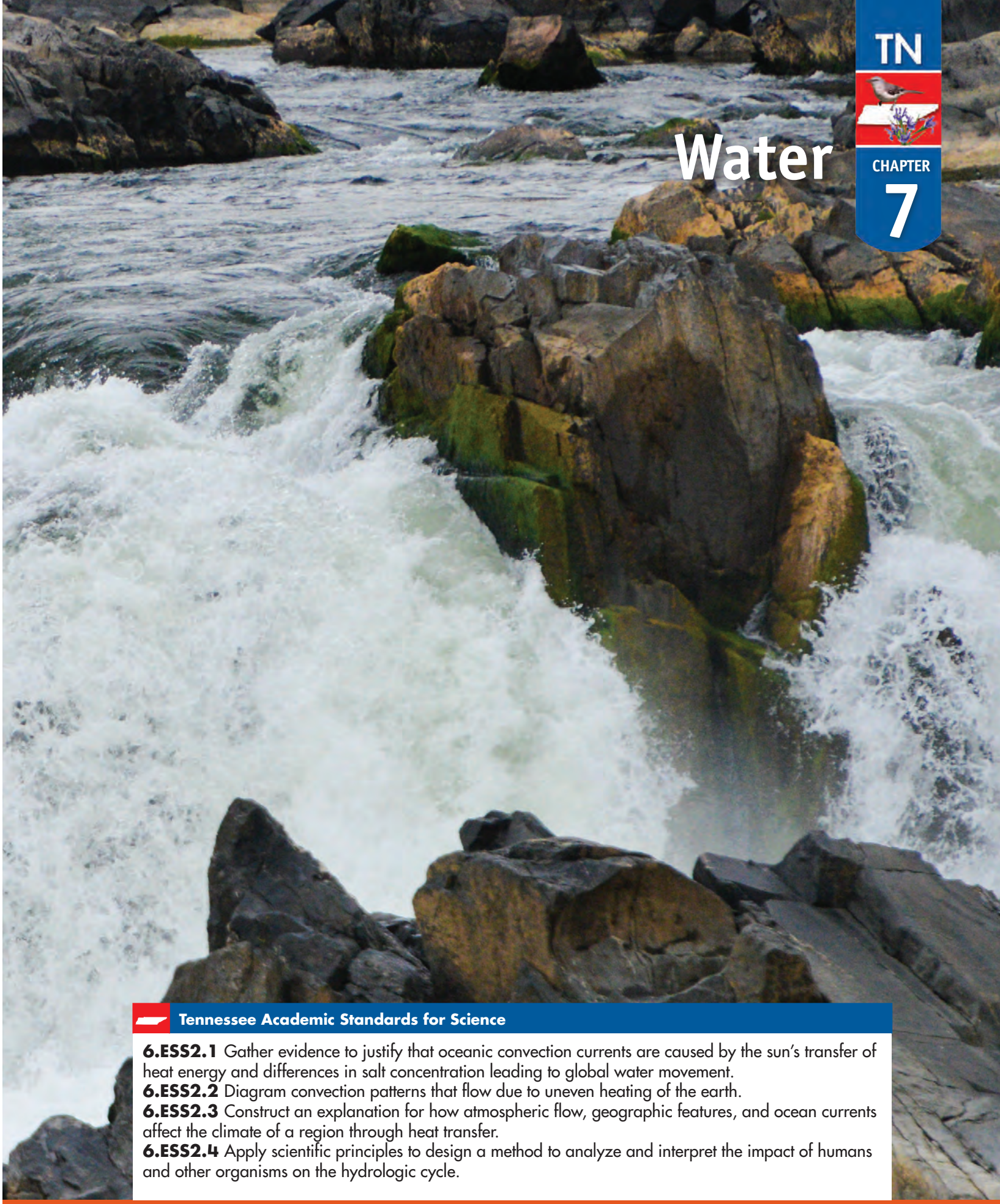
How does fresh water cycle on Earth?

Watch out below! This river is carrying the kayaker straight down. But where did the water come from in the first place? Where is it going? And why is water important?

Develop Hypotheses **Explain where you think the water in the river came from and where it will go next.**

Watch the **Untamed Science** video to learn more about water on Earth.



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CHAPTER 7

Water

Tennessee Academic Standards for Science

6.ESS2.1 Gather evidence to justify that oceanic convection currents are caused by the sun's transfer of heat energy and differences in salt concentration leading to global water movement.
6.ESS2.2 Diagram convection patterns that flow due to uneven heating of the earth.
6.ESS2.3 Construct an explanation for how atmospheric flow, geographic features, and ocean currents affect the climate of a region through heat transfer.
6.ESS2.4 Apply scientific principles to design a method to analyze and interpret the impact of humans and other organisms on the hydrologic cycle.

CHAPTER 7

Getting Started

Check Your Understanding

1. Background Read the paragraph below and then answer the question.

Have you ever sat at a window on a misty day? You might see **condensation** as drops of water form on the glass. These drops form when **water vapor** in the air cools and turns into a liquid. **Gravity** pulls the drops down the windowpane toward Earth's surface.

Condensation occurs when a substance changes from a gas to a liquid.

Water vapor is water in the gaseous state.

Gravity is a force that attracts all objects toward each other.

- How do water drops form on the window?

Vocabulary Skill

Latin Word Origins Many science words come to English from Latin. In this chapter you will learn the term *permeable*. *Permeable* comes from the Latin word parts *per-*, meaning "through"; *meare*, meaning "to go" or "to pass"; and *-bilis*, meaning "capable of."

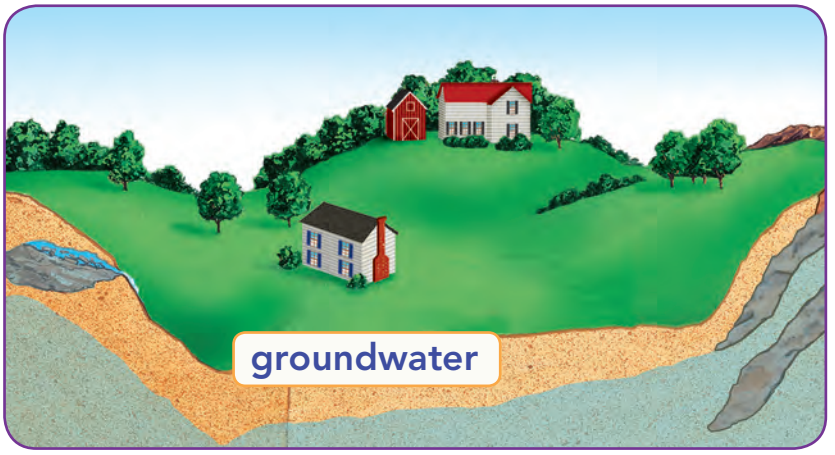
per- (through) + *meare* (go or pass) + *-bilis* (capable of) = *permeable* (capable of going through)

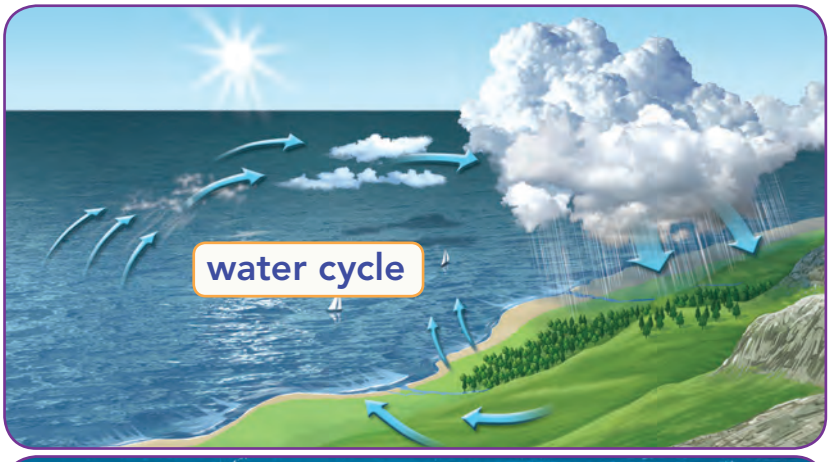
Learn these Latin word parts to help you remember the vocabulary terms.

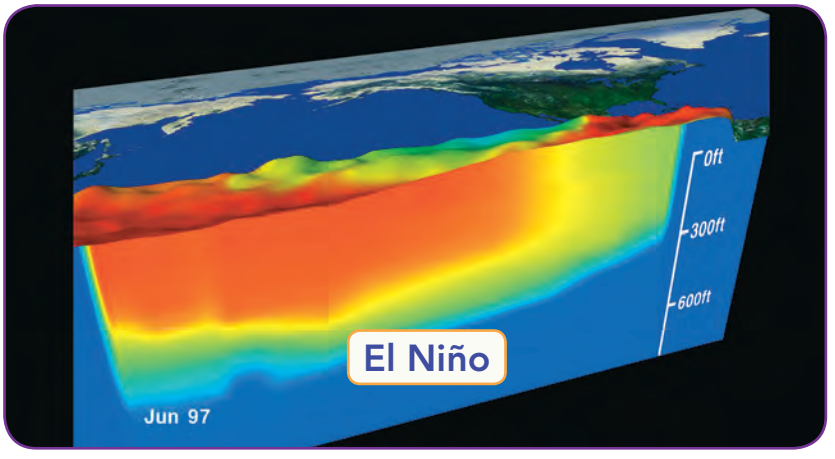
Latin Origin	Meaning	Example
trans-	across	transpiration, *n.*
spirare	to breathe	transpiration, *n.*
vapor	steam	evaporation, *n.*
videre	to separate	divide, *v.*

2. Quick Check **Use the table to answer the question.**

- Based on the table, predict the meaning of *transpiration*.







Chapter Preview

LESSON 1

- habitat • groundwater
- water cycle • evaporation
- transpiration • precipitation

Identify the Main Idea
Observe

LESSON 2

- tributary • watershed
- divide • reservoir
- eutrophication

Sequence
Form Operational Definitions

LESSON 3

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

Relate Cause and Effect
Predict

LESSON 4

- salinity • sonar • seamount
- trench • continental slope
- continental shelf • abyssal plain
- mid-ocean ridge

Identify the Main Idea
Interpret Data

LESSON 5

- wave • wavelength • frequency
- wave height • tsunami
- longshore drift • rip current
- groin

Relate Cause and Effect
Form Operational Definitions

LESSON 6

- current • Coriolis effect
- climate • El Niño • La Niña

Compare and Contrast
Infer

CCC: Energy and Matter

Inquiry **STEM Activity**

I Wouldn't Drink That!

SEP: Constructing Explanations (for Science) and Designing Solutions (for Engineering)

An underground layer of permeable rock or sediment that holds water and allows it to flow is called an aquifer. People drill wells into aquifers and pump the water to the surface. Much of the water for drinking, farming, and industry comes from aquifers.

Underground water is not a still pool. It seeps through spaces between rocks and slowly moves great distances. Surface pollution can soak into aquifers and contaminate wells far away. In this activity, you will design, build, and test a model of how an aquifer can become polluted.

Identify the Problem

1. Suppose you wanted to drill a well into an aquifer. Explain why it is important to understand groundwater pollution. What problem will your design help solve?

Do Research

Examine the diagrams of aquifers, wells, and cisterns provided by your teacher.

2. What features are important to include in a working model that demonstrates groundwater pollution? Explain.

Go to the materials station(s). Examine the materials. Think about which materials may be useful for your model. Leave the materials where they are.

3. What are your design constraints?

Develop Possible Solutions

☑ **4.** Describe ways in which you could use the materials to build a model that demonstrates how groundwater may become polluted. Identify at least two ways you could show evidence of pollution of wells.

Choose One Solution

☑ **5.** List the material(s) you will use for your model.

☑ **6.** On separate paper, draw your design. Label all the parts. Describe how you will build your model.

☑ **7.** Describe how your model will show how groundwater pollution occurs.

Design and Construct a Prototype

Have your teacher review and approve your design. Then, gather the materials you need to build your model. Build a prototype, the first working version of your design. Be sure to wear safety goggles as you build and test your prototype. If you can, document your construction process by taking photos or recording video as you go.

☑ **8.** On a separate sheet of paper, record the design details and dimensions of your prototype.

9. On a separate sheet of paper, draw detailed diagrams of your completed prototype. Draw a top view and cross-sections that show the positions and depths of wells. Label the features and measurements. Assign an identification number to each well.

10. On a separate sheet of paper, describe how your prototype will allow you to show that a pollutant can reach well sites.

Test the Prototype

Test your prototype. Observe what effects the pollution has on the wells.

11. How did you test your prototype's wells for contamination?

12. How did pollution affect the water in each well? Record your observations in the table below.

Well ID Number	Quality of the water at this well:

13. Summarize your conclusions about the data in the table.

Communicate Results

☑ **14.** Collect the materials that document the design, construction, and testing of your prototype. Assemble a portfolio that includes your diagrams, your photographs or video of the process, and a record of your test results. Use a data table to show your test results. Write a short summary of how data like your could be useful for a person planning to drill a well into an aquifer.

☑ **15.** Prepare a computer slide show or poster that visually maps your contamination findings. Clearly mark the site of the pollution source, and use different colors to represent clean versus contaminated wells and deep versus shallow wells. Caption your poster or slides with the percentages of contamination in the deep, shallow, and total wells.

Evaluate and Redesign

☑ **16.** Evaluate your prototype using the following rubric. Check one answer for each question.

Does the prototype…	Very Much	Somewhat	Not At All
fit within the provided foil pan?			
include both deep and shallow wells?			
permit visual verification of well contamination?			

☑ **17.** Analyze all the prototypes built by the class. Describe the one that you think worked best. Explain why.

☑ **18.** How could you change your prototype to make it better?

TN

LESSON 1

6.ESS2.4

Water on Earth

UNLOCK THE BIG ?

- Why Is Water Important?
- Where Is Water Found?
- What Is the Water Cycle?

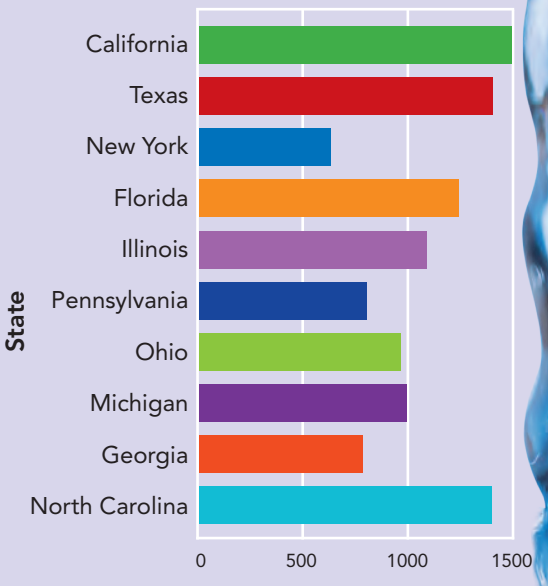
my planet Diary

How Much Water Do You Use?

You take a shower. You brush your teeth. You take a big drink after soccer practice. All day long, you need water! How much water do you use in a day? How much do you think your whole state uses? The graph shows the water used per person in the ten states of the United States with the largest populations. The data include the water used for all purposes, including farming, industry, and electric power.

SCIENCE STATS

Water Use per Person per Day



Study the graph. Then answer the questions below.

1. In which state is the water use per person greatest? In which state is it least?

2. What do you think might explain the difference in water use between states?

Lab zone® Do the Inquiry Warm-Up *Where Does the Water Come From?*

Vocabulary

- habitat
- groundwater
- water cycle
- evaporation
- transpiration
- precipitation

Skills

Reading: Identify the Main Idea

Inquiry: Observe

Why Is Water Important?

What do you and an apple have in common? You both consist mostly of water! Water makes up nearly two thirds of your body's mass. That water is necessary to keep your body functioning.

All living things need water in order to carry out their body processes. In addition, many living things live in water.

Body Processes Without water, neither you nor an apple could survive. Water allows organisms to break down food, grow, reproduce, and get and use materials they need from their environments. Animals obtain water by drinking it or by eating foods that contain water. Most animals cannot survive more than a few days without water.

Plants and other organisms that make their own food also need water. Algae and plants use water, along with carbon dioxide and energy from the sun, to make their own food in a process called photosynthesis (foh toh SIN thuh sis). Other organisms get food by eating the plants, or by eating organisms that eat the plants.

Habitats Water provides habitats for many living things. An organism's **habitat** is the place where it lives and obtains all the things it needs to survive. Some organisms cannot live out of water. You are probably familiar with large water-dwelling organisms such as sharks. But most such organisms are microscopic. In fact, aquatic, or water, habitats contain more types of organisms than land habitats do.

