- **D** all of the above

Answer

The correct answer is **D,** all of the above. Fresh water is found in icebergs, rivers and lakes, and groundwater.

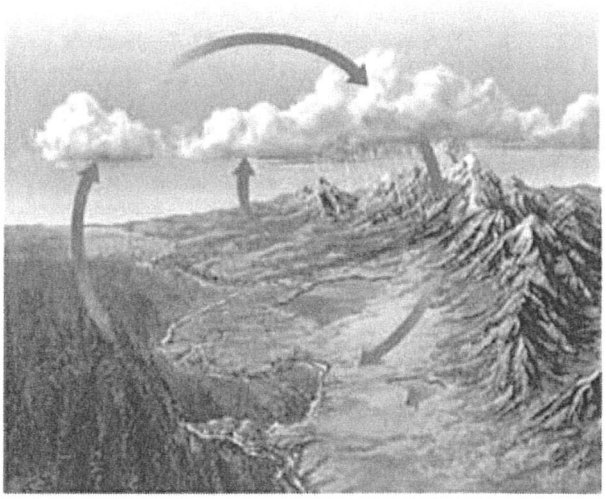
Choose the letter of the best answer.

1. Why don't plants normally grow on the bottoms of deep lakes?
   - **A** The water is too salty.
   - **B** The water is too cold.
   - **C** Photosynthesis does not occur in water.
   - **D** There is not enough sunlight for photosynthesis to occur. **S6E3.a**

2. Which of the following is an example of a point source of water pollution?
   - **A** runoff of pesticides from wheat fields
   - **B** salt spread on parking lots to melt ice
   - **C** chemicals flowing from a factory into a stream
   - **D** fertilizer from corn fields that runs off into streams **S6E5.i**

3. For a science project you must build a model of an aquifer. What material would be the best to use for the layer that will hold water?
   - **A** an impermeable material, such as clay
   - **B** an impermeable material, such as granite
   - **C** a permeable material, such as gravel
   - **D** a material that does not have pores **S6E3.a**

Use the diagram below and your knowledge of science to answer Questions 4–5.



4. Which of the following is a process that occurs in the water cycle?
   - **A** evaporation
   - **B** precipitation
   - **C** condensation
   - **D** all of the above **S6E3.b**

5. What is the energy source that drives the continuous process shown in the diagram?
   - **A** the sun
   - **B** the ocean
   - **C** gravity
   - **D** the tides **S6E6.a**

Constructed Response

6. Explain what a wetland is and why wetlands are important. Describe one threat to wetlands and the actions being taken to protect wetlands from this threat. **S6E3.a**