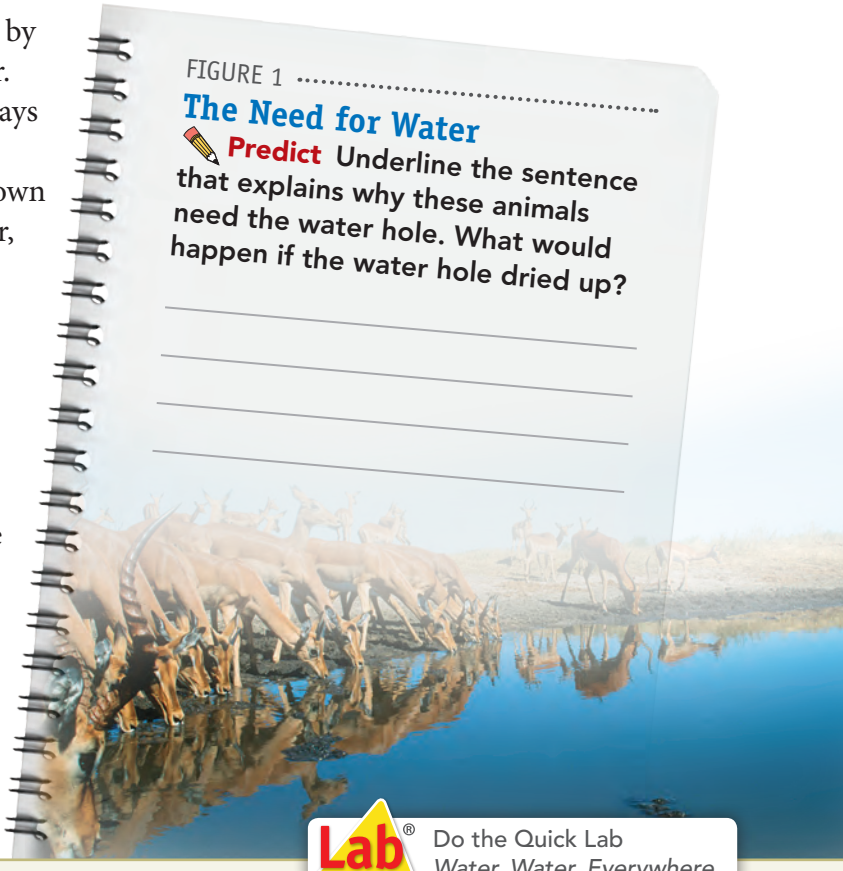


FIGURE 1

The Need for Water

Predict Underline the sentence that explains why these animals need the water hole. What would happen if the water hole dried up?

Lab zone® Do the Quick Lab *Water, Water, Everywhere.*

Assess Your Understanding

got it?

- I get it! Now I know that living things use water _____
- I need extra help with _____

Where Is Water Found?

When you turn on the tap, it might seem that an endless supply of fresh water comes out! But Earth's freshwater supply is very limited. **Most of Earth's surface water—roughly 97 percent—is salt water found in oceans. Only 3 percent is fresh water.**

Of that 3 percent, about two thirds is frozen in huge masses of ice near the North and South poles. About a third of the fresh water is underground. A tiny fraction of fresh water occurs in lakes and rivers. An even tinier fraction is found in the atmosphere, most of it in the form of invisible water vapor, the gaseous form of water.

Identify the Main Idea
Underline the main idea in each paragraph on this page.

Oceans Find the oceans on the map in **Figure 2.** Pacific, Atlantic, Indian, and Arctic are the names used for the different parts of the ocean. (Some scientists call the area around Antarctica the Southern Ocean.) But the waters are really all interconnected, making up one big ocean. The Pacific Ocean is the largest, covering an area greater than all the land on Earth. The Atlantic Ocean is next largest, though the Indian Ocean is deeper. The Arctic Ocean surrounds the North Pole. Smaller saltwater bodies are called seas.

Ice Much of Earth's fresh water is frozen into sheets of ice. Massive ice sheets cover most of Greenland and Antarctica. Icebergs are floating chunks of ice made of fresh water that break off from ice sheets. You could also find icebergs in the Arctic Ocean and in the North Atlantic.

do the math!

Analyzing Data

These graphs show how much of Earth's water is found in different forms.

1 **Read Graphs** Where is most water on Earth found? _____

2 **Read Graphs** About what fraction of Earth's fresh water is in the form of ice?

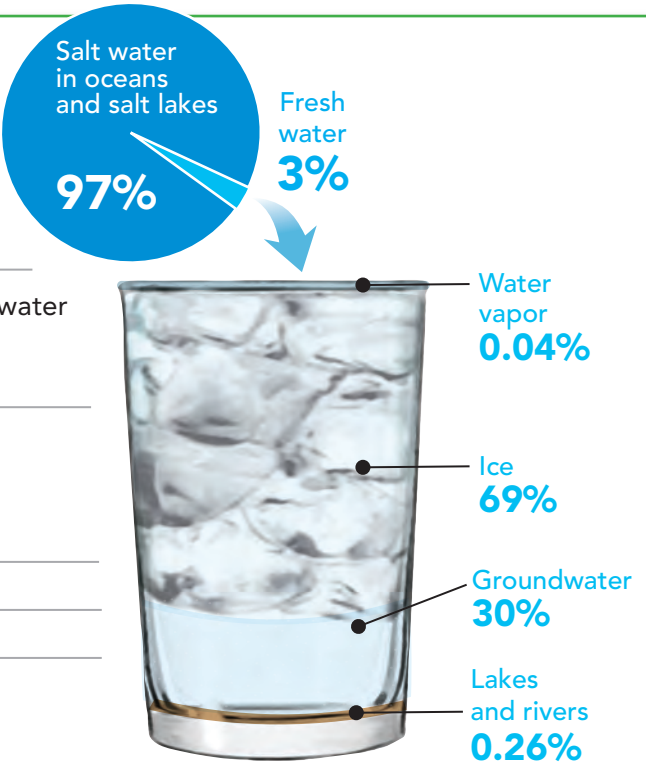
_____

3 **Interpret Data** How does the total amount of groundwater compare to the total amount of ice?

_____

_____

_____



Rivers and Lakes

Look at **Figure 2.** All the rivers and lakes marked on the map contain fresh water, as do many other smaller rivers and lakes. North America's five Great Lakes contain about 20 percent of all the water in the world's freshwater lakes.

Groundwater

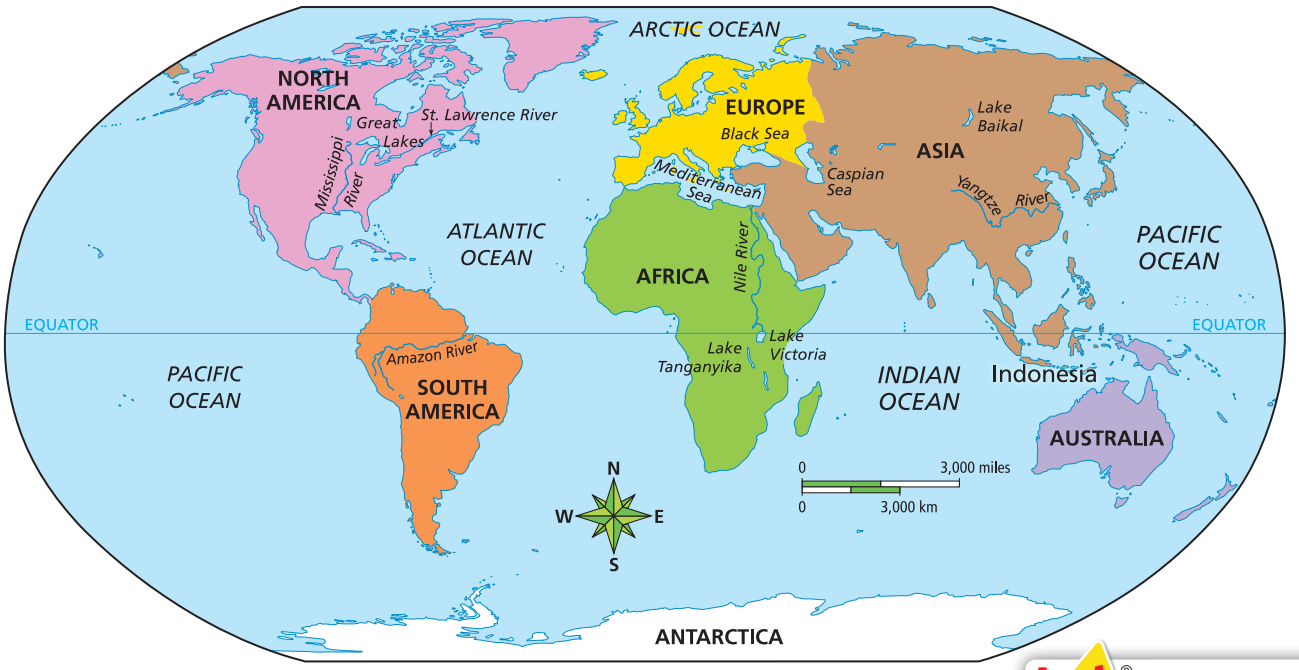
To find some of the fresh water on Earth, you have to look underground. When it rains or snows, most water that doesn't evaporate soaks into the ground. This water trickles through spaces between particles of soil and rock. Water that fills the cracks and spaces in underground soil and rock layers is called **groundwater.** Far more fresh water is located underground than in all of Earth's rivers and lakes.

FIGURE 2

Earth's Major Waterways

The map shows Earth's oceans and some major freshwater sources.

Classify Circle the names of three saltwater sources. Underline the names of three freshwater sources.



Lab zone® Do the Quick Lab *Water on Earth.*

Assess Your Understanding

1a. List What are the four main sources of fresh water on Earth?

b. Make Judgments Which freshwater source do you think is most important to people? Why?

got it?

- ○ **I get it!** Now I know that Earth's water is found in _____
- ○ I need extra help with _____

What Is the Water Cycle?

Earth has its own built-in water recycling system: the water cycle. The **water cycle** is the continuous process by which water moves from Earth's surface to the atmosphere and back, driven by energy from the sun and gravity. **In the water cycle, water moves between land, living things, bodies of water on Earth's surface, and the atmosphere.**

Water Evaporates

Where does the water in a puddle go when it disappears? It evaporates, becoming water vapor. **Evaporation** is the process by which molecules at the surface of a liquid absorb enough energy to change to a gaseous state. Water constantly evaporates from the surfaces of bodies of water such as oceans and lakes, as well as from soil and your skin. Plants play a role, too, in this step of the water cycle. Plants draw in water from the soil through their roots. Eventually the water is given off through the leaves as water vapor in a process called **transpiration.**

Vocabulary Latin Word Origins
The letter *e* in *evaporation* comes from the Latin word *ex,* meaning "away." *Vapor* is Latin for "water vapor." What do you predict that *evaporation* means?

FIGURE 3

The Water Cycle
The diagram below shows the processes of the water cycle.

Apply Concepts As you read these two pages, label each process shown in the diagram.

Condensation Forms Clouds

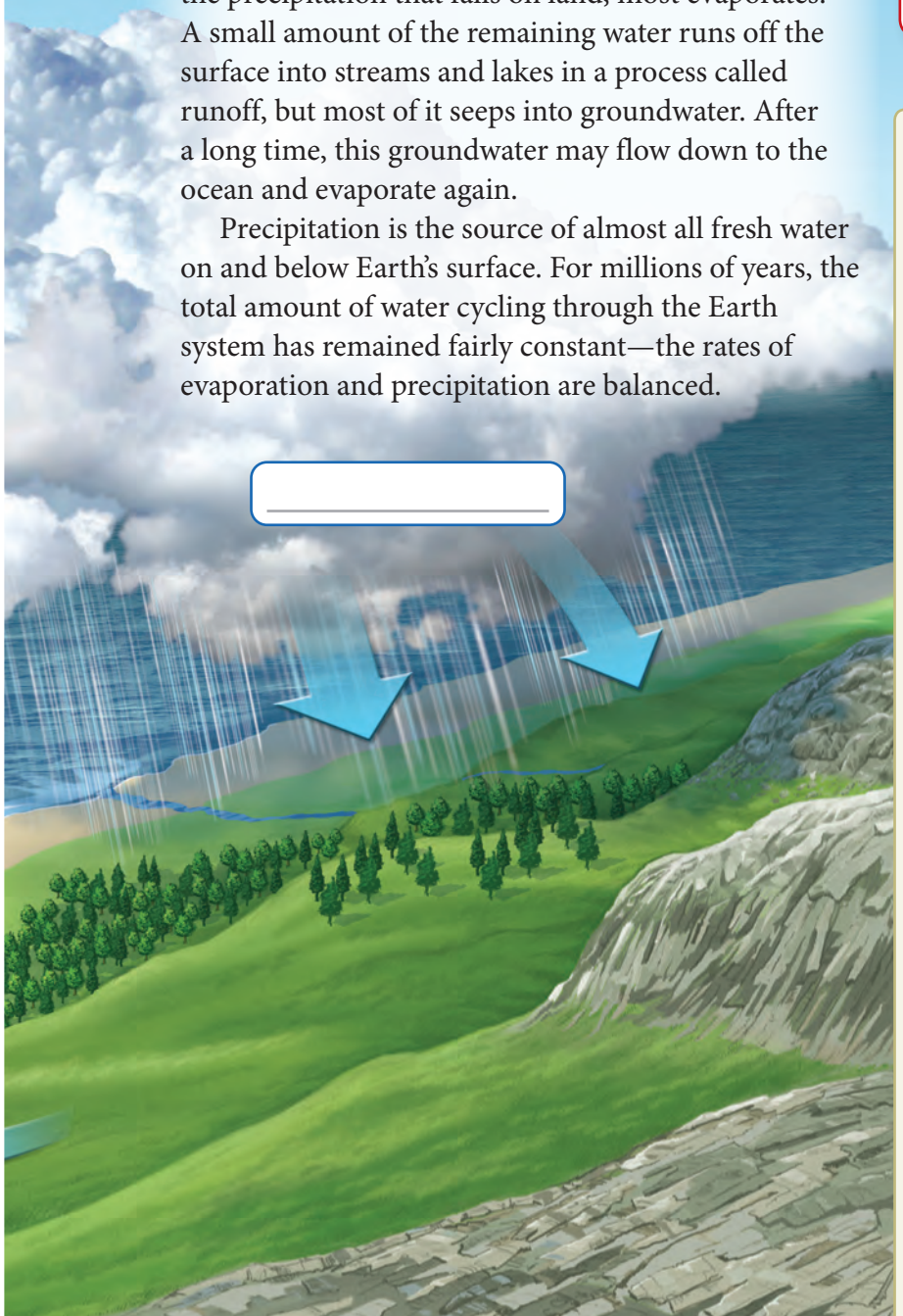
After a water molecule evaporates, warm air can carry the water molecule upward. Air tends to become colder as it rises. Water vapor condenses more easily at lower temperatures, so some water vapor cools and condenses into liquid water. Droplets of liquid water clump around solid particles in the air, forming clouds.

Water Falls as Precipitation

As more water vapor condenses, the water droplets grow larger. Eventually, they become so heavy that they fall back to Earth. Water that falls to Earth as rain, snow, hail, or sleet is called **precipitation.**

Most precipitation falls directly into the ocean. Of the precipitation that falls on land, most evaporates. A small amount of the remaining water runs off the surface into streams and lakes in a process called runoff, but most of it seeps into groundwater. After a long time, this groundwater may flow down to the ocean and evaporate again.

Precipitation is the source of almost all fresh water on and below Earth's surface. For millions of years, the total amount of water cycling through the Earth system has remained fairly constant—the rates of evaporation and precipitation are balanced.



apply it!

1. **Observe** What water cycle process can you observe here?

2. **CHALLENGE** What other process or processes can you infer are also taking place?

3. Give an example of a water cycle process you have seen.

Lab zone® Do the Lab Investigation *Water From Trees.*

Assess Your Understanding

2a. Identify What are the three major steps in the water cycle?

b. Sequence Start with a puddle on a sunny day. How might water move through the water cycle and eventually fall as rain?

got it?

- ○ **I get it!** Now I know that the water cycle is _____
- ○ I need extra help with _____

TN

LESSON 2

6.ESS2.4

Surface Water

UNLOCK THE BIG ?

- What Is a River System?
- What Are Ponds and Lakes?
- How Can Lakes Change?

MY PLANET DIARY

So Near, So Far

In Colorado's mountains, some rain seeps into the Fryingpan River. That river flows into the Colorado River and, more than 2,000 kilometers later, into the Gulf of California. Less than 15 kilometers away, rain seeps into the Arkansas River, which flows 2,350 kilometers until it joins the Mississippi River. Eventually, the Mississippi flows into the Gulf of Mexico. Water that fell less than 15 kilometers apart ends up almost 3,000 kilometers apart, in different oceans!

FUN FACT

Use the map and your knowledge of science to answer the following question.

Why do you think the two rivers that start so close together flow to such different locations?

Lab zone® Do the Inquiry Warm-Up *Mapping Surface Waters.*

Vocabulary

- tributary
- watershed
- divide
- reservoir
- eutrophication

Skills

- Reading: Sequence
- Inquiry: Form Operational Definitions

What Is a River System?

If you were hiking near the beginning of the Fryingpan and Arkansas rivers, you could observe tiny streams of water from melted snow. Gravity causes these tiny streams to flow downhill. As you follow one small stream, you would notice that the stream reaches another stream and joins it, forming a larger stream. That larger stream joins other streams until a small river forms.

Tributaries As you continue following the small river downhill, you might notice more streams joining the river. Eventually, the small river itself flows into a larger river. This river grows as more small rivers flow into it, before finally spilling into the ocean. 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 the streams and smaller rivers that flow into it together make up a river system.**

Why is the Arkansas River considered a tributary of the Mississippi River?

FIGURE 1

The Arkansas River

Make Judgments Put a *K* on the map where you might go kayaking. Put an *F* where you might get water for farming. Put an *M* where you might build a manufacturing plant. Explain why you chose the locations you did.

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 2,** the Missouri and Ohio rivers are quite long. Yet they flow into the Mississippi River. When rivers join another river system, the areas they drain become part of the largest river's watershed. The watershed of the Mississippi River covers nearly one third of the United States!

FIGURE 2

Major Watersheds of the United States

This map shows watersheds of several large rivers in the United States. **Interpret Maps** **Draw the path that water would take from the Platte River's source to the ocean. Which watersheds would the water pass through?**

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 Great Divide (also called the Continental Divide) is the longest divide in North America. It follows the line of the Rocky Mountains. West of this divide, water flows toward the Pacific Ocean. Some water is trapped between the Rockies and the Sierra Nevadas, in the Great Basin. Between the Rocky and Appalachian mountains, water flows toward the Mississippi River and into the Gulf of Mexico.

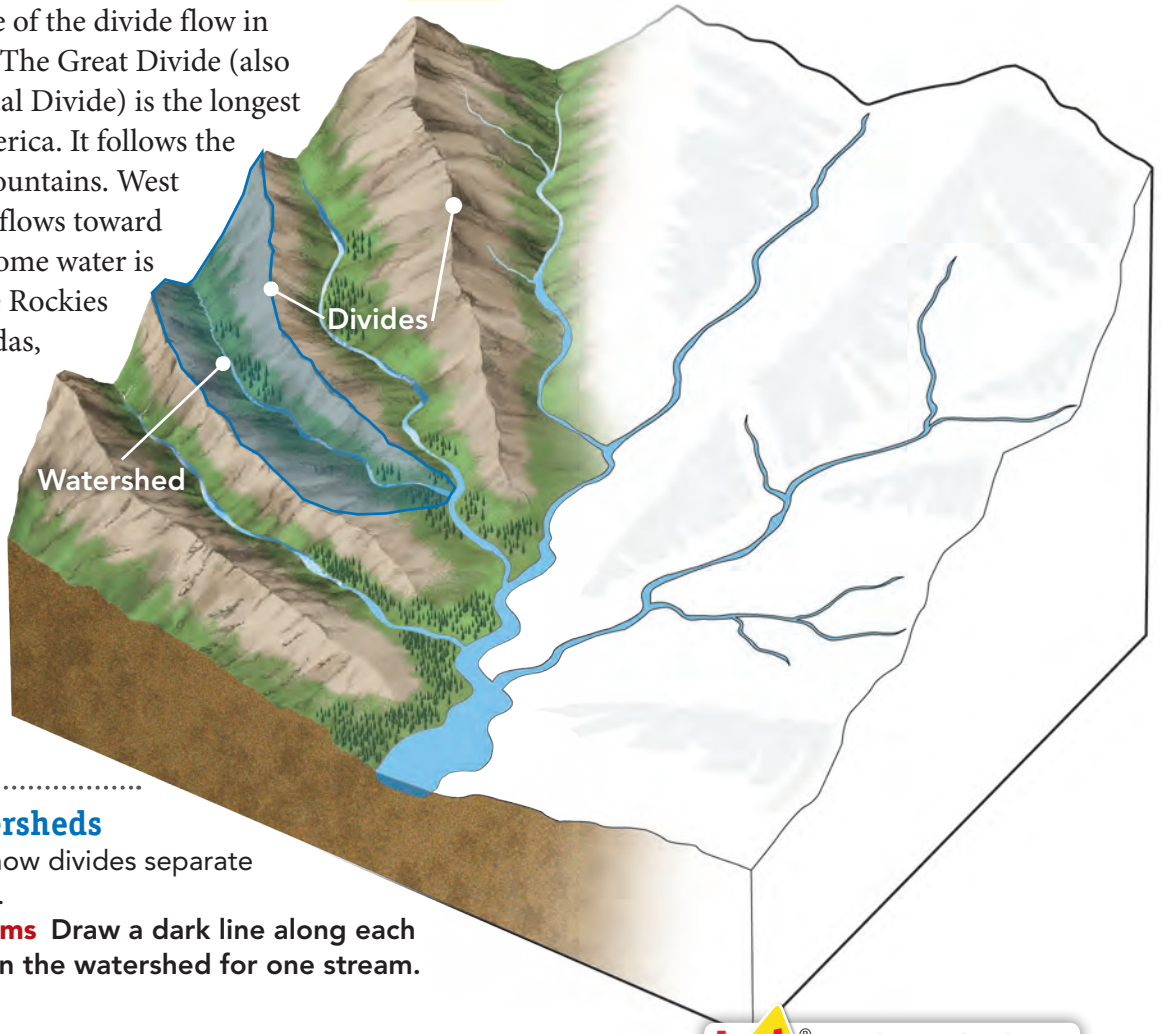


FIGURE 3

Divides and Watersheds
The diagram shows how divides separate land into watersheds.
Interpret Diagrams **Draw a dark line along each divide. Then shade in the watershed for one stream.**

Lab zone® Do the Quick Lab *What Is a Watershed?*

Assess Your Understanding

1a. Identify A (divide/tributary) separates two watersheds.

b. Summarize How is a watershed related to a river system? _____

c. Make Generalizations How can a stream be part of more than one watershed? _____

got it?

○ **I get it!** Now I know that a river system is _____

○ I need extra help with _____

What Are Ponds and Lakes?

What makes a lake or pond different from a river? Unlike streams and rivers, ponds and lakes contain still water. In general, ponds are smaller and shallower than lakes. Sunlight usually reaches to the bottom of all parts of a pond. Most lakes have areas where the water is too deep for much sunlight to reach the bottom.

Where does pond and lake water come from? Some ponds and lakes are supplied by rainfall, melting snow and ice, and runoff. Others are fed by rivers or groundwater. **Ponds and lakes form when water collects in hollows and low-lying areas of land.**

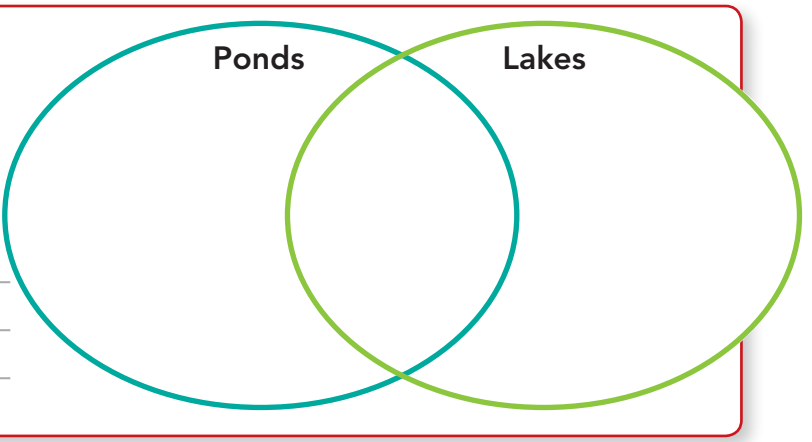
Exploring a Pond Because the water is shallow enough for sunlight to reach the bottom, plants grow throughout a pond. Bacteria and plantlike organisms called algae also live in the pond. The plants and algae produce oxygen as they use sunlight to make food. Fish and other animals in the pond use the oxygen and food provided by plants and algae. Some animals also use these plants for shelter.

Exploring a Lake Lakes are usually larger and deeper than ponds, so little sunlight reaches the bottom of a deep lake. Fewer plants can live in in the chilly, dark depths of such a lake. Mollusks and worms move along the lake's sandy or rocky bottom. They eat food particles that drift down from the surface. Young bony fishes such as pike and sturgeon eat the tiny bottom-dwellers, while the adult fish eat other fish.

apply it!

1. Complete the Venn diagram to compare and contrast characteristics of lakes and ponds.

2. **Form Operational Definitions** Based on your answers, write an operational definition for *lake*.



Lake Formation

Lakes can form through several natural processes. A river, for example, may bend and loop as it encounters obstacles in its path. Eventually, a new channel might form, cutting off a loop. The cutoff loop may become an oxbow lake.

Some 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 that formed long, deep valleys called rift valleys. In Africa, Lake Tanganyika lies in a rift valley. Volcanoes can also form lakes. Lava or mud from a volcano can block a river, forming a lake. Lakes can also form in the empty craters of volcanoes.

People can create a lake by building a dam. A lake that stores water for human use is called a **reservoir.**

FIGURE 4

Types of Lakes

The photos show examples of glacial, volcanic, and rift valley lakes. **Classify** **Write *G* on the glacial lake, *V* on the volcanic lake, and *R* on the rift valley lake.**

Lab zone® Do the Quick Lab *Modeling How a Lake Forms.*

Assess Your Understanding

2a. Explain What is one major difference between a lake and a pond?

b. Compare and Contrast How is a reservoir different from other kinds of lakes?

got it?

○ **I get it!** Now I know that lakes and ponds are _____

○ I need extra help with _____

How Can Lakes Change?

If you watch a lake or pond over many years, you will see it change. In time, the lake may shrink and become shallower. **Natural processes and human activities can cause lakes to disappear.**

Sequence Which of the following processes occurs first during eutrophication?

- ◯ Nutrients build up in a lake.
- ◯ A lake is replaced by a meadow.
- ◯ Plants stop carrying out photosynthesis.

Eutrophication

As lake organisms die, bacteria break down the bodies and release nutrients into the water. These nutrients, such as nitrogen and phosphorus, are chemicals that other organisms need. Over time, nutrients can build up in the lake in a process called **eutrophication** (yoo troh fih KAY shun). Algae use these nutrients and spread, forming a layer on the lake's surface.

Figure 5 shows how eutrophication can change a lake. When the algae layer becomes so thick that it blocks sunlight, plants cannot carry out photosynthesis, and they die. Without food and oxygen from the plants, animals die. Decaying material from dead organisms piles up on the bottom, making the lake shallower. As the area fills in, land plants grow in the mud. Eventually, the area fills with plants, and a meadow replaces the former lake.

The Human Role

Though eutrophication occurs naturally, human activities can also cause or increase it. For example, fertilizer from farms runs off into ponds and lakes, providing extra nutrients to the algae. The extra nutrients speed up the growth of algae, leading to faster eutrophication.

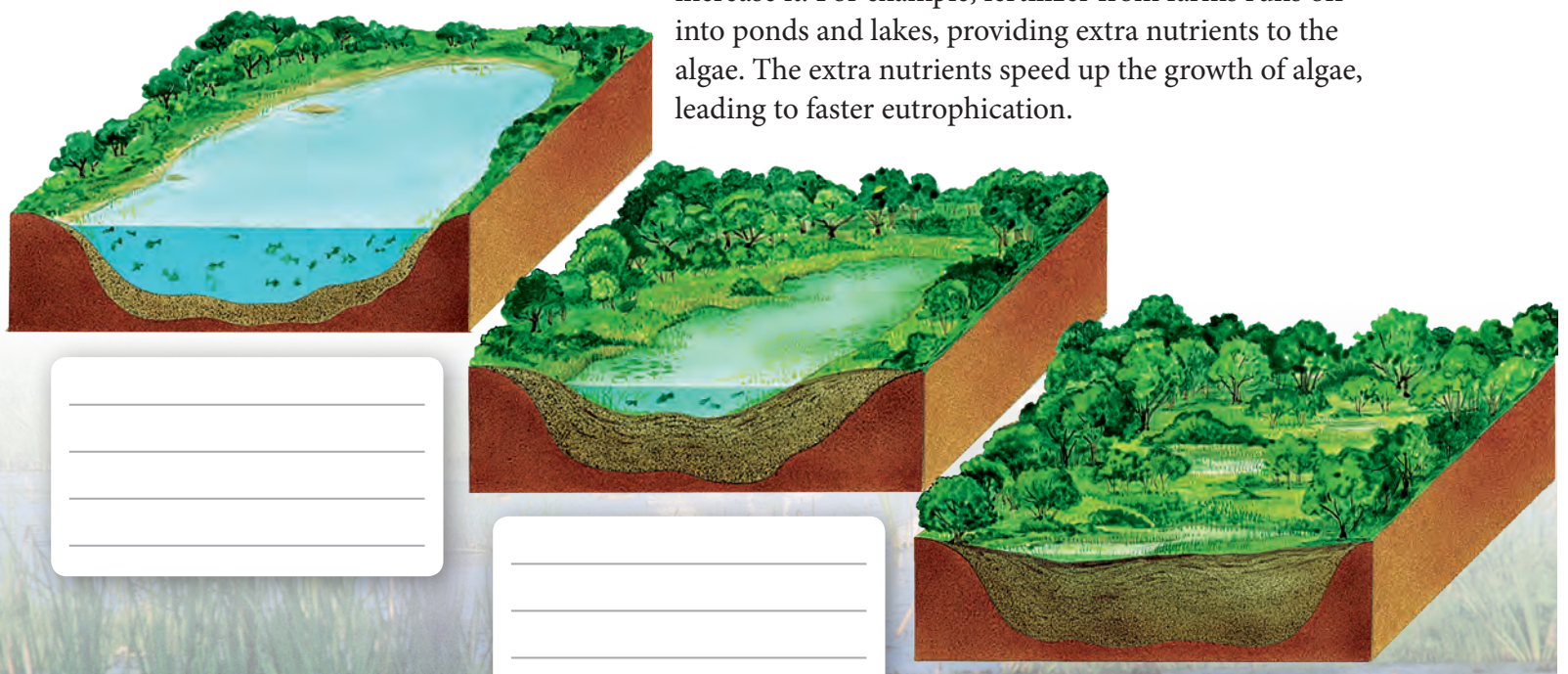


FIGURE 5
Eutrophication
Summarize Write a caption for each diagram explaining the changes that occur during eutrophication.

EXPLORE THE BIG ?

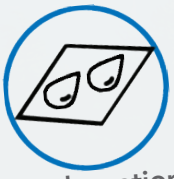
An Endless Cycle

How does fresh water cycle on Earth?

FIGURE 6
Make a cycle diagram to show how water cycles. Include the processes listed below.

Processes


Evaporation


Condensation


Transpiration


Precipitation


Runoff

Include examples of:
a river system
a lake or pond
an ocean
groundwater

Lab zone® Do the Quick Lab *How Can Algal Growth Affect Pond Life?*

Assess Your Understanding

3a. Explain Eutrophication occurs when algae block sunlight in a lake or pond and plants cannot _____

b. ANSWER THE BIG ? How does fresh water cycle on Earth?

_____

got it?

○ **I get it!** Now I know that lakes can change due to _____

○ I need extra help with _____

TN

LESSON 3

6.ESS2.4

Water Underground

UNLOCK THE BIG QUESTION

- How Does Water Move Underground?
- How Do People Use Groundwater?

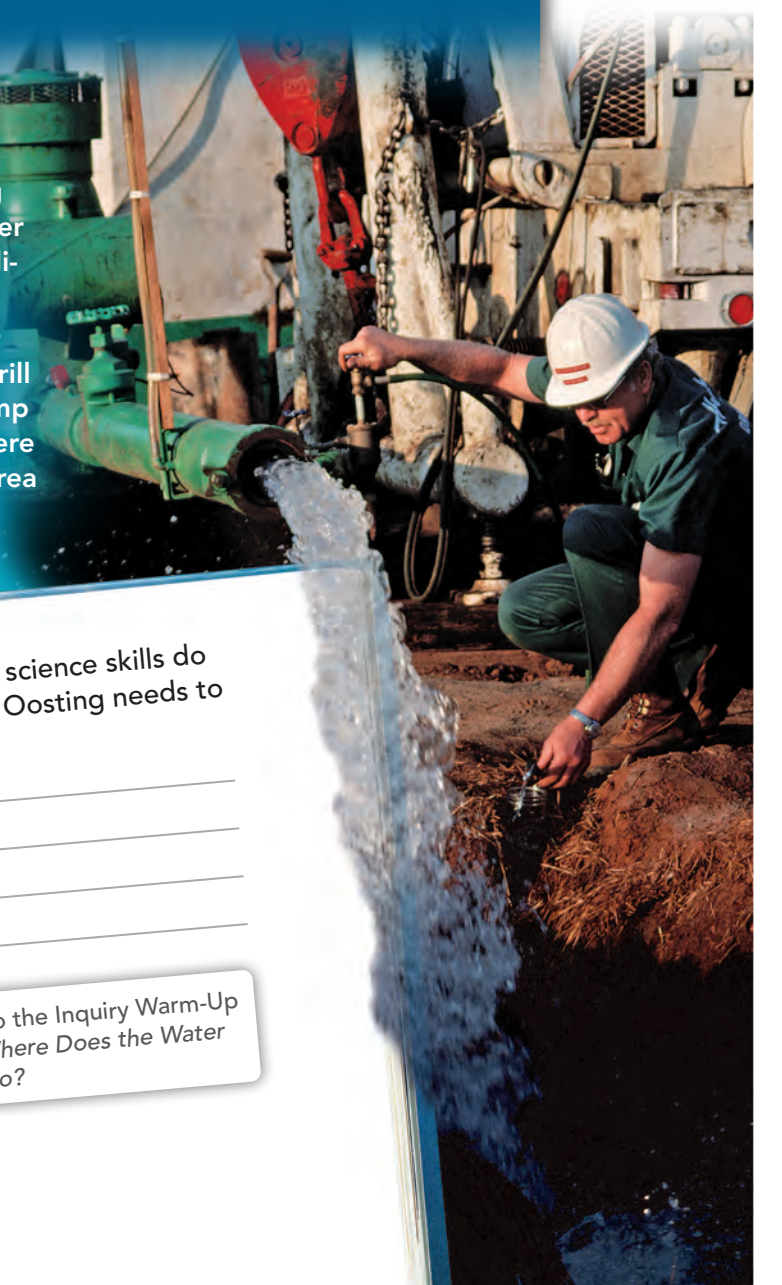
MY PLANET DIARY

CAREER

Looking for Water

How do you know where the water you drink comes from? Saskia Oosting could help you find out! Ms. Oosting works for a company that locates and protects groundwater supplies. She is a project manager, which means she coordinates the work of many other people.

One of her company's jobs is figuring out where the water in a particular well comes from. Scientists and engineers drill other wells near the well they're observing. Then they pump water out of the first well and watch the others to see where the level of groundwater drops. Once they've found the area that contributes water to the well, the company can help people who use that water keep the supply clean.



Communicate With a partner, discuss your answers to these questions.

1. How do engineers find out where the water in a well comes from?

2. What kinds of science skills do you think Ms. Oosting needs to do her job?

Lab zone® Do the Inquiry Warm-Up *Where Does the Water Go?*

Vocabulary

- permeable
- impermeable
- unsaturated zone
- saturated zone
- water table
- aquifer
- artesian well

Skills

- Reading: Relate Cause and Effect
- Inquiry: Predict

How Does Water Move Underground?

Where does underground water come from? Like surface water, underground water generally comes from precipitation. Some precipitation soaks into the ground, pulled by gravity.

If you pour water into a glass full of pebbles, the water flows 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 1.** The size of the pores and the connections between them determine how easily water moves. 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.

Other materials have few or no pores or cracks, or the pores are very small. Clay has very small pores and is less permeable than sand. Unless it is cracked, granite is **impermeable,** meaning that water cannot pass through easily.

FIGURE 1

Permeable and Impermeable Materials

Compare how water moves in clay (left) and gravel (right).

Compare and Contrast

Which material is more permeable? (gravel/clay) **Why?**

Water Zones

Water from precipitation soaks down through permeable rock and soil layers. These layers contain air as well as water, so they are not saturated, or filled, with water. This top layer is thus called the **unsaturated zone.**

However, at some depth, the water reaches a level where the pores in the ground are saturated with water, 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.

The saturated zone often reaches deep into Earth, even though the rock becomes less permeable the deeper you go. Sometimes the direction of the water's flow is changed by impermeable layers, which the water has a harder time flowing through.

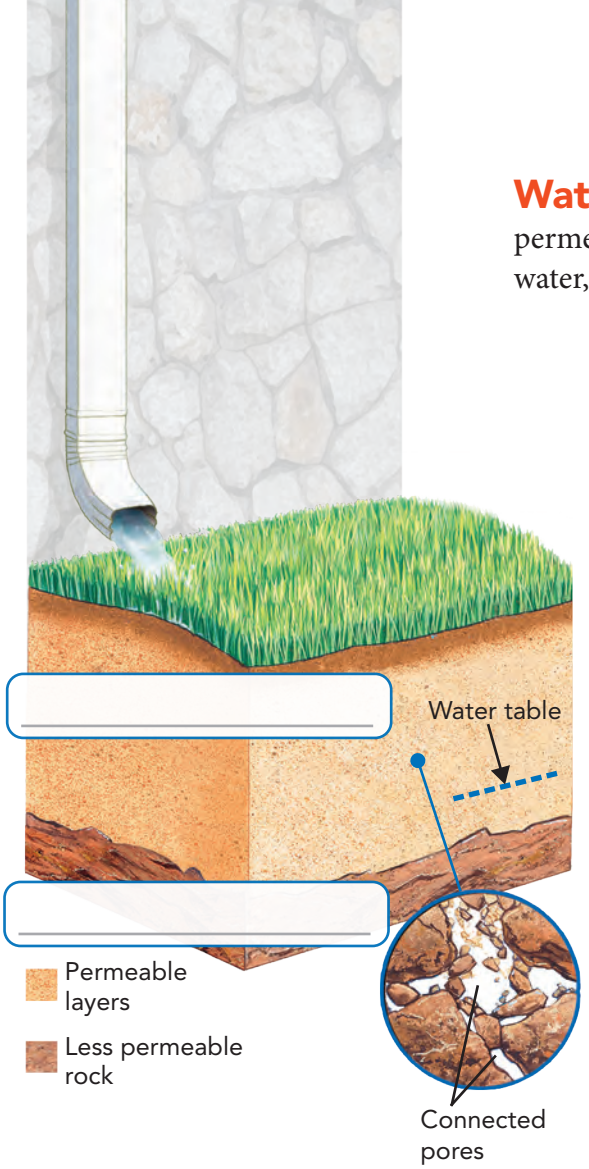


FIGURE 2

Groundwater Formation

Upper areas of the soil contain both air and water, while lower areas, including less permeable rock, are saturated with water.

Interpret Diagrams **Label the saturated and unsaturated zones. Shade in the area where water will collect.**

Lab zone® Do the Quick Lab *Soil Percolation.*

Assess Your Understanding

1a. Review Water slows down when it reaches (permeable/impermeable) material.

b. Explain What is the water table?

c. Infer The rock deep within the saturated zone most likely has (large/small) and (connected/unconnected) pores. Explain your answer.

got it?

○ **I get it!** Now I know that water moves through soil by _____

○ I need extra help with _____

How Do People Use Groundwater?

Suppose you live far from a river, lake, or pond. How could you reach groundwater for your needs? You might 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.

Aquifers Any underground layer of permeable rock or sediment that holds water and allows it to flow is called an **aquifer.** Aquifers can range in size from a small patch to an area the size of several states. The huge Ogallala aquifer lies beneath the plains of the Midwest, from South Dakota to Texas. This aquifer provides water for millions of people, as well as for crops and livestock.

Aquifers are not unlimited sources of water. If people take water from the aquifer faster than the aquifer refills, the level of the aquifer will drop. As you'll see on the next page, this will make it more difficult to reach water in the future.

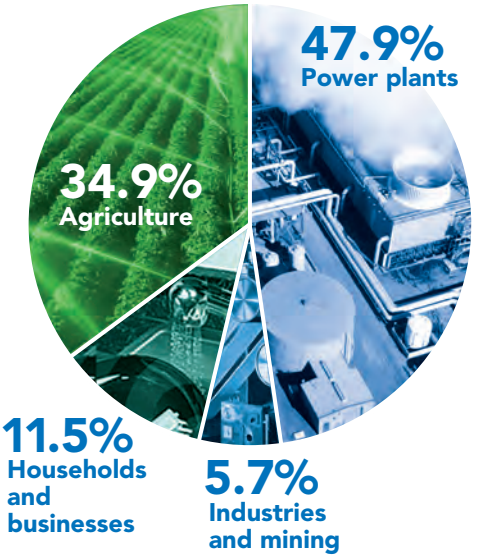
Vocabulary The Latin root *aqua-* is found in words such as *aquarium* and *aquatic* as well as *aquifer*. What do you think this root means?

_____

do the math!

Uses of Water

The graph shows water use in the United States. Use the graph to answer the questions below.



1. **Read Graphs** What would be a good title for this graph? _____

2. **Interpret Data** The two largest categories combine to make up about what percentage of the total water used in the United States? _____

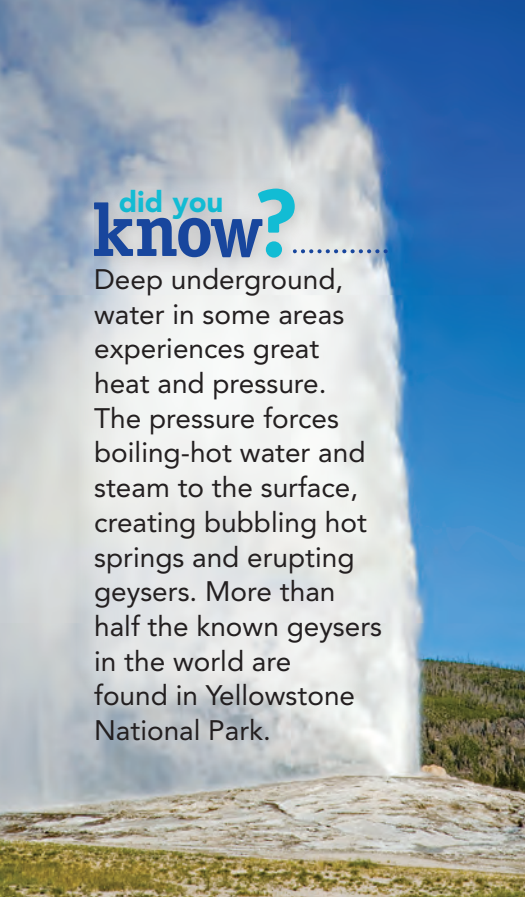
3. **Predict** How would an increase in the amount of land used for farms affect this graph?

_____

_____

4. **Calculate** If the total daily usage of water in the United States is 1,280 billion liters, about how many liters are used by power plants?

_____



did you know?

Deep underground, water in some areas experiences great heat and pressure. The pressure forces boiling-hot water and steam to the surface, creating bubbling hot springs and erupting geysers. More than half the known geysers in the world are found in Yellowstone National Park.

Movement in Aquifers

Do you picture groundwater as a large, still pool beneath Earth's surface? In fact, the water is moving, seeping through layers of rock or soil. The rate of motion depends largely on the slope of the water table and the permeability of the rocks. Some groundwater 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.

Wells

The depth and level of a water table can vary greatly over a small area. Generally, the level of a water table follows the shape of the surface of the land, as shown in **Figure 3.** The level can rise during heavy rains or snow melts, and fall in times of dry weather.

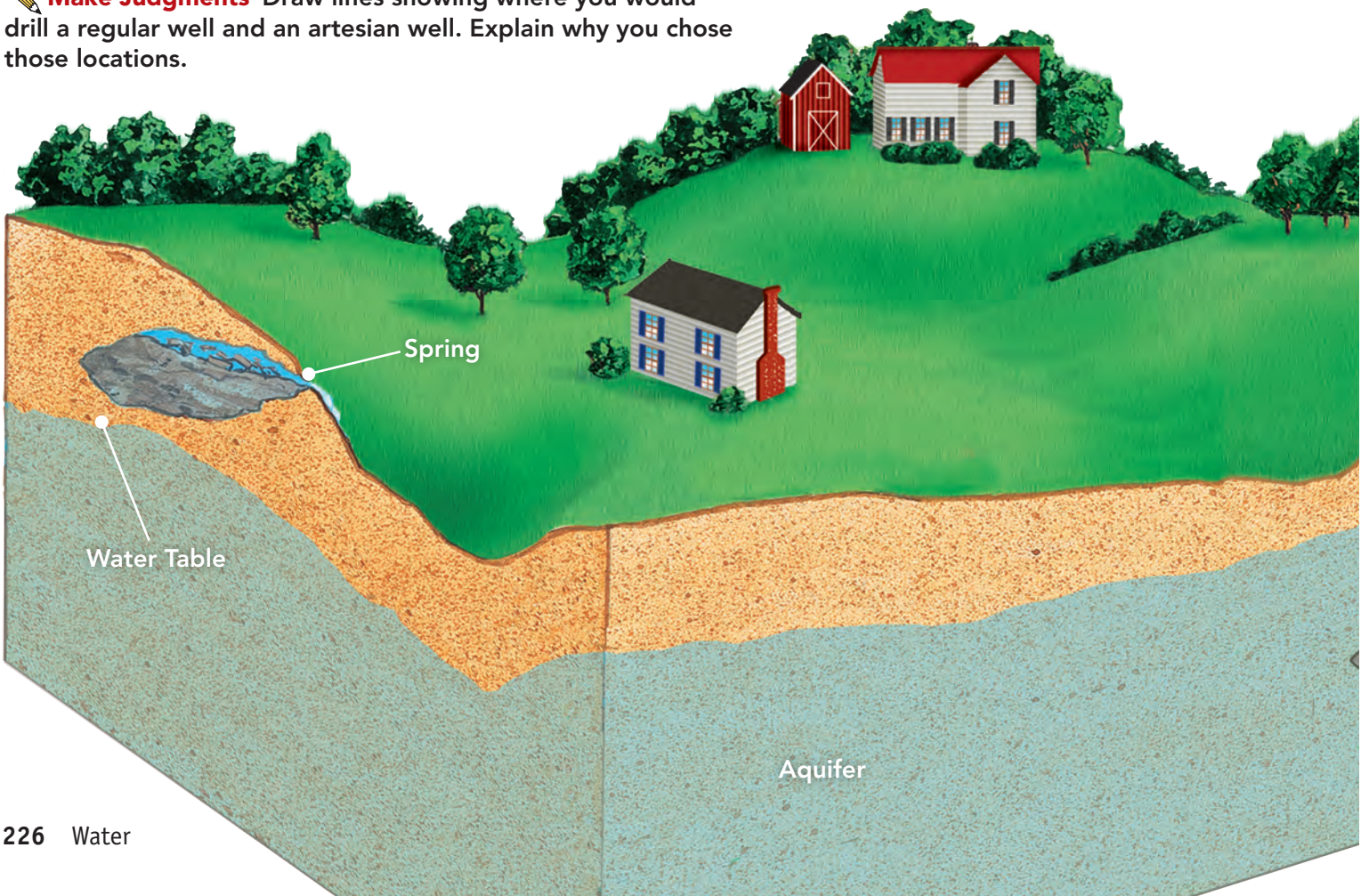
Since ancient times, people have brought groundwater to the surface for drinking and other everyday uses. **People can obtain groundwater from an aquifer by drilling a well below the water table.** When the bottom of the well is in a saturated zone, the well contains water. If the water table drops below the bottom of the well, the well will run dry and water cannot be obtained from it.

FIGURE 3

Springs and Wells

Suppose you are a farmer looking for water sources.

Make Judgments **Draw lines showing where you would drill a regular well and an artesian well. Explain why you chose those locations.**



Using Pumps

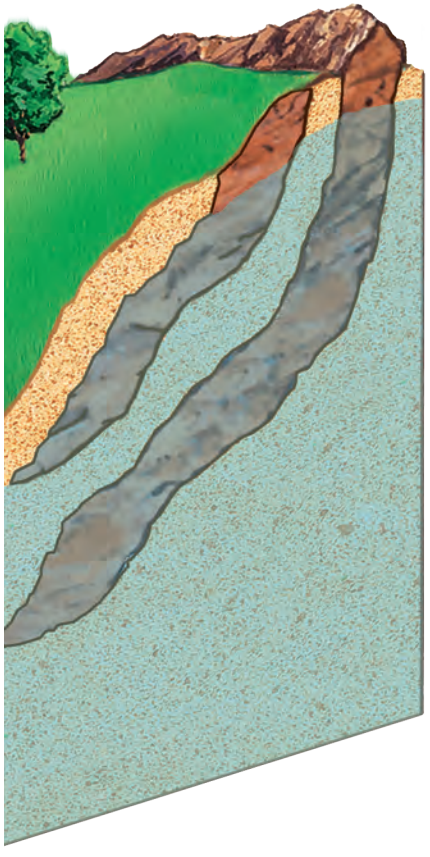
Long ago, people dug wells by hand. They used a bucket to bring up the water. People may also have used simple pumps. Today, however, most wells are dug with well-drilling equipment. Mechanical pumps bring up the groundwater.

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.

Relying on Pressure

Another option for bringing up groundwater is an artesian well. In an **artesian well** (ahr TEE zhun), water rises on its own because of pressure within an aquifer.

In some aquifers, groundwater becomes trapped between two layers of impermeable rock or sediment. This water is under great pressure from the water extending back up the aquifer. 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, water pressure does the job.



Relate Cause and Effect
If the water table near a well is (raised/lowered), the well may run dry.

Lab zone® Do the Quick Lab *An Artesian Well.*

Assess Your Understanding

2a. Describe What are three ways people can get water from an aquifer?

b. Infer Use **Figure 3** as a guide. Why is it important to know the depth of an aquifer before drilling a well?

c. Solve Problems During the winter, you draw your water from a well. Every summer, the well dries up. What might be the reason for the change?

got it?

- ○ **I get it!** Now I know that people reach underground water by _____
- ○ I need extra help with _____

TN

LESSON 4

Related to 6.ESS2: Earth's Systems

Exploring the Ocean

UNLOCK THE BIG ?

- How Do Conditions Vary in Earth's Oceans?
- What Are Some Features of the Ocean Floor?

MY PLANET DIARY — SCIENCE AND TECHNOLOGY

Deep-Sea Escape

You've heard of how parachutes are used for escapes. But have you heard of a special suit that allows people to escape from a submarine 183 meters under water? The suit is designed to help sailors survive very cold temperatures and very high pressure. In an emergency, sailors put on this suit and enter a water-filled rescue chamber. Then the sailors shoot out, rising at two to three meters per second. If the suit tears, they have to exhale all the way to the surface so their lungs don't explode. At the surface, part of the suit inflates to become a life raft.

Discuss these questions with a classmate and write your answers below.

1. What technology was developed to help sailors escape a submarine accident?

2. What would it feel like to escape from a submarine deep under water? How would you help your body adjust to the changing pressure?

Lab zone® Do the Inquiry Warm-Up *What Can You Learn Without Seeing?*

How Do Conditions Vary in Earth's Oceans?

People have explored the ocean since ancient times. For centuries, the ocean has provided food and served as a route for trade and travel. Modern scientists have studied the characteristics of the ocean's waters and the ocean floor. **The water in Earth's oceans varies in salinity, temperature, and depth.**

Vocabulary

- salinity
- sonar
- seamount
- trench
- continental slope
- continental shelf
- abyssal plain
- mid-ocean ridge

Skills

Reading: Identify the Main Idea

Inquiry: Interpret Data

Salinity If you've ever swallowed a mouthful of water while you were swimming in the ocean, you know it's pretty salty. But just how salty? If you boiled a kilogram of ocean water in a pot until the water was gone, there would be about 35 grams of salt left in the pot. That's about two tablespoons of salt. **Salinity** is the total amount of dissolved salts in a sample of water. In most parts of the ocean, the salinity is between 34 and 37 parts per thousand.

The substance you know as table salt is sodium chloride. This salt is present in the greatest amount in ocean water. When sodium chloride dissolves in water, it separates into sodium and chloride particles called ions. Ocean water also contains smaller amounts of more than a dozen ions, including magnesium and calcium.

Near the ocean's surface, rain, snow, and melting ice add fresh water, lowering the salinity. Evaporation, on the other hand, increases salinity. Salt is left behind as the water evaporates. Salinity can also be higher near the poles. As the surface water freezes into ice, the salt is left behind in the remaining water.

Effects of Salinity Salinity affects ocean water in different ways. For instance, fresh water freezes at 0°C. But ocean water doesn't freeze until the temperature drops to about –1.9°C. The salt acts as a kind of antifreeze by interfering with the formation of ice. Salt water also has a higher density than fresh water. That means that the mass of one liter of salt water is greater than the mass of one liter of fresh water. Because its density is greater, seawater lifts, or buoys up, less dense objects floating in it.

Vocabulary Suffixes Circle the correct word to complete the sentence below.

Ocean water has a higher (salinity/saline) than fresh water.

Composition of Ocean Water

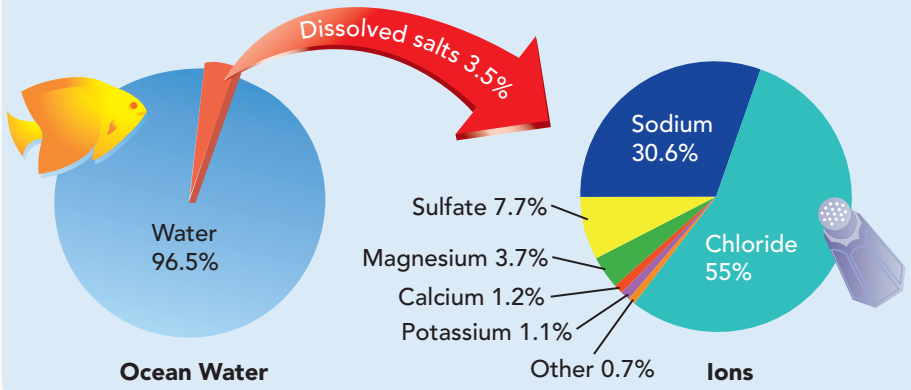


FIGURE 1

Composition of Ocean Water

When salts dissolve, they separate into particles called ions.

Read Graphs **In ocean water, which ion is most common? Which salt?**

Identify the Main Idea
Underline the two changes that happen with depth.

Temperature

The broad surface of the ocean absorbs energy from the sun. **Like temperatures on land, temperatures at the surface of the ocean vary with location and the seasons.** Near the equator, surface ocean temperatures often reach 25°C, about room temperature. The temperatures drop as you travel away from the equator. Warm water is less dense than cold water, so it doesn't sink. Warm water forms only a thin layer on the ocean surface.

Depth

If you could swim from the surface of the ocean to the ocean floor, you would pass through a vertical section of the ocean. This section, shown in **Figure 2,** is referred to as the water column. **As you descend through the ocean, the water temperature decreases.** There are three temperature zones in the water column. The surface zone is the warmest. It typically extends from the surface to between 100 and 500 meters. The average temperature worldwide for this zone is 16.1°C. Next is the transition zone, which extends from the bottom of the surface zone to about 1 kilometer. Temperatures in the transition zone drop very quickly to about 4°C. Below the transition zone is the deep zone. Average temperatures there are 3.5°C in most of the ocean.

Water pressure, the force exerted by the weight of water, also changes with depth. **In the ocean, pressure increases by 1 bar, the air pressure at sea level, with each 10 meters of depth.** Due to the high pressure in the deep ocean, divers can descend safely only to about 40 meters without specialized equipment. To observe the deep ocean, scientists can use a submersible, an underwater vehicle built of materials that resist pressure.

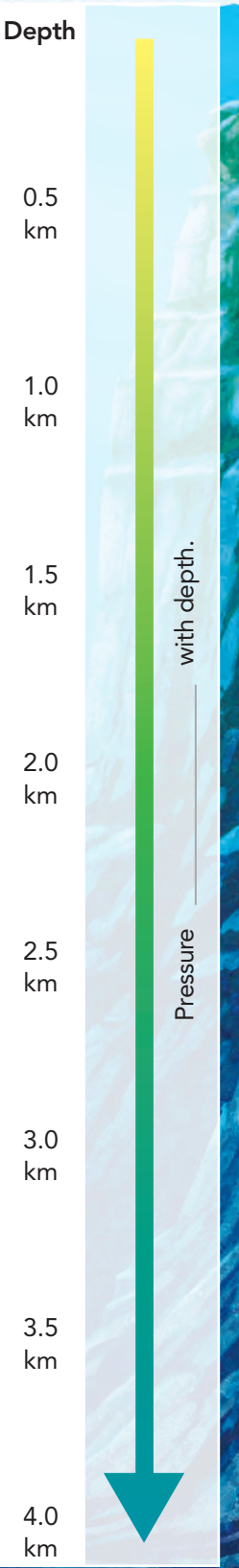


FIGURE 2
Changes With Depth
Relate Text and Visuals The conditions in Earth's oceans change with depth.

1. Shade in each temperature zone in the depth bar and make a key.
2. Fill in the blank in the pressure bar to identify what happens to pressure with depth.

Key

☐ _____
☐ _____
☐ _____

apply it!

Each panel of dials provides information about conditions at various depths in the ocean.

1 **Interpret Data** Find the incorrect dial in each panel and correct its reading.

2 Label where in the ocean you might find each set of readings: surface zone, transition zone, or deep zone.

3 **CHALLENGE** Based on the information in the panels, where is the most dense water in the ocean?

did you know?

The Deep Flight Super Falcon is the first winged submersible available to the public. It can "fly" quickly and easily to depths of more than 100 meters.

Lab zone® Do the Quick Lab *Ocean Conditions.*

Assess Your Understanding

got it?

- ○ **I get it!** Now I know that the water in Earth's oceans varies in _____
- ○ I need extra help with _____

What Are Some Features of the Ocean Floor?

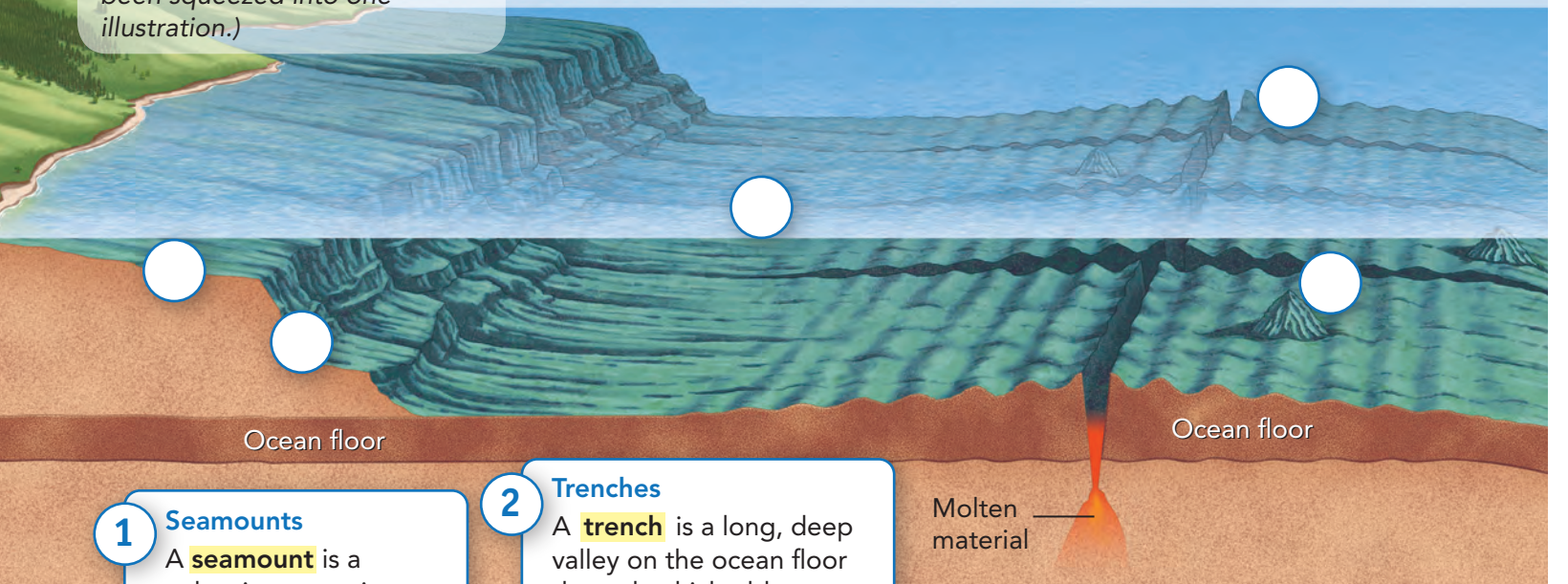
The ocean is very deep—3.8 kilometers deep on average. That's more than twice as deep as the Grand Canyon. Humans can't survive the darkness, cold temperatures, and extreme pressure of the deep ocean. So scientists have developed technology to study the ocean floor. A major advance in ocean-floor mapping was **sonar,** SOund NAvigation and Ranging. This system uses sound waves to calculate the distance to an object. A ship's sonar system sends out pulses of sound that bounce off the ocean floor. The equipment then measures how quickly the sound waves return to the ship.

Once scientists mapped the ocean floor, they discovered that the deep waters hid mountain ranges bigger than any on land, as well as deep canyons. **Major ocean floor features include trenches, the continental shelf, the continental slope, the abyssal plain, and the mid-ocean ridge. These features have all been formed by the interaction of Earth's plates.** You can see these feaures in **Figure 3.**

FIGURE 3

Ocean Floor

Relate Text and Visuals
Match the descriptions below with the ocean floor features in the image. Write the number for each description in the corresponding circles.
(Image not to scale. To show major ocean floor features, thousands of kilometers have been squeezed into one illustration.)



1 Seamounts
A **seamount** is a volcanic mountain rising from the ocean floor that doesn't reach the surface. Seamounts often form near mid-ocean ridges. Some seamounts were once volcanic islands. But they slowly sank because of the movement of the ocean floor toward a trench.

2 Trenches
A **trench** is a long, deep valley on the ocean floor through which old ocean floor sinks back toward the mantle. The Marianas Trench in the Pacific Ocean is 11 kilometers deep.

3 Continental Slope
At 130 meters down, the slope of the ocean floor gets steeper. The steep edge of the continental shelf is called the **continental slope.**

4 Continental Shelf
The **continental shelf** is a gently sloping, shallow area that extends outward from the edge of each continent. Its width varies from a few kilometers to as much as 1,300 kilometers.

EXPLORE THE BIG ?

LOST AT SEA

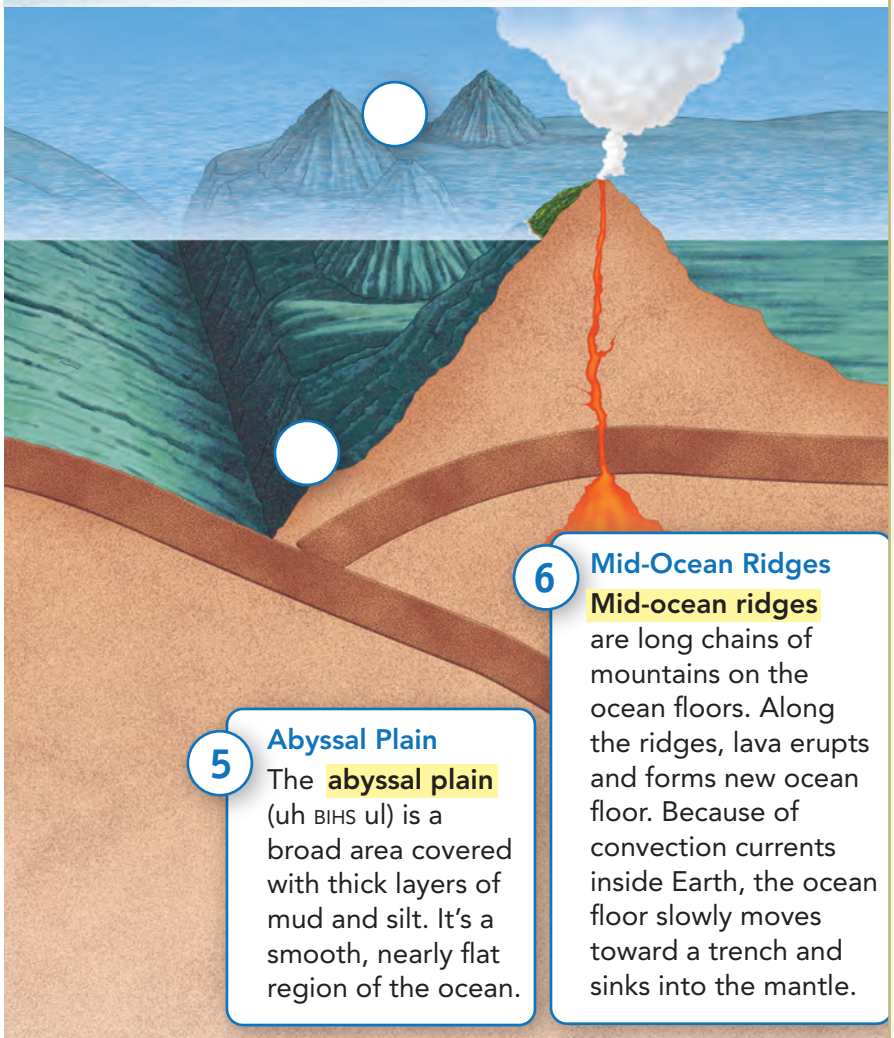
FIGURE 4

What are some characteristics of Earth's oceans?

Predict Your ship has been radioed by a submarine that has lost the use of its navigation instruments. Based on the information in their last transmission, where might the vessel be? What might the conditions of the water be at this depth? Discuss your prediction with a partner.

Last transmission from sub: "Depth reading 3,000 meters; passed over a flat plain...sonar returned waves quickly; possibly approaching mountains."

Lab zone® Do the Quick Lab *The Shape of the Ocean Floor.*



5 Abyssal Plain

The **abyssal plain** (uh BIHS ul) is a broad area covered with thick layers of mud and silt. It's a smooth, nearly flat region of the ocean.

6 Mid-Ocean Ridges

Mid-ocean ridges are long chains of mountains on the ocean floors. Along the ridges, lava erupts and forms new ocean floor. Because of convection currents inside Earth, the ocean floor slowly moves toward a trench and sinks into the mantle.

Assess Your Understanding

1a. List What are four features of the ocean floor?

b. Explain Why has investigation of the ocean been difficult?

c. ANSWER THE BIG ? What are some characteristics of Earth's oceans?

got it?

- ○ **I get it!** Now I know that the ocean floor has many different features formed by _____
- ○ I need extra help with _____

TN

LESSON 5

Related to 6.ESS2: Earth's Systems

Wave Action

UNLOCK THE BIG ?

- How Do Waves Form and Change?
- How Do Waves Affect the Shore?

my planet Diary

Rogue Waves

For hundreds of years, sailors have returned from the sea to tell of 30-meter-high waves that appeared out of nowhere. These waves, they said, plunged the largest ships into the ocean depths. For hundreds of years, these tales were taken no more seriously than the Scottish legend of the Loch Ness monster. Ships were sunk, scientists said, in storms.

Then, in 1995, an oil rig in the North Sea was struck by a rogue wave. Instruments on board measured the wave's height at 26 meters. As a result, the European Union set up a project to study these rogue waves using satellites. What the scientists found was shocking. Within three weeks, they tracked ten different giant waves.

DISASTER

Discuss these questions with a classmate and write your answers below.

1. Why did people begin to believe in rogue waves?

2. How might you track a rogue wave?

Lab zone® Do the Inquiry Warm-Up *How Do Waves Change a Beach?*

Vocabulary

- wave
- wavelength
- frequency
- wave height
- tsunami
- longshore drift
- rip current
- groin

Skills

Reading: Relate Cause and Effect

Inquiry: Form Operational Definitions

How Do Waves Form and Change?

When you watch a surfer's wave crash onto a beach, you are seeing the last step in the development of a wave. A **wave** is the movement of energy through a body of water. Wave development usually begins with wind. Without the energy of wind, the surface of the ocean would be as smooth as a mirror. **Most waves form when winds blowing across the water's surface transmit their energy to the water.**

The size of a wave depends on the strength of the wind and on the length of time it blows. A gentle breeze creates small ripples on the surface of the water. Stronger winds create larger waves. The size of a wave also depends on the distance over which the wind blows. Winds blowing across longer distances build up bigger waves. That's why small ponds have ripples but the Great Lakes have waves you can surf!

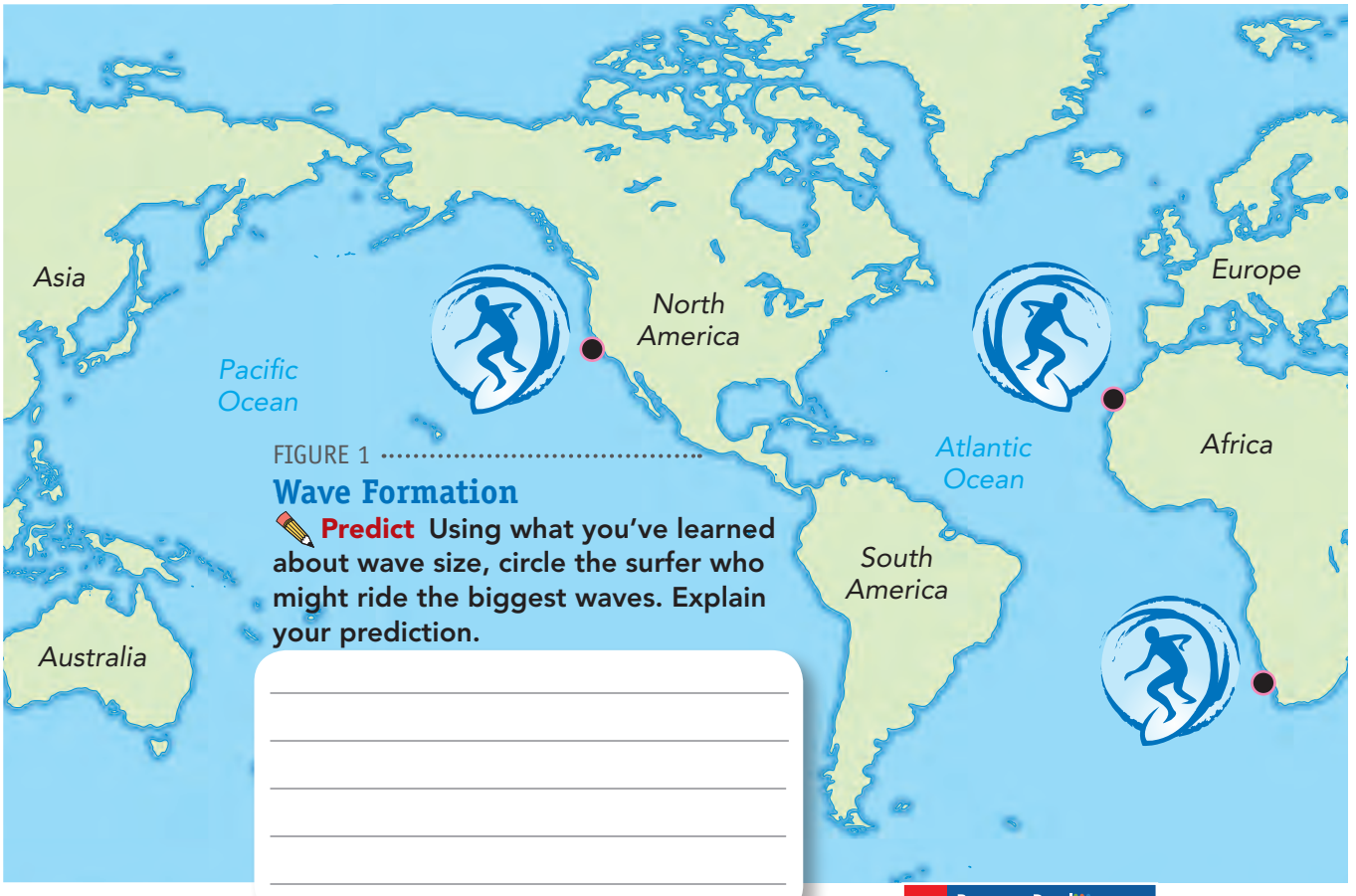


FIGURE 1

Wave Formation

Predict Using what you've learned about wave size, circle the surfer who might ride the biggest waves. Explain your prediction.

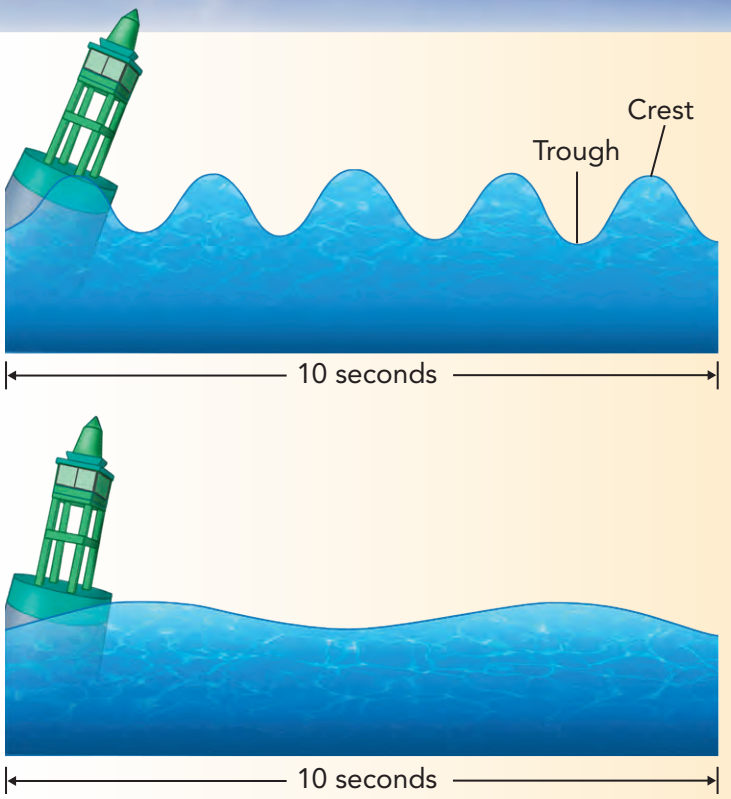


FIGURE 2

Wave Characteristics

Scientists have a vocabulary to describe the characteristics of waves. The name for the highest part of a wave is the crest. The horizontal distance between crests is the **wavelength.** Long, rolling waves with lots of space between crests have long wavelengths. Short, choppy waves have shorter wavelengths. Waves are also measured by their **frequency,** the number of waves that pass a point in a certain amount of time.

As you can see in **Figure 2,** the lowest part of a wave is the trough. The vertical distance from the crest to the trough is the **wave height.** The energy and strength of a wave depend mainly on its wave height. In the open ocean, most waves are between 2 and 5 meters high. During storms, waves can grow much higher and more powerful.

Wave Characteristics

There are many different types of waves, but they have similar characteristics.

Read the text and complete the activity.

1. **Identify** Find and label wavelength, wave height, crest, and trough on the diagrams. *Hint:* One diagram is started.

2. **Compare and Contrast** How does the frequency of the waves compare in the two diagrams?

apply it!

Conditions at sea are constantly changing.

1. Use the scientific vocabulary you learned above to describe the conditions at sea in the photo.

2. **Form Operational Definitions** Write your own definition for one of the scientific terms you used above.

Wave Energy

Waves may appear to carry water toward shore, but water doesn't actually move forward in deep water. If it did, ocean water would eventually pile up on the coasts of every continent! The energy of the wave moves toward shore, but the water itself remains in place. You can test this by floating a cork in a bowl of water. Use a spoon to make a wave in the bowl. As the wave passes, the cork lurches forward a little; then it bobs backward. It ends up in almost the same spot where it started.

Water Motion

What happens to the water as a wave travels along? Notice in **Figure 3** that as the wave passes, water particles move in a circular path. They swing forward and down with the energy of the wave, then back up to their original position. Deeper water particles move in smaller circles than those near the surface. At a depth equal to about one half the wavelength, water particles are not affected by the surface wave.

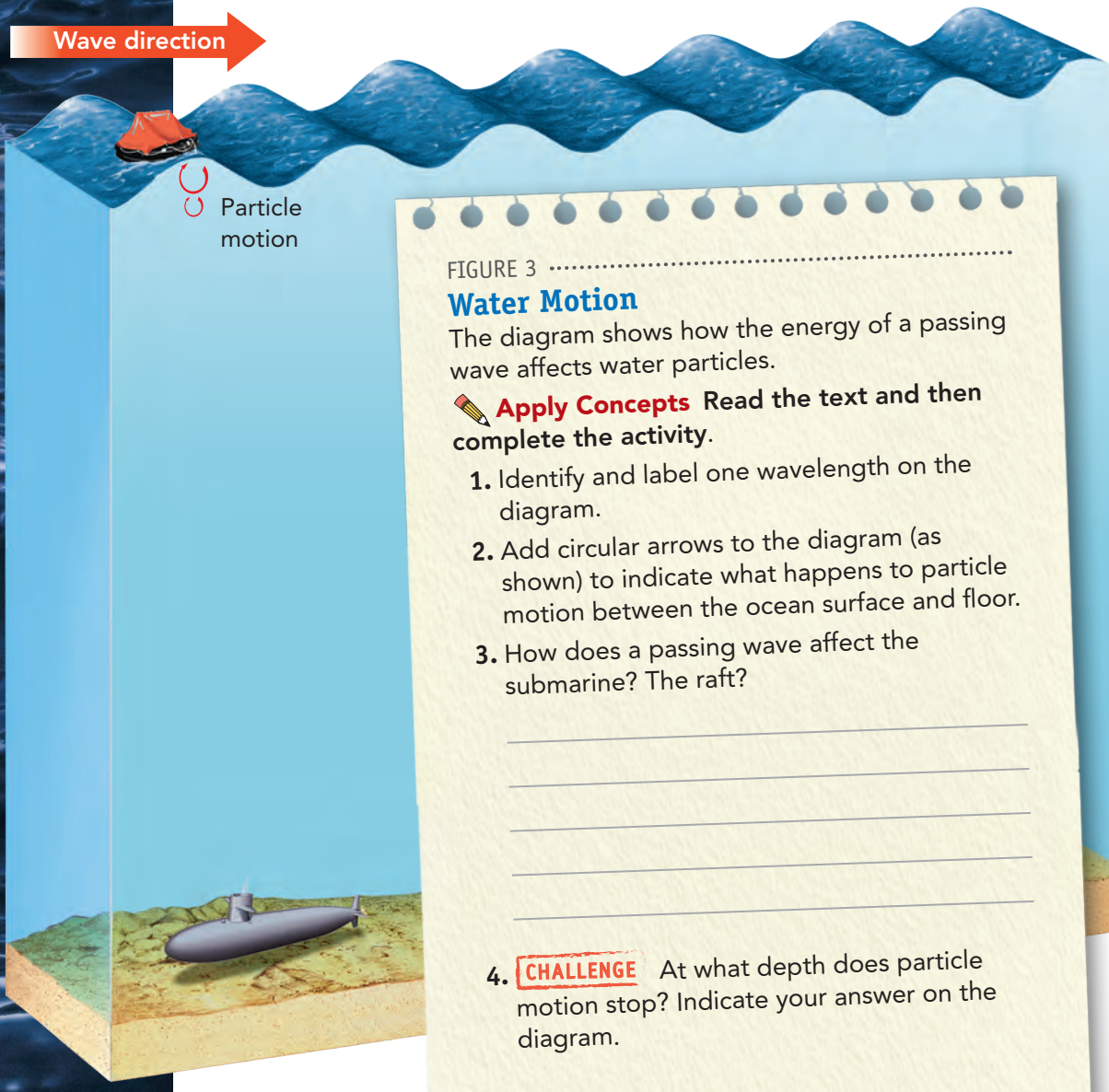


FIGURE 3

Water Motion

The diagram shows how the energy of a passing wave affects water particles.

Apply Concepts **Read the text and then complete the activity.**

1. Identify and label one wavelength on the diagram.
2. Add circular arrows to the diagram (as shown) to indicate what happens to particle motion between the ocean surface and floor.
3. How does a passing wave affect the submarine? The raft?

4. CHALLENGE At what depth does particle motion stop? Indicate your answer on the diagram.

Relate Cause and Effect
Read the text. Then, underline the cause of breakers and circle the effect.

Breakers The white-capped waves that crash onto shore are often called "breakers." In deep water, these waves usually travel as long, low waves called swells. As the waves approach the shore, the water becomes shallower. The bottoms of the waves begin to touch the sloping ocean floor. Friction between the ocean floor and the water causes the waves to slow down. As the speed of the waves decreases, their shapes change. **Near shore, wave height increases and wavelength decreases.** When a wave reaches a certain height, the crest of the wave topples. The wave breaks onto the shore, forming surf.

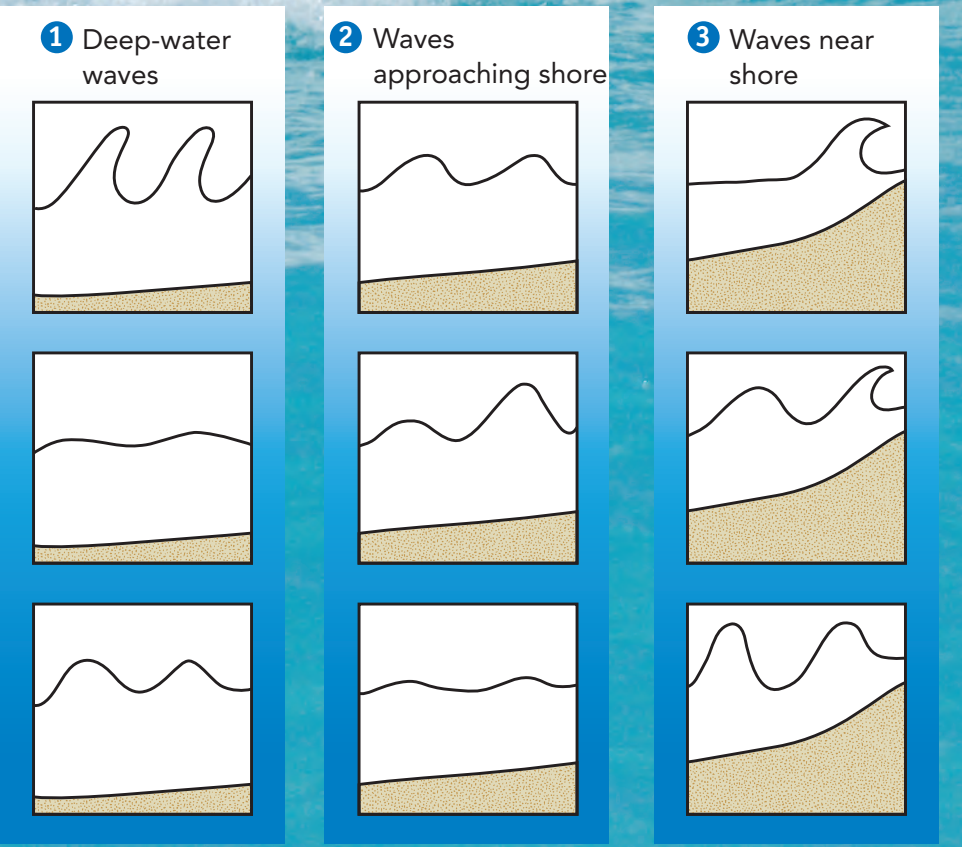
As the wave breaks, it continues to move forward. At first the breaker surges up the beach. But gravity soon slows it down, eventually stopping it. The water that has rushed up the beach then flows back out to sea. Have you ever stood at the water's edge and felt the pull of the water rushing back out to the ocean? This pull, often called an undertow, carries shells, seaweed, and sand away from the beach. A strong undertow can be dangerous to swimmers.

FIGURE 4

Breakers

After you read about breakers, do the activity to show how waves change shape as they get closer to shore.

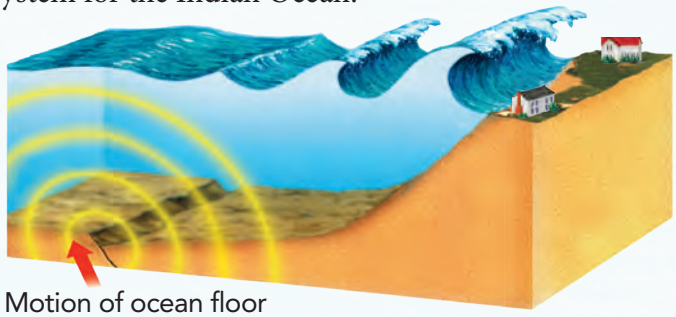
1. **Interpret Diagrams** Shade in one drawing in each column to show the sequence of how a wave forms.
2. **Summarize** How does the wave change as it approaches shore?



Tsunami So far you've been reading about waves that are caused by the wind. But another kind of wave forms far below the ocean surface. This type of wave, called a **tsunami,** is usually caused by an earthquake beneath the ocean floor. The ocean floor's abrupt movement sends pulses of energy through the water, shown in the diagram below.

Despite the huge amount of energy a tsunami carries, people on a ship at sea may not even realize a tsunami is passing. How is this possible? A tsunami in deep water may have a wavelength of 200 kilometers or more, but a wave height of less than a meter. When the tsunami reaches shallow water near the coast, friction with the ocean floor causes the long wavelength to decrease suddenly. The wave height increases as the water "piles up." Some tsunamis have reached heights of 20 meters or more—taller than a five-story building!

Tsunamis are most common in the Pacific Ocean, often striking Alaska, Hawaii, and Japan. In response, nations in the Pacific have developed a warning system, which can alert them if a tsunami forms. On March 11, 2011, an enormous Tsunami devastated Japan. But not all tsunamis occur in the Pacific Ocean. On December 26, 2004, a major earthquake in the Indian Ocean caused tremendous tsunamis that hit 11 nations. Tragically, these tsunamis took the lives of more than 230,000 people. Several nations are now developing a warning system for the Indian Ocean.



Motion of ocean floor

FIGURE 5

Tsunami

Communicate Use the diagram below, showing how a tsunami forms, to help you develop a tsunami warning system. Include how you would warn people living in remote areas.

An Indonesian village hit by the 2004 tsunami

Lab zone® Do the Quick Lab *Making Waves.*

Assess Your Understanding

got it?

- ○ **I get it!** Now I know that waves change as they approach shore because _____
- ○ I need extra help with _____

How Do Waves Affect the Shore?

As waves approach and crash onto the shore, the beach can change. Wave direction at sea is determined by the wind. Waves usually roll toward shore at an angle. But as they touch bottom, the shallower water slows the shoreward side of the wave first. The rows of waves gradually turn and become more nearly parallel to the shore.

Longshore Drift

As waves come into shore, water washes up the beach at an angle, carrying sand grains, as shown in **Figure 6.** The water and sand then run down the beach. This movement of sand along the beach is called **longshore drift.** **As the waves slow down, they deposit the sand they are carrying on the shallow, underwater slope, forming a long ridge called a sandbar.**

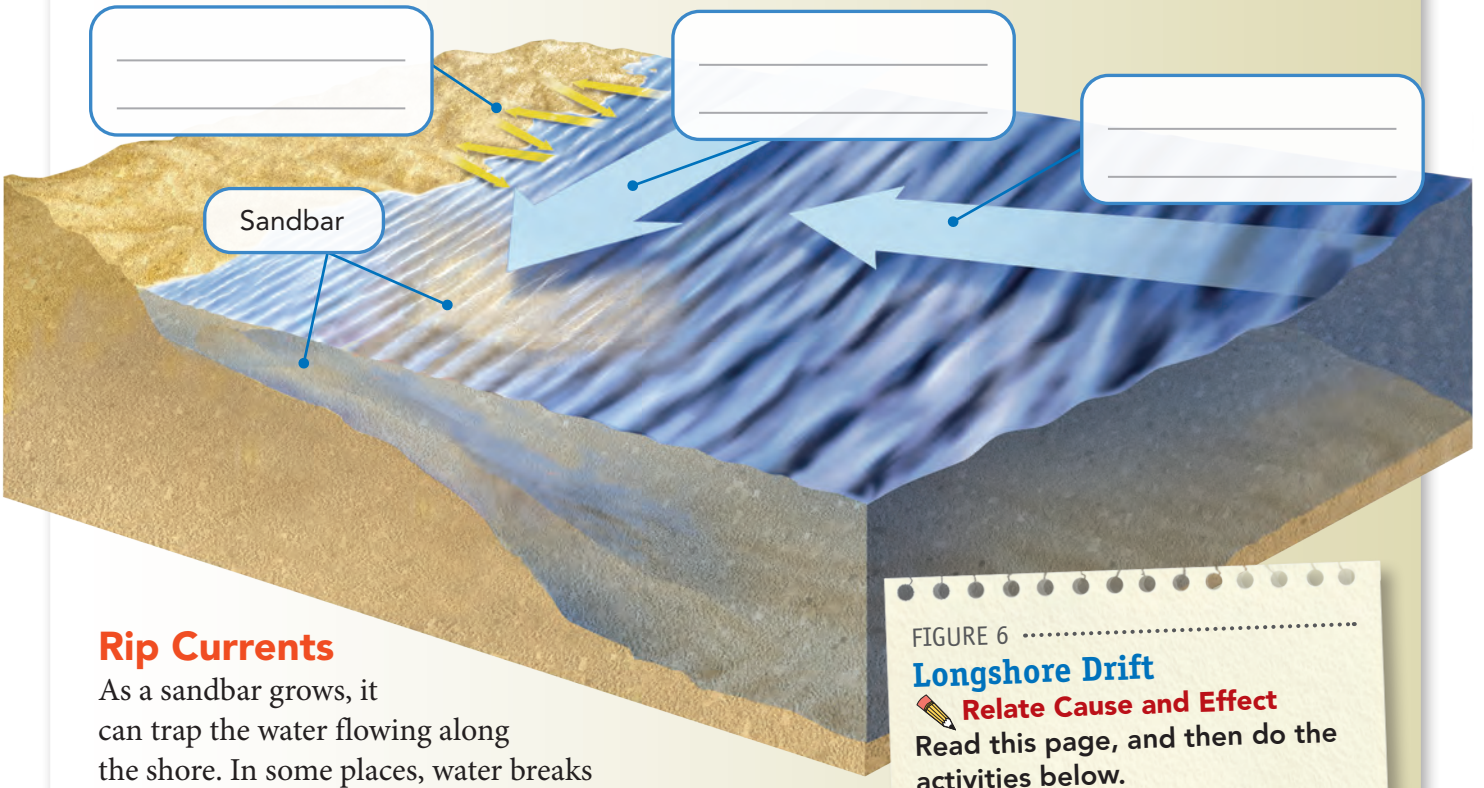


FIGURE 6

Longshore Drift

Relate Cause and Effect

Read this page, and then do the activities below.

1. Label these areas on the diagram: direction of incoming waves, direction of longshore drift, movement of sand.
2. Draw an arrow in the area where a rip current would form.

Rip Currents

As a sandbar grows, it can trap the water flowing along the shore. In some places, water breaks through the sandbar and begins to flow back down the sloping ocean bottom. This process creates a **rip current,** a rush of water that flows rapidly back to sea through a narrow opening. Rip currents can carry a swimmer out into deep water. Because rip currents are narrow, a strong swimmer can usually escape by swimming across the current, parallel to the beach.

Beach Erosion

If you walk on the same beach every day, you might not notice that it's changing. But if you visit a beach just once each year, you might be startled by the changes you see. **Waves shape a beach by eroding the shore in some places and building it up in others.**

Barrier Beaches Long sand deposits called barrier beaches form parallel to the shore and are separated from the mainland by a shallow lagoon. Waves break against the barrier beach, protecting the mainland from erosion. For this reason, people are working to preserve barrier beaches along the Atlantic coast from Georgia to Massachusetts.

Sand Dunes Hills of windblown sand, called sand dunes, can make a beach more stable and protect the shore from erosion. The strong roots of dune plants hold the sand in place and help slow erosion. Without them, sand dunes can be easily washed away by wave action.

Groins Many people like to live near the ocean, but erosion can threaten buildings near the beach. One way to reduce beach erosion is to build a wall of rocks or concrete, called a **groin,** outward from the beach. Sand carried by the water piles up on one side of the groin instead of moving down shore. However, groins increase erosion farther down the beach.

FIGURE 7

Beach Erosion

Evaluate the Impact on Society Your community planning board wants to limit beach erosion. Do you vote to protect the dunes from being built on or to construct a groin instead? Why?

Lab zone® Do the Quick Lab *Modeling Currents.*

Assess Your Understanding

got it?

- ○ **I get it!** Now I know that waves shape the beach by _____
- ○ I need extra help with _____

TN

LESSON 6

6.ESS2.1, 6.ESS2.2, 6.ESS2.3, 6.ESS2.4

Currents and Climate

UNLOCK THE BIG ?

- What Causes Surface Currents?
- What Causes Deep Currents?

MY PLANET DIARY

EVERYDAY SCIENCE

Ducky Overboard

What happens when a ship loses its cargo at sea? Is it gone forever? You might think so. One ship traveling from Hong Kong to Tacoma, Washington, lost 29,000 plastic toys. They fell overboard in a storm and were considered lost at sea. But when hundreds of the toys began washing up on distant shores, scientists got excited.

One way scientists study ocean currents is by releasing empty bottles into the ocean. But of 500 to 1,000 bottles released, scientists might only recover 10. That doesn't give them much data. The large number of floating toys could give scientists better data from more data points.

The first toys were spotted off the coast of Alaska. Then beachcombers began finding them in Canada, in Washington, and even as far away as Scotland.

Discuss these questions with a classmate and write your answers below.

1. Why was the plastic toy spill so helpful to scientists studying ocean currents?

2. Have you ever found objects on the beach? What data would scientists need from you for their research?

Lab zone® Do the Inquiry Warm-Up *Bottom to Top.*

Vocabulary

- current
- Coriolis effect
- climate
- El Niño
- La Niña

Skills

- Reading: Compare and Contrast
- Inquiry: Infer

What Causes Surface Currents?

A **current** is a large stream of moving water that flows through the oceans. Unlike waves, currents carry water from one place to another. Some currents move water at the surface of the ocean. Other currents move water deep in the ocean.

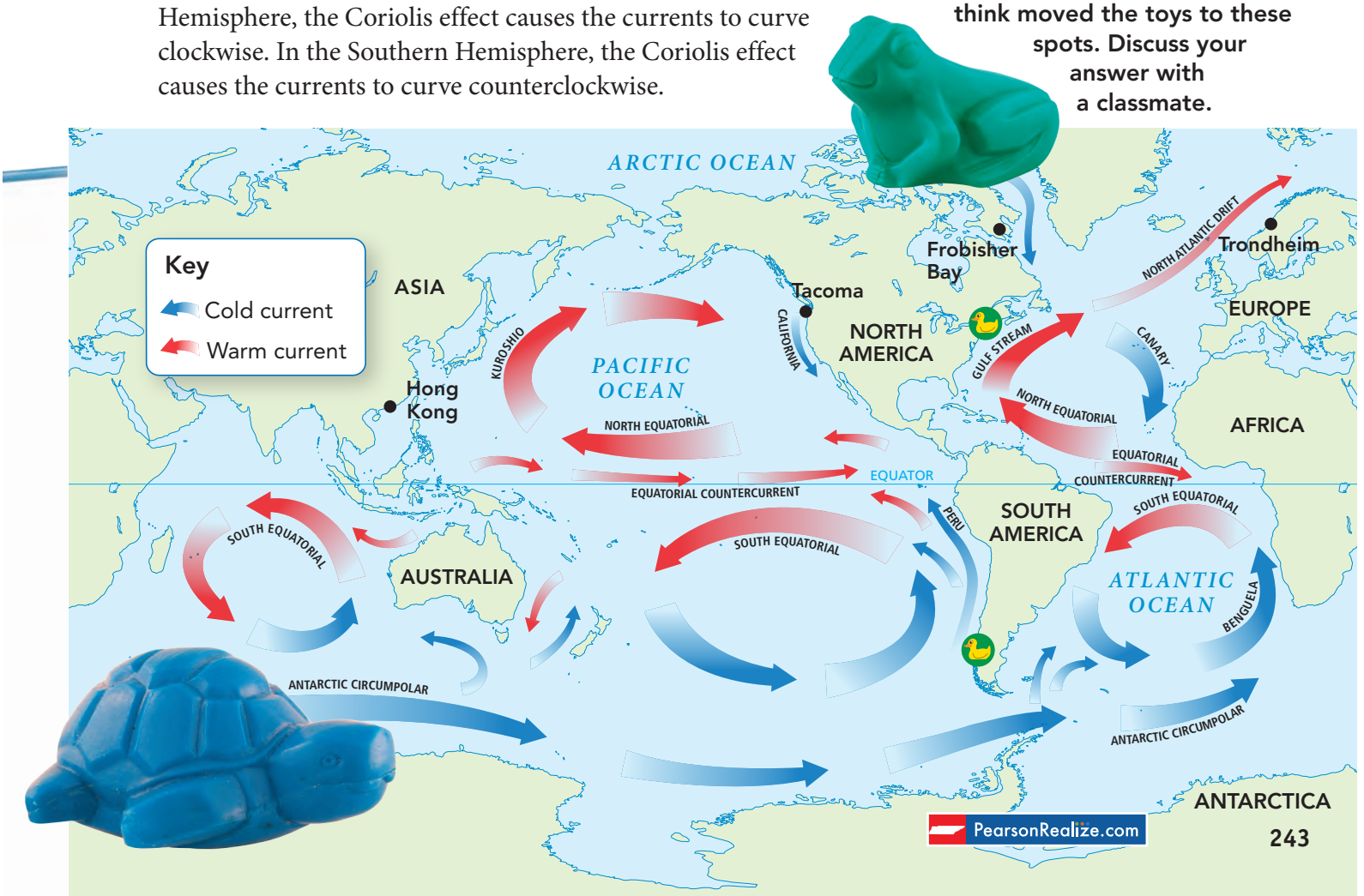
Surface currents affect water to a depth of several hundred meters. They are driven mainly by winds. Surface currents follow Earth's major wind patterns. They move in circular patterns in the five major oceans. Most of the currents flow east or west, then double back to complete the circle, as shown in **Figure 1.**

Coriolis Effect Why do the currents move in these circular patterns? If Earth were standing still, winds and currents would flow in more direct paths between the poles and the equator. But as Earth rotates, the paths of the winds and currents curve. This effect of Earth's rotation on the direction of winds and currents is called the **Coriolis effect** (kawr ee OH lis). In the Northern Hemisphere, the Coriolis effect causes the currents to curve clockwise. In the Southern Hemisphere, the Coriolis effect causes the currents to curve counterclockwise.

FIGURE 1

Surface Currents

Infer The toys that fell overboard washed up in many places. Two of the locations are marked with ducks below. Circle the currents that you think moved the toys to these spots. Discuss your answer with a classmate.



Compare and Contrast Use the space below to compare and contrast the effects of warm and cold currents on climate.

Effects of the Sun

The sun's energy enters Earth's atmosphere, transferring energy as it moves to Earth's surface. This energy is absorbed by the molecules in the atmosphere, Earth's surface, and the hydrosphere. Water holds heat better than air or land does, and therefore will maintain a higher temperature for a longer period of time. As this warmer water moves, the solar energy absorbed will affect the areas in close relation to the moving warm water.

Gulf Stream

The Gulf Stream is the largest and most powerful surface current in the North Atlantic Ocean. This current, more than 30 kilometers wide and 30 meters deep, is caused by strong winds from the west. The Gulf Stream moves warm water from the Gulf of Mexico to the Caribbean Sea, then continues northward along the east coast of the United States. Near Cape Hatteras, North Carolina, it curves eastward across the Atlantic, as a result of the Coriolis effect, at which point it crosses the Atlantic and becomes the North Atlantic Drift.

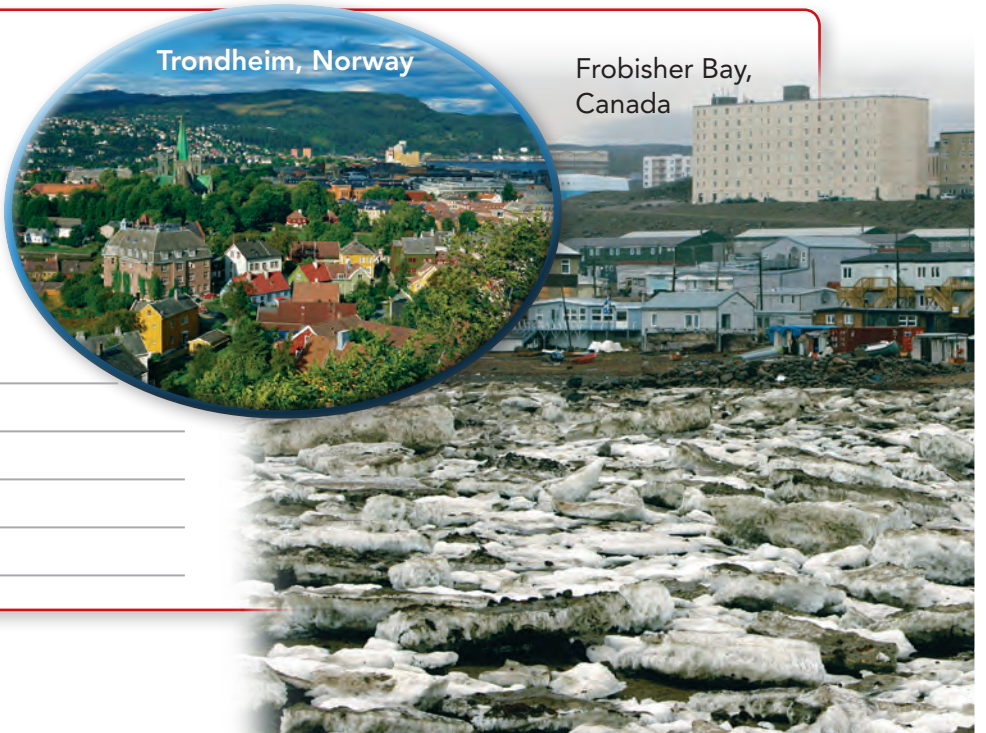
Effects on Climate

The Gulf Stream has a warming effect on the climate of nearby land areas. **Climate** is the pattern of temperature and precipitation typical of an area over a long period of time. The mid-Atlantic region of the United States has a more moderate climate because of the Gulf Stream. Winters are very mild and summers are humid. Currents affect climate by moving cold and warm water around the globe. Currents generally move warm water from the tropics toward the poles and bring cold water back toward the equator. **A surface current warms or cools the air above it. This affects the climate of land near the coast.** Winds pick up moisture as they blow across warm-water currents. This explains why the warm Kuroshio Current brings mild, rainy weather to the southern islands of Japan. Cold-water currents cool the air above them, which holds less moisture than warm air. So cold currents tend to bring cool, dry weather to land areas in their path.

apply it!

Trondheim, Norway, and Frobisher Bay, Canada, are shown here in July. They are at roughly the same latitude, but they have very different climates.

Infer Why does Trondheim have a mild climate? *Hint:* Refer to the map on the previous page.



El Niño Changes in wind patterns and currents can have a major impact on the oceans and nearby land. One example of such changes is **El Niño,** a climate event that occurs every two to seven years in the Pacific Ocean. El Niño begins when an unusual pattern of winds forms over the western Pacific. This causes a vast sheet of warm water to move east toward the South American coast, as shown in **Figure 2.** This warm water prevents the cold deep water from moving to the surface. El Niño conditions can last for one to two years before the usual winds and currents return.

El Niño causes shifts in weather patterns. This leads to unusual and often severe conditions in different areas. A major El Niño occurred between 1997 and 1998. It caused an especially warm winter in the northeastern United States. It was also responsible for heavy rains, flooding, and mudslides in California, as well as a string of deadly tornadoes in Florida.

La Niña When surface waters in the eastern Pacific are colder than normal, a climate event known as **La Niña** occurs. A La Niña event is the opposite of an El Niño event. La Niña events typically bring colder than normal winters and greater precipitation to the Pacific Northwest and the north central United States.

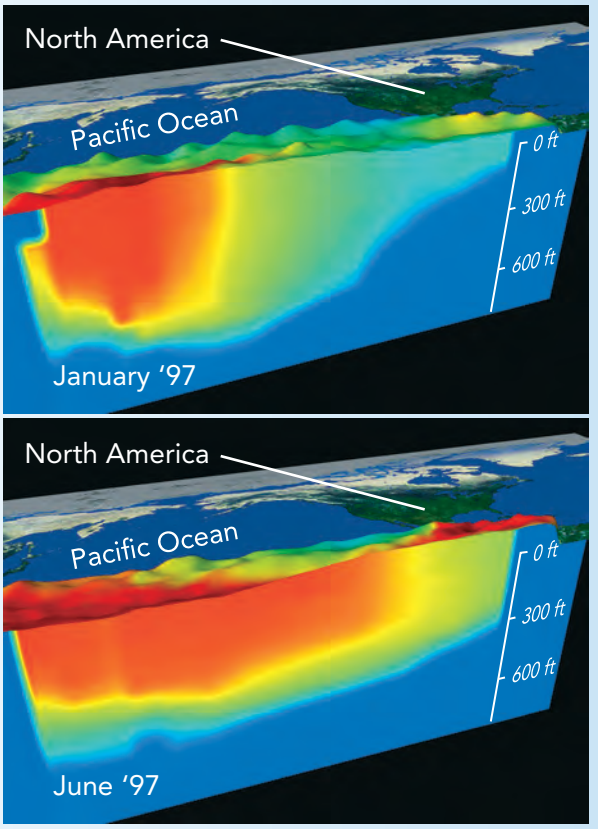


FIGURE 2

Warming Sea Temperature

The images show what happens to temperature below the surface of the ocean during an El Niño event. Red indicates a warmer sea surface temperature.

Draw Conclusions **What happened to the the water temperature over six months?**

Lab zone® Do the Lab Investigation *Modeling Ocean Currents.*

Assess Your Understanding

1a. Define What is a current?

b. Describe What causes surface currents?

c. CHALLENGE Why is it helpful to a community to be able to predict an El Niño event?

got it?

○ **I get it!** Now I know that currents are driven mainly by

○ I need extra help with

What Causes Deep Currents?

Deep below the ocean surface, another type of current causes chilly waters to creep slowly across the ocean floor. **Deep currents are caused by differences in the density of ocean water.** Recall that cold water is more dense than warm water.

Salinity When a warm surface current moves from the equator toward one of the poles, it gradually cools. As ice forms near the poles, the salinity of the water increases from the salt left behind during freezing. As the water's temperature decreases and its salinity increases, the water becomes denser and sinks. Then, the cold water flows back along the ocean floor as a deep current. Deep currents are affected by the Coriolis effect, which causes them to curve.

Deep currents move and mix water around the world. They carry cold water from the poles toward the equator. Deep currents flow slowly. They may take as long as 1,000 years to circulate between the oceans back to where they started.

Global Ocean Conveyor The simplified pattern of ocean currents in **Figure 3** looks like a conveyor belt, moving water between the oceans. This pattern of ocean currents results from density differences due to temperature and salinity. The currents bring oxygen into the deep ocean that is needed for marine life.

The ocean's deep currents mostly start as cold water in the North Atlantic Ocean. This is the same water that moved north across the Atlantic as part of the Gulf Stream. This cold, salty water, called the North Atlantic Deep Water, is dense. It sinks to the bottom of the ocean and flows southward toward Antarctica. From there it flows northward into both the Indian and Pacific oceans. The deep cold water rises to the surface in the Indian and Pacific oceans, warms, and eventually flows back along the surface into the Atlantic.

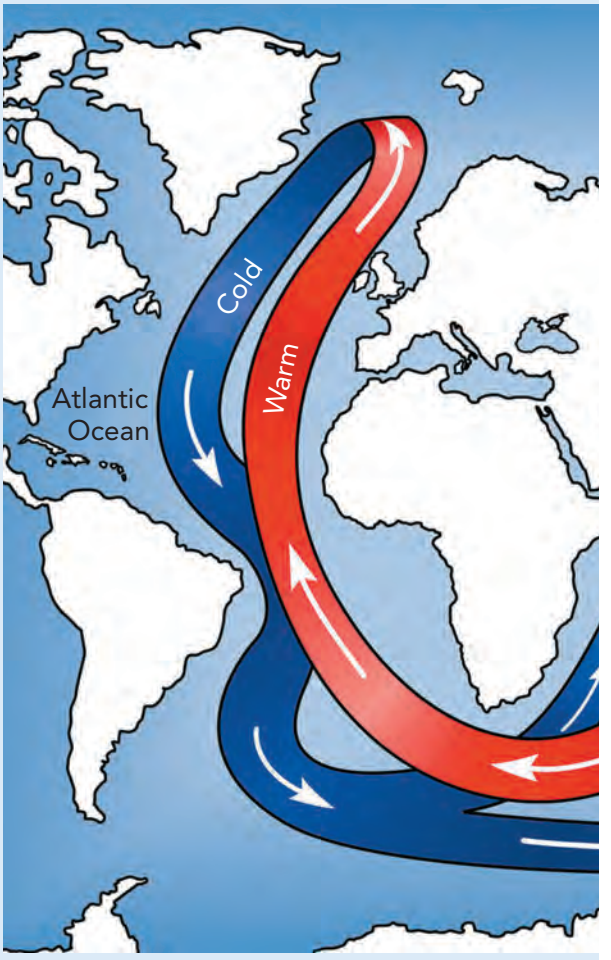


FIGURE 3

Global Conveyor

Predict What might happen if the global conveyor stopped?

do the math! Analyzing Data

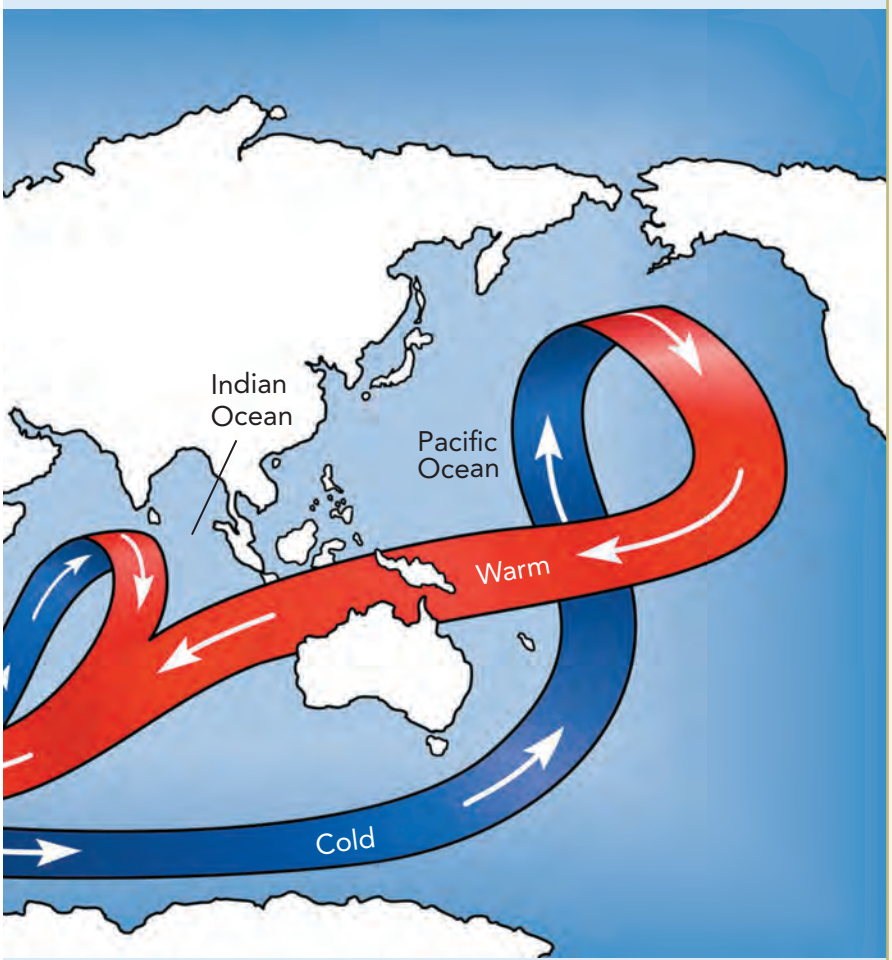
Calculating Density

Temperature affects the density of ocean water. To calculate the density of a substance, divide the mass of the substance by its volume.

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

Practice Problem

Calculate Find the density of the following 1-L samples of ocean water. Sample A has a mass of 1.01 kg; Sample B has a mass of 1.06 kg. Which sample is likely to have the higher salinity? Why?



Lab zone® Do the Quick Lab *Deep Currents.*

Assess Your Understanding

2a. Review What causes deep currents?

b. Explain How does the temperature of ocean water affect its density?

got it?

○ **I get it!** Now I know how the global ocean conveyor moves: _____

○ I need extra help with _____

CHAPTER 7

Study Guide

REVIEW THE BIG QUESTION

Fresh water on Earth cycles between _____, _____, and the atmosphere.

LESSON 1 Water on Earth

- All living things need water in order to carry out their body processes.
- Most of Earth's surface water—roughly 97 percent—is salt water found in oceans. Only 3 percent is fresh water.
- In the water cycle, water moves between land, living things, bodies of water on Earth's surface, and the atmosphere.

Vocabulary

- habitat
- groundwater
- water cycle
- evaporation
- transpiration
- precipitation

LESSON 2 Surface Water

- A river and all the streams and smaller rivers that flow into it together make up a river system.
- Ponds and lakes form when water collects in hollows and low-lying areas of land.
- Natural processes and human activities can cause lakes to disappear.

Vocabulary

- tributary
- watershed
- divide
- reservoir
- eutrophication

LESSON 3 Water Underground

- 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.

Vocabulary

- permeable
- impermeable
- unsaturated zone
- saturated zone
- water table
- aquifer
- artesian well

LESSON 4 Exploring the Ocean

- The water in Earth's oceans varies in salinity, temperature, and depth.
- Ocean surface temperatures vary with location and the seasons. The water temperature decreases with increasing depth.
- In the ocean, pressure increases with depth.
- Major ocean floor features include trenches, the continental shelf, the continental slope, the abyssal plain, and the mid-ocean ridge.

Vocabulary

- salinity
- sonar
- seamount
- trench
- continental slope
- continental shelf
- abyssal plain
- mid-ocean ridge

LESSON 5 Wave Action

- Most waves form when winds blowing across the water's surface transmit energy to the water.
- Near shore, wave height increases and wavelength decreases.
- Waves shape a beach by eroding the shore in some places and building it up in others.

Vocabulary

- wave
- wavelength
- frequency
- wave height
- tsunami
- longshore drift
- rip current
- groin

LESSON 6 Currents and Climate

- Surface currents are driven mainly by winds. A surface current warms or cools the air above it, affecting the climate of the land near the coast.
- Deep currents are caused by differences in the density of ocean water. They move and mix water around the world and carry cold water from the poles toward the equator.

Vocabulary

- current
- Coriolis effect
- climate
- El Niño
- La Niña

Review and Assessment

LESSON 1 Water on Earth

1. Where is most of Earth's total water supply found?

a. atmosphere **b.** groundwater
c. ice sheets **d.** oceans

2. Apply Concepts Why is so little of Earth's water available for human use?

3. math! About 3 percent of Earth's water is fresh water. Of that 3 percent, about 69 percent is ice. About what percent of Earth's total water supply is ice?

LESSON 2 Surface Water

4. What is the area that supplies water to a river system called?

a. reservoir **b.** tributary
c. watershed **d.** wetland

5. Two watersheds are separated by a(n) _____.

6. Classify How can a large river also be a tributary?

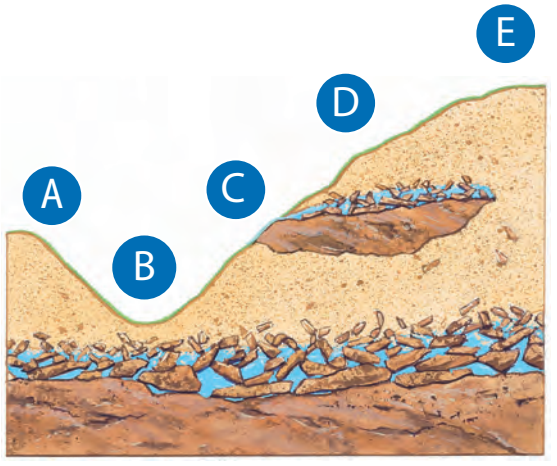
LESSON 3 Water Underground

7. The top of the saturated zone forms the

a. artesian well. **b.** impermeable rock.
c. unsaturated zone. **d.** water table.

8. Water can flow through pores or cracks in a _____ material.

Use the diagram to answer Questions 9–11.



9. Make Judgments Would location D or E be a better place to dig a well? Explain.

10. Infer At which location could you obtain water without using a pump? What is this called?

11. Predict What changes would you expect to see in this area during a very rainy season?

CHAPTER 7

Review and Assessment

LESSON 4 Exploring the Ocean

12. Why is ocean water more dense than fresh water at the same temperature?

a. circular winds **b.** less pressure
c. deep currents **d.** higher salinity

13. Relate Cause and Effect Name two properties of ocean water affected by depth. How does depth affect each?

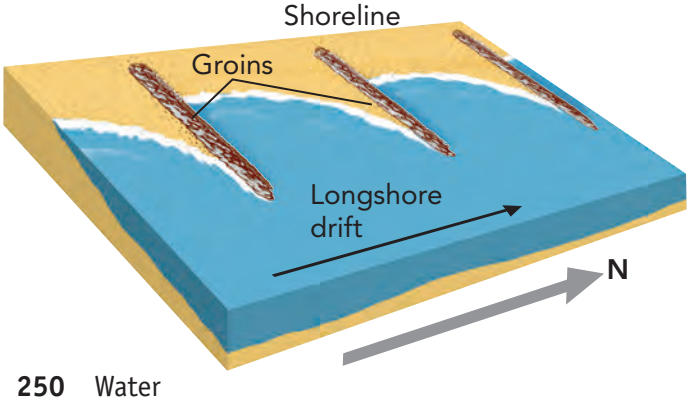
14. Write About It In what ways is the ocean at 1,000 meters deep different from the ocean at the surface in the same location?

LESSON 5 Wave Action

15. Which describes rolling waves with a large horizontal distance between crests?

a. long wavelength **b.** deep trough
c. great wave height **d.** high frequency

16. Interpret Diagrams Where will sand pile up against the groins shown in the diagram? Explain.



LESSON 6 Currents and Climate

17. What makes winds and currents move in curved paths?

a. Coriolis effect **b.** wave height
c. longshore drift **d.** ocean trenches

18. Flooding is common during an El Niño, which is _____

19. Compare and Contrast What causes surface currents? Deep currents?

APPLY THE BIG ? How does fresh water cycle on Earth?

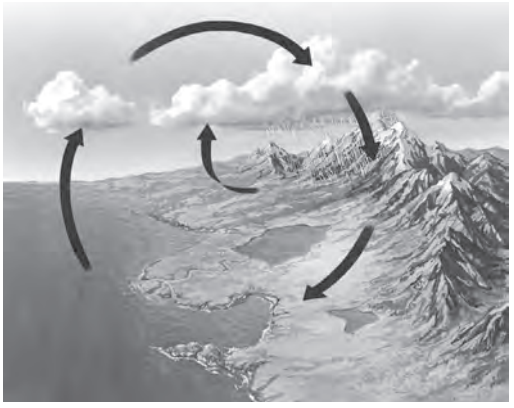
20. In a process called cloud seeding, small particles of chemicals such as dry ice are spread into clouds from airplanes. The goal is to provide a place for condensation, causing raindrops to form and fall as precipitation. How would increased condensation affect the other processes of the water cycle?

TNReady Prep

6.ESS2.1, 6.ESS2.2, 6.ESS2.3, 6.ESS2.4

Read each question and choose the best answer.

1. Use the diagram to answer the question.



Which of the following is a process that occurs in the water cycle?

A condensation **B** evaporation
C precipitation **D** all of the above

2. How do waves shape beaches?

A by preventing beach erosion
B by counteracting longshore drift
C by compacting the sand into permanent position
D by eroding the shore in some places and building it up in others

3. For a science project, you must build a model of an aquifer. What material would be best to use for the layer where the water will accumulate?

A clay
B granite
C gravel
D bedrock

4. What is a watershed?

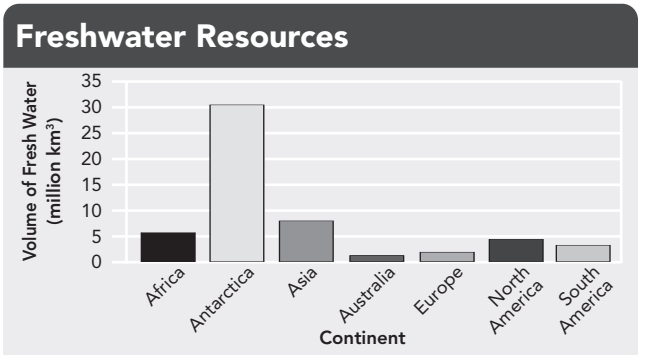
A the land area that supplies a river system
B the amount of oxygen in a lake
C the total water supply within a lake
D sediment from streams that fills up lakes

5. A major warm ocean surface current flows along a coastal area. What type of climate would you most likely find in the area influenced by the current?

A cool and dry
B very cool and wet
C mild and wet
D very hot and dry

Constructed Response

Use the graph and your knowledge of science to answer Question 6. Write your answer on a separate sheet of paper.



6. The graph shows the total amount of fresh water in all forms found on each continent. Why is so much of Earth's fresh water located in Antarctica? Is that water usable by humans? Explain your answer.

A Pearl of a Solution

▲ Oysters filter nutrients and pollutants from the water in which they feed.

It's hard to say who are the bigger heroes in the Chesapeake Bay—the scientists or the oysters.

The Chesapeake Bay is the world's third-largest estuary. More than 17 million people live within the Chesapeake watershed. For many years, fishing has been an important industry for people in the area. People depend on the bay for food and work. Pollution and habitat loss in the watershed have dramatically reduced marine life in the bay, and people who live and work there have found it more difficult to find food or earn a living.

Now, scientists and volunteers are using oysters to help clean the bay's waters. Oysters get their food by filtering plankton and other nutrients from the water. In this way, oysters help remove pollutants from the water. The oyster population has fallen sharply in recent years, and there are not enough oysters to keep up with the pollution. The Chesapeake Bay Foundation is hoping to restock the bay with 31 million oysters in the next 10 years. If they succeed, other marine life may also return to the bay.

Research It Make a map that shows the Chesapeake Bay watershed and the major rivers that drain into it. On the map, indicate how freshwater pollutants, such as excess fertilizer, enter the bay. Write a paragraph explaining the impact on society if the pollution is allowed to continue.

What Was Fort Miami?

Ohio's 2,000-Year-Old Aqueduct

▲ Archaeologists use computer-generated images to show what the 2,000-year-old irrigation system might have looked like when it was built.

Archaeologists from the University of Cincinnati have made a startling discovery. They had thought that a 2,000-year-old ruin on a hilltop in southwestern Ohio was a fort used by the Shawnee people native to the region to defend their lands from attack. Recently, however, archaeologists have found evidence that the ruin was actually a complex system of dams and canals, stretching almost 6 kilometers! At one spot, the Shawnee constructed a dam nearly 61 meters high!

The Shawnee built the system to collect water from a series of springs and to transport it to farmland, so that they could grow enough food to support their society. Climate records suggest that 2,000 years ago, when the Shawnee built the system, the region was colder and drier than it is now. So moving water from its source to where it was needed for farming would have helped the Shawnee survive.

Design It Find out more about water management systems used by ancient civilizations such as the Maya. Make a presentation that compares how two different civilizations used natural resources. Explain how the climate each group faced may have affected its water management systems.

▲ Archaeologists sift carefully through dirt removed from the site of the Fort Miami water works.